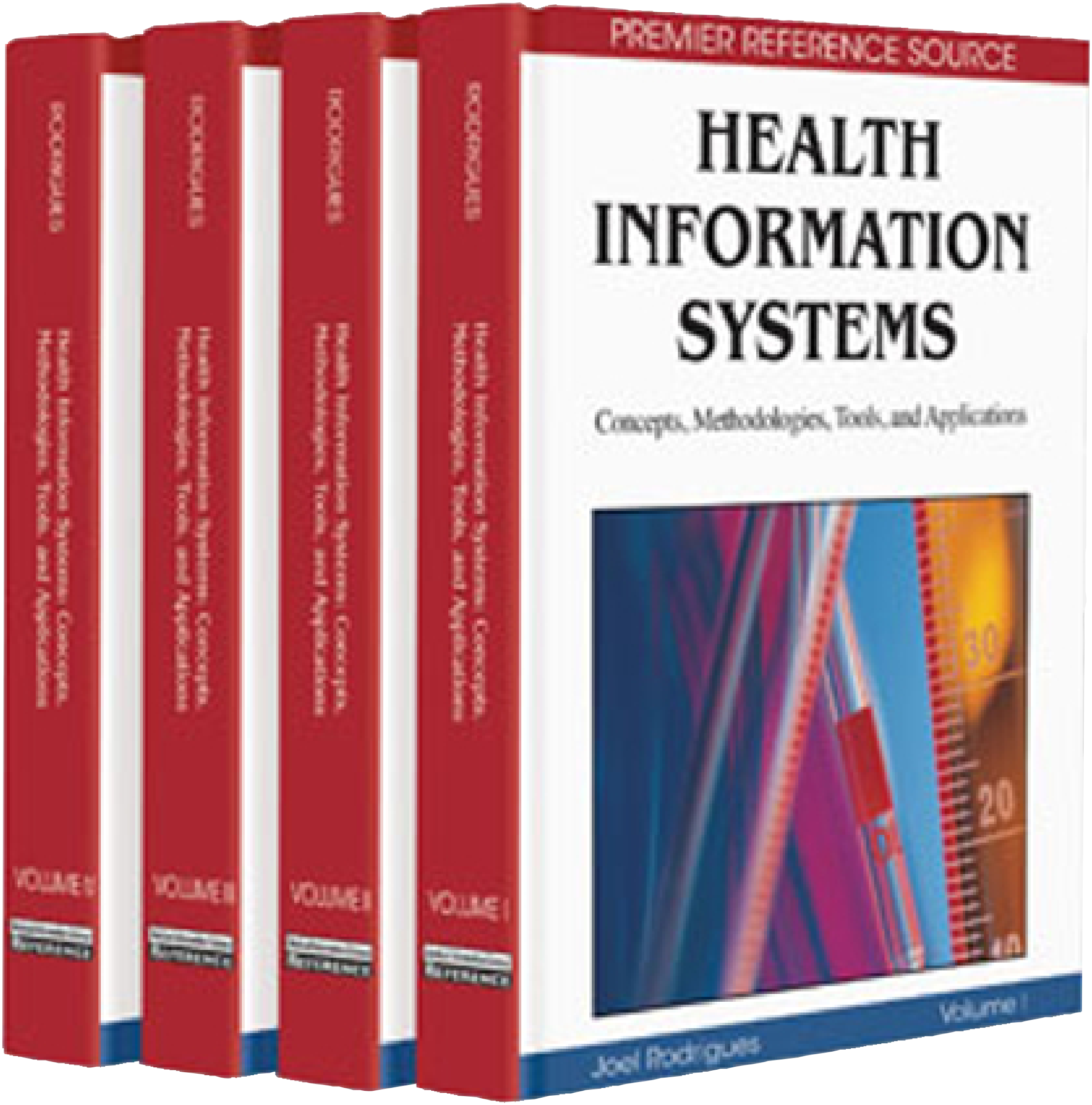


PREMIER REFERENCE SOURCE

HEALTH INFORMATION SYSTEMS

Concepts, Methodologies, Tools, and Applications

Volume I

Joel Rodrigues

Health Information Systems:
Concepts, Methodologies, Tools, and Applications

Joel Rodrigues
University of Beira Interior, Portugal

Volume I

MEDICAL INFORMATION SCIENCE REFERENCE
Hershey · New York

Director of Editorial Content: Kristin Klinger
Development Editor Julia Mosemann
Senior Managing Editor: Jamie Snavely
Assistant Managing Editor, MVB: Michael Brehm
Typesetters: Michael Brehm, Carole Coulson, Elizabeth Duke-Wilson, Devvin Earnest, Kate Griffin, Christopher Hrobak, Michael Killian, Ricardo Mendoza, Kurt Smith, Susan Timperio, Sean Woznicki, Deanna Zombro
Cover Design: Lisa Tosheff
Printed at: Yurchak Printing Inc.

Published in the United States of America by
Medical Information Science Reference (an imprint of IGI Global)
701 E. Chocolate Avenue
Hershey PA 17033
Tel: 717-533-8845
Fax: 717-533-8661
E-mail: cust@igi-global.com
Web site: http://www.igi-global.com/reference

and in the United Kingdom by
Medical Information Science Reference (an imprint of IGI Global)
3 Henrietta Street
Covent Garden
London WC2E 8LU
Tel: 44 20 7240 0856
Fax: 44 20 7379 0609
Web site: http://www.eurospanbookstore.com

Library of Congress Cataloging-in-Publication Data

Health information systems : concepts, methodologies, tools and applications / Joel Rodrigues, editor.
p. ; cm.
Includes bibliographical references and index.
Summary: “This reference set provides a complete understanding of the development of applications and concepts in clinical, patient, and hospital information systems”--Provided by publisher. ISBN 978-1-60566-988-5 (hardcover)
1. Medical informatics. 2. Information storage and retrieval systems--Medical care. I. Rodrigues, Joel, 1972-
[DNLM: 1. Information Systems. 2. Electronic Health Records. 3. Medical Informatics--methods. W 26.55.I4 H43407 2010]
R858.H357 2010
610.285--dc22
2009052763

British Cataloguing in Publication Data
A Cataloguing in Publication record for this book is available from the British Library.

Editor-in-Chief

Associate Editors

Editorial Advisory Board

Additional Research Collections found in the "Contemporary Research in Information Science and Technology" Book Series

Data Mining and Warehousing: Concepts, Methodologies, Tools, and Applications
John Wang, Montclair University, USA • 6-volume set • ISBN 978-1-60566-056-1

Electronic Business: Concepts, Methodologies, Tools, and Applications
In Lee, Western Illinois University • 4-volume set • ISBN 978-1-59904-943-4

Electronic Commerce: Concepts, Methodologies, Tools, and Applications
S. Ann Becker, Florida Institute of Technology, USA • 4-volume set • ISBN 978-1-59904-943-4

Electronic Government: Concepts, Methodologies, Tools, and Applications
Ari-Veikko Anttiroiko, University of Tampere, Finland • 6-volume set • ISBN 978-1-59904-947-2

Knowledge Management: Concepts, Methodologies, Tools, and Applications
Murray E. Jennex, San Diego State University, USA • 6-volume set • ISBN 978-1-59904-933-5

Information Communication Technologies: Concepts, Methodologies, Tools, and Applications
Craig Van Slyke, University of Central Florida, USA • 6-volume set • ISBN 978-1-59904-949-6

Intelligent Information Technologies: Concepts, Methodologies, Tools, and Applications
Vijayan Sugumaran, Oakland University, USA • 4-volume set • ISBN 978-1-59904-941-0

Information Security and Ethics: Concepts, Methodologies, Tools, and Applications
Hamid Nemati, The University of North Carolina at Greensboro, USA • 6-volume set • ISBN 978-1-59904-937-3

Medical Informatics: Concepts, Methodologies, Tools, and Applications
Joseph Tan, Wayne State University, USA • 4-volume set • ISBN 978-1-60566-050-9

Mobile Computing: Concepts, Methodologies, Tools, and Applications
David Taniar, Monash University, Australia • 6-volume set • ISBN 978-1-60566-054-7

Multimedia Technologies: Concepts, Methodologies, Tools, and Applications
Syed Mahbubur Rahman, Minnesota State University, Mankato, USA • 3-volume set • ISBN 978-1-60566-054-7

Virtual Technologies: Concepts, Methodologies, Tools, and Applications
Jerzy Kisielnicki, Warsaw University, Poland • 3-volume set • ISBN 978-1-59904-955-7

Free institution-wide online access with the purchase of a print collection!

Information Science REFERENCE

INFORMATION SCIENCE REFERENCE
Hershey · New York
Order online at www.igi-global.com or call 717-533-8845 ext.100
Mon–Fri 8:30am–5:00 pm (est) or fax 24 hours a day 717-533-7115

List of Contributors

Adam, Frederic \ *University College Cork, Ireland*	1151
Alamantariotou, Kleopatra \ *City University London, UK*	204
Álamo, José M. Reyes \ *Iowa State University, USA*	2091
Alasaarela, Esko \ *University of Oulu, Finland*	790
Anderson, James G. \ *Purdue University, USA*	133
Andronikou, Vassiliki \ *National Technical University of Athens, Greece*	1415
Anifalaje, Adebusoye A. \ *London School of Economics and Political Science, UK*	1115
Arevalo, Oscar \ *University of Kentucky, USA*	418
Armfield, Nigel R. \ *University of Queensland, Australia*	323
Asgari, Pooyan \ *The University of Sydney, Australia*	1954
Ayoade, John \ *American University of Nigeria, Nigeria*	933
Baars, I.J. \ *Maastricht University, The Netherlands*	1066
Babbitt, Ryan \ *Iowa State University, USA*	2091
Badidi, Elarbi \ *United Arab Emirates University, UAE*	1939
Bali, R.K. \ *BIOCORE Coventry University, UK*	889
Bali, Rajeev K. \ *Coventry University, UK*	2206
Bamidis, Panagiotis \ *The Medical School, AUTH, Greece*	2145
Bandara, Wasana \ *Queensland University of Technology, Australia*	1600
Banderker, Nesaar \ *University of Cape Town, South Africa*	773
Barnett, Jeff \ *University of Victoria, Canada*	1726
Bauer, Keith \ *Marquette University, USA*	1761
Baykal, Nazife \ *Informatics Institute Metu, Turkey*	339
Bensink, Mark \ *University of Queensland, Australia*	323
Berzunza, Gustavo \ *CICESE, Mexico*	2079
Bilsel, R. Ufuk \ *The Pennsylvania State University, USA*	1976
Biswas, Rakesh \ *People's College of Medical Sciences, India*	480
Blechman, Elaine A. \ *University of Colorado at Boulder, USA*	1534
Bobashev, Georgiy \ *RTI International, Russia*	1431
Bolsin, Stephen \ *Melbourne University & The Geelong Hospital, Australia*	71
Boone, Gloria M. \ *Suffolk University, USA*	845
Boonstra, Albert \ *University of Groningen, The Netherlands*	1656
Borshchev, Andrei \ *XJ Technologies, Russia*	1431
Borycki, Elizabeth M. \ *University of Victoria, Canada*	2057
Bosomworth, John \ *University of Victoria, Canada*	994
Boulton-Lewis, Gillian M. \ *Queensland University of Technology, Australia*	146

Boydell, Katherine M. \ *University of Toronto, Canada* ... 2044
Brear, Michelle \ *University of New South Wales, Australia* ... 1295
Breas, Robert \ *National IT Institute for Healthcare (NICTIZ), The Netherlands* ... 1328
Brender, Jytte \ *University of Aalborg and Virtual Center for Health Informatics, Denmark* ... 605
Buys, Laurie \ *Queensland University of Technology, Australia* ... 146
Buyukozkan, Gulcin \ *Galatasaray University, Turkey* ... 1976
Cain, Monica \ *Winston-Salem State University, USA* ... 1930
Carbone, Daniel \ *University of Melbourne, Australia* ... 1994
Carpender, S. Kay \ *Texas A&M Health Science Center, USA* ... 1582
Ceglowski, Andrzej S. \ *Monash University, Australia* ... 1916
Cellucci, Leigh W. \ *Idaho State University, USA* ... 1014
Chahal, Kirandeep \ *Brunel University, UK* ... 1342
Chang, Carl \ *Iowa State University, USA* ... 2091
Chattopadhyay, Amit \ *University of Kentucky, USA* ... 418
Cheng, Chen-Yang \ *Tunghai University, Taiwan* ... 945
Cheung, S.C. \ *Hong Kong University of Science and Technology, Hong Kong* ... 674
Chiu, Dickson K.W. \ *Dickson Computer Systems, Hong Kong* ... 674
Churilov, Leonid \ *The University of Melbourne, Australia* ... 1916
Clark, Frank C. \ *Medical University of South Carolina, USA* ... 1140
Clark, Jan Guynes \ *The University of Texas at San Antonio, USA* ... 1553
Collmann, Jeff \ *Georgetown University Medical Center, USA* ... 1454
Colson, Mark \ *The Geelong Hospital, Australia* ... 71
Cooper, Lesley \ *Wilfrid Laurier University, Canada* ... 1669
Cooper, Ted \ *Stanford University Medical Center, USA* ... 1454
Copen, John \ *University of Victoria, Canada* ... 994
Crenshaw, Katie M. \ *University of Alabama at Birmingham, USA* ... 2125
Crisóstomo-Acevedo, María José \ *Jerez Hospital, Spain* ... 1, 315, 1628
Currie, Wendy L. \ *University of Warwick, UK* ... 1228
D'Andrea, Alessia \ *IRPPS-CNR, Rome, Italy* ... 1373
Daly, Herbert \ *Brunel University, UK* ... 1342
Datla, Raju V. \ *Massachusetts Medical Society, USA* ... 2125
David, Dessa \ *Morgan State University, USA* ... 393, 986
De Luca, Stefano \ *Evodevo s.r.l., Italy* ... 233
de Quirós, Fernán González Bernaldo \ *Hospital Italiano de Buenos Aires, Argentina* ... 445
De Souza, Lorraine H. \ *Brunel University, UK* ... 717
de Souza, Tiago Coelho \ *University of Kentucky, USA* ... 418
DeMello, Steven \ *Health Technology Center, USA* ... 790
Diallo, Gayo \ *Laboratoire TIMC-IMAG, Institut de l'Ingénierie et de l'Information de Santé, France* ... 185
Dong, Changyu \ *Imperial College London, UK* ... 659
Doulamis, Anastasios \ *National Technical University of Athens, Greece* ... 1857
Dualy, Naranker \ *Imperial College London, UK* ... 659
Dwivedi, A. \ *University of Hull, UK* ... 889
Edirippulige, Sisira \ *University of Queensland, Australia* ... 323
Edwards, James W. \ *Agfa Healthcare, Canada* ... 1939
Edwards, Sylvia L. \ *Queensland University of Technology, Australia* ... 146

Eldabi, Tillal	*Brunel University, UK*	1342
Esmahi, Larbi	*Athabasca University, Canada*	1939
Favela, Jesus	*CICESE, Mexico*	2079
Federici, Tommaso	*University of Tuscia, Italy*	1400, 2160
Ferri, Fernando	*IRPPS-CNR, Rome, Italy*	1373
Filho, Raimir Holanda	*Universidade de Fortaleza, Brazil*	903
Finnegan, David J.	*University of Warwick, UK*	1228
Firopoulos, Michael	*Intracom IT Services, Greece*	1415
Fister, Kristina	*University of Zagreb, School of Medicine, Andrija Stampar School of Public Health, Croatia*	1544
Fox, Dana	*Athena Software, Canada*	1669
Gallant, Linda M.	*Emerson College, USA*	845
Gans, Günter	*RWTH Aachen University, Germany*	1640
Gao, Wei	*Fordham University, USA*	256
Ghosh, Biswadip	*Metropolitan State College of Denver, USA*	1826
Gill, Simerjit	*University of Regina & TRLabs Regina, Canada*	356
Ginter, Thomas	*Aurora BayCare Medical Center, USA*	1172
Gogia, Shashi Bhushan	*S.A.T.H.I, AMLA MEDIQUIP and Indian Association for Medical Informatics, India*	1051
Gore, Justin	*Northwick Park Hospital, UK*	717
Graeber, Stefan M.	*Saarland University, Germany*	60
Grifoni, Patrizia	*IRPPS-CNR, Rome, Italy*	1373
Guah, Matthew Waritay	*Erasmus University Rotterdam, The Netherlands*	1304, 1328
Guo, Chengqi	*Mississippi State University, USA*	1243
Gurney, Tiana	*University of Southern Queensland, Australia*	811
Gururajan, Raj	*University of Southern Queensland, Australia*	811, 1197, 1212
Hafeez-Baig, Abdul	*University of Southern Queensland, Australia*	811
Håheim, Lise Lund	*Norwegian Knowledge Centre for the Health Services, Norway*	26
Halkos, Dimitrios	*National Technical University of Athens, Greece*	1415
Hamid, Alalwany	*Brunel University, UK*	8
Harno, Kari	*Helsinki University Central Hospital, Finland*	554
Heilman, George E.	*Winston-Salem State University, USA*	1930
Hermens, Hermie J.	*University of Twente, The Netherlands*	489
Ho, Francis	*University of Victoria, Canada*	2057
Holtz, Bree	*Michigan State University, USA*	117
Hung, Patrick C.K.	*University of Ontario Institute of Technology, Canada*	674
Irizarry, Cynthia	*Suffolk University, USA*	845
Jain, Jitendra	*People's College of Medical Sciences, India*	480
Janamanchi, Balaji	*Texas A&M International University, USA*	256
Järvinen, Olli P.	*Finnish Game and Fisheries Research Institute, Finland*	1744
Jean-Jules, Joachim	*Université de Sherbrooke, Canada*	2012
Jeong, Byungho	*Chonbuk National University, Korea*	945
Joshi, Ankur	*People's College of Medical Sciences, India*	480
Kafeza, Eleanna	*Athens University of Economics and Business, Greece*	674
Kafeza, Marina	*University Hospital of Heraklion, Greece*	674
Kallio, Markku	*The Finnish Medical Society Duodecim, Finland*	733

Karahanna, Elena \ *University of Georgia, USA* ... 1513
Kart, Firat \ *University of California, Santa Barbara, USA* ... 527
Kastania, Anastasia \ *Athens University of Economics and Business, Greece* ... 1777
Katsamakas, Evangelos \ *Fordham University, USA* ... 256
Kern, Josipa \ *University of Zagreb, School of Medicine, Andrija Stampar School of Public Health, Croatia* ... 1544
Kerr, Karolyn \ *Simpl, New Zealand* ... 218
Keshavjee, Karim \ *InfoClin Inc., Canada* ... 994
Kethers, Stefanie \ *Monash University, Australia* ... 1640
Khan, Khaled M. \ *Qatar University, Qatar* ... 1720
Kim, Mincheol \ *Cheju National University, South Korea* ... 1243
Kisilowska, Malgorzata \ *University of Warsaw, Poland* ... 461
Kitsiou, Spyros \ *University of Macedonia Economic and Social Science, Greece* ... 374
Klepack, William \ *Dryden Family Medicine, USA* ... 1503
Kolker, Alexander \ *Children's Hospital and Health Systems, USA* ... 1874
Krol, Emily \ *The University of Texas at Austin, USA* ... 540
Kucukyazici, Beste \ *McGill University, Canada* ... 994
Kudyba, Stephan \ *New Jersey Institute of Technology, USA* ... 1318
Kushniruk, Andre W. \ *University of Victoria, Canada* ... 2057
Kutscha, Ansgar \ *Diakonie Hospital Schwaebisch Hall gGmbH, Germany* ... 60
Kuwata, Shige \ *Tottori University Hospital, Japan* ... 2057
Kuziemsky, Craig E. \ *University of Ottawa, Canada* ... 642
Kwok, Benny W. C. \ *The Chinese University of Hong Kong, Hong Kong* ... 674
Kyriazis, Dimosthenis \ *National Technical University of Athens, Greece* ... 1857
Lai, James \ *University of British Columbia, Canada* ... 994
Lecnzarowicz, Dorota \ *University of Westminster, UK* ... 2179
Lee, Chooi \ *Kingston Hospital, UK* ... 2179
Lee, Ki Jung \ *Drexel University, USA* ... 226
Leiviskä, Katja \ *University of Oulu, Finland* ... 733
Lemire, Marc \ *University of Montreal, Canada* ... 958
LeRouge, Cynthia \ *St. Louis University, USA* ... 89
Li, Jingquan \ *Texas A&M University-Kingsville, USA* ... 1795
Mackert, Michael \ *The University of Texas at Austin, USA* ... 117, 540
Maglaveras, Nicos \ *The Medical School, AUTH, Greece* ... 2145
Malek, Jean-Nicolas \ *HEC Montréal, Canada* ... 958
Mamykina, Lena \ *GVU Center Georgia Institute of Technology, USA* ... 510
Manthou, Vicky \ *University of Macedonia Economic and Social Science, Greece* ... 374
Martin, Carmel M. \ *Northern Ontario School of Medicine, Canada* ... 480
Martin, Jennifer \ *RMIT University, Australia* ... 627
Mas, José Ruiz \ *University of Zaragoza, Spain* ... 830
Maumbe, Blessing M. \ *Eastern Kentucky University, USA* ... 1074, 1090
Mauro, Alejandro \ *Hospital Italiano de Buenos Aires, Argentina* ... 445
McKay, Elspeth \ *RMIT University, Australia* ... 627
McLeod Jr., Alexander J. \ *University of Nevada, USA* ... 1553
McNeal, Ramona \ *University of Northern Iowa, USA* ... 1472
Medina-Garrido, José Aurelio \ *University of Cadiz, Spain* ... 1

Medina-Garrido, José Aurelio \ *University of Cadiz, Spain* ... 315, 1628
Mei, HaiLiang \ *University of Twente, The Netherlands* ... 489
Meinert, David \ *Missouri State University, USA* ... 1491
Melliar-Smith, P. M. \ *University of California, Santa Barbara, USA* ... 527
Memo, Enrico \ *Ca' Foscari University, Italy* ... 233
Meneses, Filipe \ *Universidade do Minho, Portugal* ... 861
Messai, Radja \ *Laboratoire TIMC-IMAG, Institut de l'Ingénierie et de l'Information de Santé, France* ... 185
Miao, Gengxin \ *University of California, Santa Barbara, USA* ... 527
Mika, Karin \ *Cleveland State University, USA* ... 274
Miller, Thomas W. \ *University of Connecticut, USA* ... 569
Miscione, Gianluca \ *International Institute for Geo-Information Science and Earth Observation, The Netherlands* ... 2218
Miyazaki, Masako \ *University of Alberta, Canada* ... 790
Moreira, Adriano \ *Universidade do Minho, Portugal* ... 861
Morgan, Robert D. \ *Texas Tech University, USA* ... 569
Mørland, Berit \ *Norwegian Knowledge Centre for the Health Services, Norway* ... 26
Morton, Russell S. \ *Winston-Salem State University, USA* ... 1930
Moser, L. E. \ *University of California, Santa Barbara, USA* ... 527
Mynatt, Elizabeth D. \ *GVU Center Georgia Institute of Technology, USA* ... 510
Naguib, R.N.G. \ *BIOCORE Coventry University, UK* ... 889
Narkhede, Vinod \ *People's College of Medical Sciences, India* ... 480
Naseer, Aisha \ *Brunel University, UK* ... 913
Navajas, Julián Fernández \ *University of Zaragoza, Spain* ... 830
Navarro, Eduardo Antonio Viruete \ *University of Zaragoza, Spain* ... 830
Nemana, Ravi \ *University of California - Berkeley, USA* ... 790
Newell, Sue \ *Bentley College, USA & Warwick Business School, UK* ... 1713
Norris, Tony \ *Massey University, New Zealand* ... 218
O'Neill, Liam \ *University of North Texas, USA* ... 1503
Oinas-Kukkonen, Harri \ *University of Oulu, Finland* ... 733
Oliver, Nick S. \ *Imperial College, UK* ... 790
Olla, Phillip \ *Madonna University, USA* ... 750
Owei, Vesper T. \ *Cape Peninsula University of Technology, Republic of South Africa* ... 1090
Ozkan, Sevgi \ *Brunel University Business School, UK* ... 339
Paavola, Teemu \ *LifeIT Plc, Finland* ... 1286
Page, Andrew C. \ *University of Western Australia, Australia* ... 871
Pajak, Sarah \ *Brunel University, UK* ... 717
Panteli, Niki \ *University of Bath, UK* ... 1686
Paranjape, Raman \ *University of Regina & TRLabs Regina, Canada* ... 356
Paré, Guy \ *HEC Montréal, Canada* ... 958
Parry, David \ *Auckland University of Technology, New Zealand* ... 178, 1272, 2192
Partridge, Helen \ *Queensland University of Technology, Australia* ... 146
Patrick, Jon \ *The University of Sydney, Australia* ... 1954
Paul, Ray J. \ *Brunel University, UK* ... 1342
Pennel, Cara L. \ *Texas A&M Health Science Center, USA* ... 1582
Perry, Theodore L. \ *Health Research Corporation, USA* ... 1318

Peterson, Dane K. \ *Missouri State University, USA* 1491
Pignatiello, Antonio \ *University of Toronto, Canada* 2044
Pitsillides, Andreas \ *University of Cyprus, Cyprus* 1686
Pitsillides, Barbara \ *Nicosia, Cyprus* 1686
Polasek, Ozren \ *University of Zagreb, School of Medicine, Andrija Stampar School of Public Health, Croatia* 1544
Prabhu, Vittal \ *The Pennsylvania State University, USA* 945
Protti, Denis \ *University of Victoria, Canada* 402
Quiram, Barbara J. \ *Texas A&M Health Science Center, USA* 1582
Radhakrishnan, Abirami \ *Morgan State University, USA* 393, 986
Raghupathi, Wullianallur \ *Fordham University, USA* 256, 585
Räisänen, Teppo \ *University of Oulu, Finland* 733
Randeree, Ebrahim \ *Florida State University, USA* 2111
Ray, Amy \ *Bentley College, USA* 1713
Reardon, John L. \ *University of Hawaii, USA* 1028
Resca, Andrea \ *LUISS 'Guido Carli' University, Italy* 1400
Rice, Jeffrey J. \ *Independent Scholar, USA* 1318
Rodrigues, Maria Andréia F. \ *Universidade de Fortaleza, Brazil* 903
Root, Jane \ *Aurora Medical Group, USA* 1172
Ruiz, Ignacio Martínez \ *University of Zaragoza, Spain* 830
Russello, Giovanni \ *Imperial College London, UK* 659
Sadanand, Asha B. \ *University of Guelph, Canada* 1569
Sadanand, Venkat \ *University of Saskatchewan, Canada* 1260
Sadasivam, Rajani S. \ *University of Massachusetts Medical School, USA* 2125
Samaras, George \ *University of Cyprus, Cyprus* 1686
Sammon, David \ *University College Cork, Ireland* 1151
Sarmad, Alshawi \ *Brunel University, UK* 8
Schmeida, Mary \ *The Cleveland Clinic, USA* 1472
Schmitz, Dominik \ *Fraunhofer FIT, Germany* 1640
Schoen, Michael J. \ *University of Alabama at Birmingham, USA* 2125
Schulman, Joseph \ *New York Presbyterian Hospital, USA* 162
Segura, Daniela \ *CICESE, Mexico* 2079
Seppänen, Matti \ *The Finnish Medical Society Duodecim, Finland* 733
Serrano, Christina I. \ *University of Georgia, USA* 1513
Settles, Burr \ *University of Wisconsin-Madison, USA* 975
Shahtahmasebi, Said \ *The Good Life Research Centre Trust, New Zealand* 42
Shaw, Mark C. \ *De Montfort University, UK* 1805
Shaw, Michael J. \ *University of Illinois at Urbana-Champaign, USA* 1795
Shivute, Meke I. \ *Polytechnic of Namibia, Namibia* 1074, 1090
Shrestha, Bhavesh \ *University of Massachusetts Dartmouth, USA* 694
Sicotte, Claude \ *University of Montreal, Canada* 958
Sideras, Gabriel \ *National Technical University of Athens, Greece* 1415
Sier, David \ *CSIRO Mathematical and Information Sciences, Australia* 1640
Sikder, Iftikhar U. \ *Cleveland State University, USA* 1842
Simoens, Steven \ *Katholieke Universiteit Leuven, Belgium* 297
Simonet, Ana \ *Laboratoire TIMC-IMAG, Institut de l'Ingénierie et de l'Information de Santé, France* 185

Contents

Volume I

Section I. Fundamental Concepts and Theories

This section serves as the foundation for this exhaustive reference tool by addressing crucial theories essential to the understanding of health information systems. Chapters found within these pages provide an excellent framework in which to position health information systems within the field of information science and technology. Individual contributions provide overviews of the future of e-health, telemedicine barriers, electronic health records, and data protection. Within this introductory section, the reader can learn and choose from a compendium of expert research on the elemental theories underscoring health information systems research

Section II. Development and Design Methodologies

This section provides in-depth coverage of conceptual architectures, frameworks and methodologies related to the design and implementation of health information systems. Throughout these contributions, research fundamentals in the discipline are presented and discussed. From broad examinations to specific discussions on particular frameworks and infrastructures, the research found within this section spans the discipline while also offering detailed, specific discussions. Basic designs, as well as abstract developments, are explained within these chapters, and frameworks for designing successful e-health systems, pervasive healthcare applications, and ICTs for human services are provided.

Volume II

Section III. Tools and Technologies

This section presents extensive coverage of the technology that informs and impacts health information systems. These chapters provide an in-depth analysis of the use and development of innumerable devices and tools, while also providing insight into new and upcoming technologies, theories, and instruments that will soon be commonplace. Within these rigorously researched chapters, readers are presented with examples of the tools that facilitate and support the emergence and advancement of health information systems. In addition, the successful implementation and resulting impact of these various tools and technologies are discussed within this collection of chapters.

Section IV. Utilization and Application

This section introduces and discusses the utilization and application of health information systems. These particular selections highlight, among other topics, challenges in electronic medical record system adoption, wireless technology adoption in healthcare, and current practices in healthcare systems. Contributions included in this section provide excellent coverage of today's online environment and insight into how health information systems impact the fabric of our present-day global village.

Volume III

Section V. Organizational and Social Implications

This section includes a wide range of research pertaining to the social and organizational impact of health information systems around the world. Chapters included in this section analyze preparing healthcare organizations for IT adoption, demographic difference in telehealth outcomes, physician characteristics and electronic medical records, and patient perspectives and roles in creating health records and recording health data. The inquiries and methods presented in this section offer insight into the implications of health information systems at both a personal and organizational level, while also emphasizing potential areas of study within the discipline.

Section VI. Managerial Impact

This section presents contemporary coverage of the managerial implications of health information systems. Particular contributions address the implantation of an enterprise system in a healthcare network and applications of a case management software system in non-profit organization. The managerial research provided in this section allows executives, practitioners, and researchers to gain a better sense of how health information systems can inform their practices and behavior.

Volume IV

Section VII. Critical Issues

This section addresses conceptual and theoretical issues related to the field of health information systems, which include issues related to privacy, security, and quality. Within these chapters, the reader is presented with analysis of the most current and relevant conceptual inquires within this growing field of study. Particular chapters address the impact of privacy legislation on patient care, quality assurance approaches to healthcare, and improving the quality of healthcare research data sets. Overall, contributions within this section ask unique, often theoretical questions related to the study of health information systems and, more often than not, conclude that solutions are both numerous and contradictory.

Section VIII. Emerging Trends

This section highlights research potential within the field of health information systems while exploring uncharted areas of study for the advancement of the discipline. Chapters within this section highlight new trends in the creation of personal health records, healthcare education, and coding and messaging systems for health informatics. These contributions, which conclude this exhaustive, multi-volume set, provide emerging trends and suggestions for future research within this rapidly expanding discipline.

Preface

Health information systems play a vital role in improving the quality and efficiency of healthcare by ensuring access to and delivery of essential information. Developing secure, efficient information systems for the healthcare industry that address the needs of patients and clinicians in an increasingly complex environment is often a difficult task.

With the constant changes in the landscape of health information systems, it is a challenge for researchers, practitioners, clinicians, and experts to take in the volume of innovative advances and up-to-the-moment research in this diverse field. Medical Information Science Reference is pleased to offer a four-volume reference collection on this rapidly growing discipline, in order to empower students, researchers, academicians, and practitioners with a wide-ranging understanding of the most critical areas within this field of study. This collection provides the most comprehensive, in-depth, and recent coverage of all issues related to the development of cutting-edge health information systems, as well as a single reference source on all conceptual, methodological, technical and managerial issues, and the opportunities, future challenges and emerging trends related to the development, application, and implications of health information systems.

This collection entitled, **"Health Information Systems: Concepts, Methodologies, Tools, and Applications"** is organized in eight (8) distinct sections, providing the most wide-ranging coverage of topics such as: 1) Fundamental Concepts and Theories; 2) Development and Design Methodologies; 3) Tools and Technologies; 4) Utilization and Application; 5) Organizational and Social Implications; 6) Managerial Impact; 7) Critical Issues; and 8) Emerging Trends. The following provides a summary of what is covered in each section of this multi-volume reference collection:

Section 1, ***Fundamental Concepts and Theories***, serves as a foundation for this extensive reference tool by addressing crucial theories essential to the understanding of health information systems. Chapters such as "Inventing the Future of E-Health" by José Aurelio Medina-Garrido and María José Crisóstomo-Acevedo and "Multi-Dimensional Criteria for the Evaluation of E-Health Services" by Alalwany Hamid and Alshawi Sarmad define essential concepts in e-health, such as electronic health records and telemedicine, and provide frameworks for their evaluation. "Quality of Health Information on the Internet," by Kleopatra Alamantariotou and "Improving Data Quality in Health Care" by Karolyn Kerr and Tony Norris provide overviews of quality assessment of health information online and offer suggestions for both patients and clinicians. Later selections, including "Overview and Analysis of Electronic Health Record Standards" by Spyros Kitsiou, Vicky Manthou, and Maro Vlachopoulou and "Process Level Benefits of an Electronic Medical Records System" by Abirami Radhakrishnan, Dessa David, and Jigish Zaveri highlight the challenges and opportunities presented by the use of electronic health records in practice . These and several other foundational chapters provide a wealth of expert research on the elemental concepts and ideas which surround information in healthcare.

Section 2, ***Development and Design Methodologies***, presents in-depth coverage of the conceptual design and architecture of a number of health systems, including e-health services, mobile healthcare, and pervasive healthcare applications. "Patient-Centered E-Health Design," by Alejandro Mauro and Fernán González Bernaldo de Quirós begins this section with an overview of tools and techniques needed for the design of efficient patient-centered e-health services. "Planning Successful Telemedicine and E-Health Systems" by Michael Mackert, Pamela Whitten, and Emily Krol highlights key points to consider when planning for the implementation of new telemedicine or e-health systems. Similarly, "Shared Healthcare in a Regional E-Health Network" by Kari Harno and "Tele-Practice Technology: A Model for Healthcare Delivery to Underserved Populations" by Thomas W. Miller, Robert D. Morgan, and Jennifer A. Wood offer overviews of key considerations for healthcare delivery in regional contexts. With contributions from leading international researchers, this section offers copious developmental approaches and methodologies for the design and implementation of health information systems.

Section 3, ***Tools and Technologies***, presents extensive coverage of the various tools and technologies used in the development and implementation of health information systems. This comprehensive section opens with the chapter "Capturing Data in Healthcare Using Patient-Centered Mobile Technology," by Sarah Pajak, Lorraine H. De Souza, Justin Gore, and Christopher G. Williams, which describes how patient perspectives can be used to inform the development of new user-centered technology in healthcare. Mobile technology in healthcare is further explored in selections such as "Managing Mobile Healthcare Knowledge: Physicians' Perceptions on Knowledge Creation and Reuse" by Teppo Räisänen, Harri Oinas-Kukkonen, Katja Leiviskä , Matti Seppänen, and Markku Kallio, "Personal Health Records Systems Go Mobile: Defining Evaluation Components" by Phillip Olla and Joseph Tan, and "Adoption of Mobile Technology by Public Healthcare Doctors: A Developing Country Perspective" by Nesaar Banderker and Jean-Paul Van Belle. Later selections such as "Collaborative Virtual Environments and Multimedia Communication Technologies in Healthcare" by Maria Andréia F. Rodrigues and Raimir Holanda Filho explain how technology can be used for training and learning in healthcare environments. In all, this section provides coverage of a variety of tools and technologies that inform and enhance modern healthcare environments.

Section 4, ***Utilization and Application***, describes how health information systems have been utilized and offers insight on important lessons for their continued use and evolution. Including chapters such as "Best Practices for Implementing Electronic Health Records and Information Systems" by Beste Kucukyazici, Karim Keshavjee, John Bosomworth, John Copen, and James Lai and "Electronic Medical Records: TAM, UTAUT, and Culture" by Ken Trimmer, Leigh W. Cellucci, Carla Wiggins, and William Woodhouse, this section investigates the numerous methodologies that have been proposed and enacted as electronic health records have grown in popularity. As this section continues, a number of case studies in health information research are presented in selections such as "Providing Telemental Health Services after Disasters: A Case Based on the Post-Tsunami Experience" by Shashi Bhushan Gogia, "Planning and Control and the Use of Information Technology in Mental Healthcare Organizations" by I.J. Baars and G.G. Van Merode, and "Assessing Physician and Nurse Satisfaction with an Ambulatory Care EMR: One Facility's Approach" by Karen A. Wager, James S. Zoller, David E. Soper, James B. Smith, John L. Waller, and Frank C. Clark. Contributions found in this section provide comprehensive coverage of the practicality and current use of health IT.

Section 5, ***Organizational and Social Implications***, includes chapters discussing the importance of addressing organizational and social impact in the evaluation and design of any health information system. Chapters such as "Preparing Healthcare Organizations for New IT Systems Adoption: A Readiness Framework" by Robert Breas and Matthew Waritay Guah and "Managing ICT in Healthcare Organization: Culture, Challenges, and Issues of Technology Adoption and Implementation" by Nasriah Zakaria, Shafiz Affendi Mohd Yusof, and Norhayati Zakaria address specific issues and trends in organizational IT adoption among patients, clinicians, and IT professionals. This section continues with investigations of community health and public healthcare in chapters such as "Understanding Computerised Information Systems Usage in Community Health" by Farideh Yaghmaei and "Managing E-Procurement in Public Healthcare: A Knowledge Management Perspective" by Tommaso Federici and Andrea Resca, concluding with discussions on topics such as patient roles in recording health data and data systems for disaster preparedness. Overall, these chapters present a detailed investigation of the complex relationship between individuals, organizations and health records and technologies.

Section 6, ***Managerial Impact***, presents focused coverage of health information systems as they relate to improvements and considerations in the workplace. "A Process Architecture Approach to Manage Health Process Reforms" by Christine Stephenson and Wasana Bandara highlights the importance of adopting a business process modeling approach to facilitate healthcare reform in the private and public sectors. "Investing Trust Relationships in a Healthcare Network" by Stefanie Kethers, Günter Gans, Dominik Schmitz, and David Sier presents a case study that explores the managerial implications of trust relationships between two separate wards in a hospital. In all, the chapters in this section offer specific perspectives on how managerial perspectives and developments in healthcare methodologies inform each other to create more meaningful user experiences.

Section 7, ***Critical Issues***, addresses vital issues related to health information systems, which include patient privacy, healthcare ethics, and information quality and reliability. Chapters such as "Security-Aware Service Specification for Healthcare Information Systems" by Khaled M. Khan discuss the importance of developing security-aware healthcare software services and the current challenges associated with doing so. Later selections, such as "Privacy Management of Patient-Centered E-Health" by Olli P. Järvinen discuss informational privacy from a patient perspective, providing a framework that addresses key patient concerns and distinctions between different e-health interests. This section continues by asking unique questions about demographic inconsistencies in healthcare environments, models for e-health service evaluation, and trends in healthcare data quality.

The concluding section of this authoritative reference tool, ***Emerging Trends***, highlights areas for future research within the field of health information systems, while exploring new avenues for the advancement of the discipline. Beginning this section is "Toward a Better Understanding of the Assimilation of Telehealth Systems" by Joachim Jean-Jules and Alain O. Villeneuve. This selection proposes a conceptual model of the determinants relevant for the assimilation of telehealth systems in healthcare organizations. Trends in the usability of health information systems are presented in "Emerging Approaches to Evaluating the Usability of Health Information Systems" by Andre W. Kushniruk, Elizabeth M. Borycki, Shige Kuwata, and Francis Ho with the aim of improving the adoption of health information systems in both hospitals and other healthcare organizations. These and several other emerging trends and suggestions for future research can be found within the final section of this exhaustive multi-volume set.

Although the primary organization of the contents in this multi-volume work is based on its eight sections, offering a progression of coverage of the important concepts, methodologies, technologies, applications, social issues, and emerging trends, the reader can also identify specific contents by utilizing the extensive indexing system listed at the end of each volume. Furthermore to ensure that the scholar, researcher and educator have access to the entire contents of this multi volume set as well as additional coverage that could not be included in the print version of this publication, the publisher will provide unlimited multi-user electronic access to the online aggregated database of this collection for the life of the edition, free of charge when a library purchases a print copy. This aggregated database provides far more contents than what can be included in the print version in addition to continual updates. This unlimited access, coupled with the continuous updates to the database ensures that the most current research is accessible to knowledge seekers.

As a comprehensive collection of research on the latest findings related to technologies and healthcare delivery, *Health Information Systems: Concepts, Methodologies, Tools, and Applications*, provides researchers, administrators and all audiences with a complete understanding of the development of applications and concepts in Clinical, Patient and Hospital Information Systems. Given the growing needs of populations around the world for care and delivery of services, as well as disease control, quality diagnostics and secure records, *Health Information Systems: Concepts, Methodologies, Tools, and Applications*, addresses the demand for a resource that encompasses the most pertinent research in health information systems, healthcare technologies and telemedicine.

Health Information Systems:
Concepts, Methodologies, Tools and Applications

Joel J. P. C. Rodrigues
Instituto de Telecomunicações, Portugal & University of Beira Interior, Covilhã, Portugal

Binod Vaidya
Instituto de Telecomunicações, Portugal

ABSTRACT

Healthcare systems are an information intensive industry in which reliable and timely information is a critical resource for the planning and monitoring of service provision. Health Information Systems can be a powerful tool to make healthcare delivery more effective and far more efficient. This chapter focuses on major current studies in the health information systems, discusses organizational, social, and managerial implications as well as critical issues, and presents emerging trends for future research efforts.

INTRODUCTION

From the early 1960s through the 1970s, a new epoch of computing in healthcare emerged. A large group of hospitals in the United States and some hospitals in Europe concurred on the necessity to advance a patient information management system prototype. These hospitals heavily invested money, time, and effort to move toward computerization. And seeing the sudden surge of interest among the hospitals and the potential market opportunities, some commercial companies also joined in an effort to support patient information systems. Nonetheless, many of the early projects did not thrive: the complexity of the information requirements of a patient management system was gravely underestimated.

Historical developments of these various systems play a paramount role in the health informatics and more specific hospital information system movements. These eventually led to the successful design and implementation of major computerized health record systems and databases such as COSTAR (Computer Stored Ambulatory Record System), RMRS (Regenstrief Medical record System), TMR (The Medical Record), HELP (Health Evaluation through Logical Processing) system, and POMR/PROMIS (the Problem-oriented Medical record/ Information system). COSTAR, a patient record system developed at Massachusetts General Hospital in the 1960s, was later extended to record patient data relating to different types of ailments and is used even today in several teaching hospitals and research universities across the globe. RMRS was a physician-designed integrated inpatient and outpatient information system implemented in 1972, and TMR is an evolving medical record system that was developed in the mid-1970s at Duke University Medical Center. Together with the success of the Technicon system, the efficiencies of these automated record systems soon provided considerable motivation for the integration of computing into health care systems (Tan, 2005).

As soon as health administrators and practitioners began to realize the efficiency and data processing power of computers, which increased when minicomputers were introduced during the late 1970s and early 1980s, computerization began to be seen as a magic bullet for controlling and managing the large and increasing volumes of medical and other administrative data processed on a daily basis. Health administrative data encompass health administrative and patient financial data and inventories of drugs and medical equipment, as well as routine transactional data including the management of patient billing, insurance co-payments, accounts receivable and payable and general ledgers. Medical data range from demographics of patients to clinical and health services data to epidemiological and health population statistics. By the early 1980s, computer miniaturization and cost reduction combined with increases in processing power resulted in a dramatic move away from massive health data processing using mainframe or minicomputers to new and more efficient forms of health management information systems, office automation, and networking technologies.

Nowadays, it is hard to imagine healthcare without Information and Communication Technology (ICT). The healthcare industry now relies on data and information for every facet of its delivery. Huge amounts of data are generated and because this occurs in a mostly unstructured paper environment, its use is restricted in supporting healthcare. ICT has capacity to transform the health industry and the way it manages its data, information and knowledge and to revolutionize the way in which clinicians work. The needs of clinicians should drive innovations that affect then and they must be vigilant overseers of any change to their practice bought about by technology.

The use of health information technology has been promoted as having tremendous promise in improving the efficiency, cost-effectiveness, quality, and safety of medical care delivery in the healthcare system. The realization of these benefits is especially important in the context of reports that show five years of consecutive annual double-digit increases in healthcare costs and increases in the numbers of adverse health events. At the same time, reports have suggested that still investments in healthcare industries are wasted on inefficient processes. Legislators and organizational leaders at the federal and state levels have emphasized the need for healthcare to follow the example of many non-healthcare industries, in which implementation of computer information technology has been critical in increasing the accessibility of mission-critical information, automating labor-intensive and inefficient processes, and minimizing human error.

Even though significant literature on health information systems is already accessible, many new ideas and applications are persistently emerging and provide potential opportunities and challenges for further research. The purposes of this introductory chapter are: (1) to review the literature on health information systems using a suitable classification and longitudinal studies to understand previous studies and future research trends, and (2) to present a framework of health information systems research which consists of concepts, methodologies, tools, applications, critical issues, and emerging trends. Our chapter is both descriptive and prescriptive, and intends to stimulate further interest in this area. It will provide a reference source for anyone interested in health information systems research and practices.

Analyzing HIS Research Trends

To provide in-depth knowledge of the health information systems, we have analyzed articles in journals and chapters of periodicals and books with extensive use of Google Scholar, ScienceDirect, IEEE Explore, and ACM Portal. Keyword searches were conducted by using mainly search strings such as "health information system", health AND "information system", and "ehealth information system". In addition, recent publications included in this volume and select journal publications were referenced to augment the literature.

This paper consists of ten sections. (1) introduction, (2) fundamental concepts and theories in health information systems, (3) health information systems development and design methodologies, (4) health information systems tools and technologies, (5) utilizations and application of health information systems, (6) organizational and social implications of health information systems, (7) managerial impact of health information systems, (8) critical issues in health information systems, (9) emerging trends in health information systems, and (10) a conclusion.

FUNDAMENTAL CONCEPTS AND THEORIES IN HEALTH INFORMATION SYSTEMS

In this section, we define Health Information System (HIS), and provide concepts and theories related to HIS. Then we classify HIS according to its use.

Defining Health Information System (HIS)

A health information system collects data as a part of the patient care process. This data can be used across a number of systems of many different purposes and as with all patient data, it must be subject to confidentiality and security safeguards. Patient data must integrate with data from other facilities and it must meet the needs of various professional groups. Health information systems generally comprise several different applications that support the needs of the organizations.

Some of the concepts and terminologies related to HIS are as follows.

- **Health/Medical Informatics and Telemetics.** Health informatics (Conrick, 2006) is the field that concerns itself with the cognitive, information processing, and communication tasks of medical practice, education, and research including the information science and technology to support those tasks. It deals with the resources, devices, and methods required to optimize acquisition, storage, and retrieval. Health informatics tools include computers as well as clinical guidelines, formal medical terminologies, and information and communication systems. More broadly speaking, its emphasis is on clinical and biomedical applications with the added possibility of the integrating these clinical components either among themselves or to more administrative-type health information system. In this regard, the field of health informatics and telematics has evolved very rapidly over the past several years.
- **Health information technology (HIT).** Health information technology (HIT) is the application of information processing involving both computer hardware and software that deals with the storage, retrieval, sharing, and use of health care information, data, and knowledge for communication and decision making (Goldschmidt, 2005).

- **Electronic medical record (EMR), Electronic health record (EHR), Electronic patient record (EPR).** Electronic medical record (EMR) is a medical record in digital format, whereas electronic health record (EHR) refers to an individual patient's medical record in digital format. EHR systems co-ordinate the storage and retrieval of individual records with the aid of computers, which are usually accessed on a computer, often over a network. One of the important trends is the move towards a universal electronic patient record (EPR). EPR is defined as electronically stored health information about one individual uniquely identified by an identifier. Essentially, EPR technology entails capturing, storing, retrieving, transmitting, and manipulating patient-specific, healthcare-related data singly and comprehensively, including clinical, administrative, and biographical data (Protti et al., 2009).

Theories Applied to HIS

There are several theories such as general systems theory, chaos theory, and activity system theory that can be applied to healthcare systems.

General systems theory (GST) (Bertalanffy, 1968) begins with the observation that what we see, hear, and interact with may be rationalized as a hierarchical network of systems and subsystems. In this regard, systems, which must have a purpose, can be whole and be part of other systems (subsystems) at the same time. Systems can also be characterized as being open or closed.

Open complex systems are characterized by input-process-output triads and feedback loops. GST easily describes the flow of appropriate and relevant information about sick patients (input), who are placed into the different subsystems of the acute health care system to be treated and cared for (process) until they are ready, perhaps, to be transferred to another subsystem such as a group home (intermediate output) before being discharged as healthy individuals who can continue to contribute to their work organizational systems (final output). Continual monitoring of the health status of these patients becomes the feedback loop in the system. These loops ensure the reliability and quality of health services provided, including those before and after the patients are discharged. A common example of an information system that controls this acute patient care process in a hospital setting is the admission-discharge-transfer (ADT) system.

In earlier works (Tan, 2001), the principles of GST concerning the behaviors of organizational systems and subsystems were used to think about the design of different classes of clinical and administrative health management information systems required to run hospitals and health provider organizations.

Previous work has demonstrated that systems that are interactively complex and coupled are prone to failure. Tan et al. (Tan et al., 2005) have analyzed how the parts of networks connect and interact to produce outcomes, and according to their research factors and challenges have been identified to consider when designing future-oriented healthcare networks. Their work discusses a chaos theory view of healthcare systems, which divides the causes of chaos into internal and external origins. Each origin is further subdivided into a human or individual level, an organizational level and a system level, and stages ranging from static to chaos. When either etiology, internal or external, surpasses the static stage, the potential for error increases.

Ideally, a health information framework should support and facilitate interventions to shift and maintain the complexity towards the static stage. In addition, it is very important that healthcare information systems are created with checks and balances to prevent system-induced chaos. Conceptually, a global health information system should provide efficient access to patient information, comprehensive surveillance, expert systems to facilitate decision-making and computational power. Information networks can be used to manage the complexity of healthcare. The adaptive system theory identifies the following concepts that should be incorporated when deploying emerging information and communication networks: acceptance of uncertainty; unpredictable healthcare systems; improved performance by feedback loops; flexible standardization; quick response time with backup redundancy at the edge of chaos; need of intelligent and effective leadership in the chaos stage (Tan et al., 2005).

The complex and dynamic components and relationships must be included in the architecture of healthcare information system in order to support the complete information needs in the healthcare activities. For this purpose, Activity System Theory (ATS) can be applied by integrating system thinking and social psychology, which uses recursive model of human activity system. A project IMIS (Integrated Mobile Information System for Diabetic Healthcare) (Bai, 2004) shows the practical application of the activity system theory for constructing healthcare information system. It was concluded that the activity system model could provide the service system designers with a comprehensive and integrated framework for designing healthcare information system.

Classification of HIS

Classification of health information systems can be done in various ways, which is shown in Table 1.

HEALTH INFORMATION SYSTEMS DEVELOPMENT AND DESIGN METHODOLOGIES

This section presents health care standardizations, frameworks for HIS development and design methodologies.

Healthcare Standardizations

Hospitals and other healthcare provider organizations typically have many different computer systems used for everything from billing records to patient tracking. Regarding the electronic health record, there have been various international efforts related to standardization, including CENTC251 in Europe (CEN-TC, 2009), HL7 in USA (HL7, 2009), the Healthcare task force of the Object Management Group (OMG, 2009), and OpenEHR (OpenEHR, 2009).

HL7 specifies a number of flexible standards, guidelines, and methodologies by which various healthcare systems can communicate with each other. Such guidelines or data standards are a set of rules that allow information to be shared and processed in a uniform and consistent manner. These data standards are meant to allow healthcare organizations to easily share clinical information. Theoretically, this ability to exchange information should help to minimize the tendency for medical care to be geographically isolated and highly variable. HL7 develops conceptual standards (i.e. HL7 RIM), document standards (i.e. HL7 CDA), application standards (i.e. HL7 CCOW) and messaging standards (i.e. HL7 v2.x and v3.0). Messaging standards are particularly important because they define how information is packaged and communicated from one party to another. Such standards set the language, structure and data types required for seamless integration from one system to another. HL7 encompasses the complete life cycle of a standards specification including the development, adoption, market recognition, utilization, and adherence (Blazona & Koncar, 2007).

Table 1. Classification of health information systems (Yusof et al., 2008)

Information Systems	**Descriptions**	**Characteristics**
Patient centered information systems	They are the electronic version of patients' information. Different terms are used to refer to these systems including EPR, EMR and computer based patient record (CPR)	• Manage comprehensive patient care information such as medical records, appointment scheduling, theatre management and ward reporting
Clinical information systems (CIS)	Represent separate systems in specialized service of clinical departments. Examples of CIS include patient monitoring systems and anesthesia documentation system	• Perform specific tasks including collection of specific data for patient care, research, management, planning and maintenance of national data repositories • Specific tasks operate in departments such as internal medicine, cardiology, neurology, obstetrics, surgery and psychiatry • CIS are used for administrative support, patient data collection, decision support, picture archiving, image analysis, monitoring, reporting, assessment and research
Radiology information systems	Support the acquisition and analysis of radiological images as well as administrative functions of radiology department. Example: picture archiving and communication systems.	• May be stand alone or integrated in hospital information systems
Laboratory information systems	Perform data validation, administration, electronic transmission and computer storage These systems often must interface with instruments and other information systems such hospital IS. A LIS is a highly configurable application, which is customized to facilitate a wide variety of laboratory workflow models. Deciding on an LIS vendor is a major undertaking for all labs. Vendor selection typically takes months of research and planning.	• In high demand when a large number of tests generate large data. Samples are analyzed fully automatically, and the results are computer generated • Support clinician to analyze trends to assess treatment effects
Pharmacy information systems	Maintain medication information	• Include functions such as keeping patients' medication records, checking prescriptions, and providing drug prescriptions and administration to physicians and nurses.
Hospital information systems	Consist of integrated hospital information processing systems. Examples: computerized physician order entry (CPOE), patient care information systems, nursing (bedside) documentation systems, nursing IS, general practitioner IS	• Support healthcare activities at the operational, tactical and strategic levels • Encompass patient management, administration, facilities management and medical applications • Contain database systems, data communication facilities and terminal or workstations
Telemedicine	It is supported by electronic processes and communication	• Facilitates exchange between primary care physicians and specialists as well as patients from disperse locations • Allows physicians to practice medicine at a distance

Frameworks for HIS Applications

Many of the information technology (IT) frameworks were developed before the advent of HIS. As HIS grew rapidly and gained strategic importance, the existing IT infrastructure became inadequate in supporting the complex capabilities of HIS applications.

The major architectural approaches in Table 2 describe architectural development processes that are broadly used in the software engineering and healthcare domains.

Table 2. Architectural approaches (Lopez & Blobel, 2009)

Architectural approaches	Related approaches	Domain	
		Software engineering	**Health informatics**
Architectural frameworks	Enterprise architectures	Zachman; FEAF; DODAF; RM-ODP; TOGAF; IEEE 1471-2000	Generic Component Model
Architectural models	Reference architecture; architecture styles	Object-oriented architectures; component-based architectures; MDA; SOA; business process models	ISO EN 13606-1; OpenEHR; HL7 RIM; CDA; GCM specialization
Description languages Middleware architectures Architecture development process	Modeling languages Component architectures; service architectures Analysis/design methods and models	UML; ACME ADL; OCL, Web services; CORBA; J2EE; COM; .NET RUP; SAAM; ATAM; ADD; TOGAF ADM; SEI CMMI; SPEM	OpenEHR, ADL OMG HDTF, CEN 12967 HL7 HDF; HL74SOA; CEN EN 12967-1

Design Methodologies for HIS Development

Traditional IT development approaches such as systems development life-cycle (SDLC) methods and functional team IT organization were outdated long before the advent of the digital economy. In response to the drawbacks of the traditional IT development approaches, various alternative systems development methods such as rapid application development (RAD) and object-oriented systems development were introduced in 1990s.

Due to its relative popularity, there are a large number of evaluation studies on clinical decision support systems (CDSS). Kaplan (Kaplan, 2001) reviewed studies focusing on the evaluation of CDSS, with the main emphasis upon changes in clinical performance and systems that could improve patient care. Kaplan's study includes many evaluations of CDSSs using designs based on laboratory experiments or Randomized Controlled Clinical Trials (RCTs).

Delpierre et al. (Delpierre et al., 2004) reviewed studies of computer-based patient record systems (CBPRS). The objective of their review was to carry out a systematic survey of studies analyzing the impact of CBPRS on medical practice, quality of care, and user and patient satisfaction.

Tan with Sheps (Tan & Sheps, 1998) use the term health decision support systems (HDSS) and, more specifically, clinical decision support systems and expert systems (CDSS/ES) to characterize many HIS applications. A group health decision support system (gHDSS) combines analytic modeling, network communications, and decision technology to support group decision-making processes such as group strategic thinking, problem formulation, and generation of goal-seeking solutions. This technology has the potential to increase the efficiency, effectiveness, and productivity of group interactions through asynchronous board meetings, on-line forums, or special group meetings in which board members and executives can network and share information with one another without being completely constrained by separation in time and geographical distance.

Intelligent decision support systems (IDSS) are basically DSS that have an intelligent component, which either replaces or enhances the model subsystem. In past years, some proposals for intelligent and agent-based decision support systems (e.g. Kebair & Serin, 2006; Liu et al., 2006; Sokolova, 2009) have been described. New approaches of researching IDSS appear following the rapid progress of agent systems and network technology.

A strategy to reduce medication error is to implement Electronic Prescribing Decision Support Systems (EPDS) (Ayres et al., 2006). In a clinical business context, EPDS should be a core function of a point of care clinical system but software vendors tend to develop it as either a standalone system or an additional module to a point-of-care clinical system.

Starting with the requirements for semantic interoperability derived from paradigm changes for health systems and their supporting health information systems, the need of an architectural approach for analyzing, designing, implementing, and maintaining advanced, sustainable, semantically interoperable HIS has been shown.

The weakest aspect in the evaluated architectural approaches for HIS development was the lack of a formal architecture development methodology covering the complete architecture lifecycle, and a clearly defined development process describing tasks, work products, roles, workflows, etc. The Rational Unified Process (RUP) (Kruchten, 2003) was found to be the most comprehensive source of methods and processes for system development, including architecture development. This development process constitutes the better approach to complete the HIS-DF, providing details on how to deliver a sound architecture description. HIS-DF tasks, responsible persons, products, guidance, phases, and workflows are described specializing (tailoring) the RUP process. RUP facilitates the flexibility, scalability and reusability of the methodology by describing method components and providing guidance and tooling for creating reusable Method Content (RUP Plug-ins) and documenting the methodology through exportable Web pages and XMI files.

Semantic interoperability is a basic challenge to be met for new generations of distributed, communicating and cooperating health information systems enabling shared care and e-health. Analysis, design, implementation and maintenance of such systems and intrinsic architectures have to follow a unified development methodology. The Generic Component Model (GCM) (Lopez & Blobel, 2009) is used as a framework for modeling any system to evaluate and harmonize state of the art architecture development approaches and standards for health information systems as well as to derive a coherent architecture development framework for sustainable, semantically interoperable HIS and their components. The proposed methodology is based on the Rational Unified Process (RUP), taking advantage of its flexibility to be configured for integrating other architectural approaches such as Service-Oriented Architecture (SOA), Model-Driven Architecture (MDA), ISO 10746, and HL7 Development Framework (HDF).

HEALTH INFORMATION SYSTEMS TOOLS AND TECHNOLOGIES

This section presents coverage of various tools and technologies and their use in creating and managing HIS. This section discusses Web technology standards, GIS technologies, artificial intelligence techniques, imaging technologies, agent technologies, data warehousing architectures, and data mining techniques.

Web Technology Standards

If the data exchange process simply provides static health information from health information systems and legacy databases, then the information dissemination process is straightforward. In this case, the Internet and the typical HTML (Hypertext Markup Language) offer a convenient platform through which the information can be predesigned, validated, and captured or presented as a user-friendly multimedia document. To improve the data's timeliness, validity, and integrity, the preferred data collection method is automated and direct data input at the source—for example, using predesigned documents stored in organizational intranets or extranets, then warehousing the completed documents either centrally or via on-line distributed network technology. Data direct entry requires that the acquired data be converted into easily readable and appealing user-oriented information.

To fulfill the need for dynamic and interactive Web interfaces, the World Wide Web Consortium (W3C) introduces a standard known as Extensible Markup Language (XML) (W3C, 2009), which is simple, extendible text format derived from SGML. A number of variations of XML have been developed. With XML, data or even documents can be simultaneously transformed into useful, meaningful, and interactive information in a format that is readily retrievable, comparable and transactional, where data can be used for exchanging dialogues and executing monetary payments. The data transfer and data distribution functions (that is, data retrieval and transmission activities) become integrated with those of presentation, exchange, and use. XML technology also allows the creation of multimedia and intelligent graphical Web interfaces and thus has the ability to compact large amounts of information conveniently. The information can be further packaged to support individual users by filtering out information that may not be needed for a particular application or for a particular data exchange transaction.

GIS Technologies

A geographical information system (GIS) is a powerful tool for collecting, recording, storing, manipulating, and displaying spatial data sets. A GIS uses spatial data such as digitized maps and can represent a combination of text, graphics, icons, and symbols on two-dimensional and three-dimensional maps. GIS technology might be used for digital mapping of a certain epidemic—for instance, HIV infection among a subpopulation across various counties in a province or state. This knowledge can then be used to effectively target interventions for specific population groups.

The development of Web-based GIS applications in medical fields has led to the collection and dissemination of information on several infectious diseases at national and international levels. Web-based GIS applications are used in several international surveillance networks.

Both GIS-related technologies and public health surveillance are concerned with the spatial and temporal dimensions of public health problems (Boulos, 2004). As part of an e-public health information system or application, GIS-related technologies can support direct or indirect (data extracted from available secondary sources) data input and verification from either a desktop computer or a Web-based browser that interfaces with a data storage system, which may be a data warehouse or a suite of databases. At least four data categories may warrant inclusion in a GIS-related application for use in bio-defense preparedness.

Artificial Intelligent Techniques

In the ICT domain, one of the most promising and interesting domains seemed to be Artificial Intelligence (AI). At the clinical level, applications utilizing AI, neural network (NN), and fuzzy logic techniques are being developed to provide clinical decision support to physicians (Coiera, 2003). It deals primarily with information used in medical decision making. The primary objective in this category of IT is to assist physicians and other medical experts in diagnosis and treatment.

Artificial intelligence (AI), combined with ontology, is becoming a powerful tool in mining data for patterns of significance within large bodies of data. As more knowledge from research is placed directly into machine-readable formats, opportunities will expand for “automated learning” in which AI systems generate hypotheses and, where possible, test them against appropriate data. These systems will be usable by consumers/patients in their own language, and by 2015, these systems will be culturally and ethnically sensitive in how they operate, present information and support health behavior and decision-making (HIS2015, 2006).

Imaging Technologies

For the storage of medical information, Picture Archiving and Communication System (PACS) have been developed to address some of the accessibility issues and e-networking requirements for the exchange of medical imaging data. Essentially, PACS are systems for storage of massive digital images, which are in accordance to DICOM (Digital imaging and communication in Medicine) standard (Blazona & Koncar, 2007). These systems also support simultaneous access to digital imaging data from various connected terminals, systems, and networks. Imaging technologies have urged healthcare facilities to implement PACS to enhance patient care and improve workflow.

With PACS and medical imaging technology maturing, the importance of organizational maturity and effective deployment of PACS in the hospital enterprise are becoming significant. Van de Weterring and Batendur illustrated relevant aspects of maturity and evolvability of PACS. From the results of a meta-analytic review on PACS maturity and evolvability, they proposed a model – the PACS maturity model (PMM) – that describes five levels of PACS maturity and the corresponding process focus (van de Wetering & Batenbur, 2009).

Agent Technologies

Agent Technology is an emerging and promising research area in software technology, which increasingly contributes to the development of value-added information systems for large healthcare organizations (Nguyen et al., 2009). Fonseca et al. (Fonseca et al., 2005) presented an inherently distributed Multi-Agent Medical Information System (MAMIS), which was designed with the goal of proving a solution for patient information search on a community of autonomous healthcare units and provide ubiquitous information access to physicians and healthcare professionals in a variety of situations.

The use of agent-based intelligent decision support systems (IDSS) to support decision making is important within HIS because they allow doctors and nurses to quickly gather information and process it in various ways in order to assist with making diagnosis and treatment decisions (Foster et al., 2005). Cohen and Hudson present an agent-based IDSS which is used for diagnosis and involves three levels. The lowest level is called agents, which contains multiple kinds of agents including user interface agents, data mining agents and problem solver agents. The second level is communicators which act as translators between the task-managers and the agents to ensure that every agent gets the information in their desired format. The top level is task-managers, which break the task up into sub problems that are assigned to agents (Cohen & Hudson, 2002).

Coffin et al. (Coffin et al., 2004) describes a reminder system. It uses intelligent agents to monitor circumstances that require notifying healthcare professionals about events. These events can include giving shots, vaccinations, surgeries, follow-up checks and other important events.

Favela et al. extended a handheld-based mobile hospital information system with ubiquitous computing technology and described how public displays are integrated with handheld and the services offered by these devices. Public displays become aware of the presence of physicians and nurses in their vicinity and adapt to provide users with personalized, relevant information. An agent-based architecture allows the integration of proactive components that offer information relevant to the case at hand, either from medical guidelines or previous similar cases (Favela et al., 2004).

Data Warehousing Architecture

Data warehousing architecture which is basically a conceptualization of how the data warehouse (DW) is built, consists of the following interconnected layers: operational database layer, data access layer, metadata layer, informational access layer. Data warehousing architecture for integrated information management simply provides an integrated source of aggregated, organized, and formatted data. The data in a DW are designed to support management decision-making and strategic planning. Accordingly, these data may sometimes be categorized in various forms, and most likely have already been aggregated and filtered after coming from legacy systems. Furthermore, DW can be combined with an executive information systems (EIS), an ES, an HDSS, group HDSS, or a GIS not only to increase data analytic and processing power but also to develop new and complex forms of e-health technologies. One of the most prominent uses of DW in e-healthcare is the automated collection of massive amounts of linked data from diverse sources for use in data mining techniques.

Sahama and Croll presented data warehouse architectures, which are practicable solutions to tackle data integration issues, and could be adopted by small to large clinical data warehouse applications (Sahama & Croll, 2007).

Data Mining Techniques

Data mining techniques explore data for hidden trends and patterns. Data mining tools include artificial neural networks, case-based (analogical) reasoning, statistical methods, genetic algorithms, and explanation-based reasoning. A number of studies have employed data mining to survey healthcare data (Kaur & Wasan, 2006; Obenshain, 2004; Silver et al., 2001).

Kaur and Wasan highlighted the use of classification based data mining techniques such as rule based, decision tree and Artificial Neural Network to massive volumes of healthcare data. In particular, they considered a case study using classification techniques on a medical data set of diabetic patients (Kaur & Wasan, 2006).

Data mining can provide the means to analyze relevant information in public health surveillance. Obsenshain presented the application of data mining of healthcare data in automated surveillance systems and explored the usefulness of data mining for research related to infection control and hospital epidemiology, especially where the data volume exceeds capabilities of traditional statistical techniques (Obenshain, 2004).

The authors focused on an analysis, which was performed by a team of physicians and IT researchers, using a commercially available on-line analytical processing (OLAP) tool in conjunction with proprietary data mining techniques (Silver et al, 2001).

The opportunity for a health maintenance organization (HMO) to explore and discover best practices by comparing and contrasting physician practice patterns for different treatment protocols corresponding to groups with specific case mixes is one benefit of applying DW and data mining technologies. The unraveling of the human genome to provide treatments for various challenging ailments is another noble example of DW and data mining technology applications.

UTILIZATION AND APPLICATION OF HEALTH INFORMATION SYSTEMS

This section investigates the use and implementation of health informatics in a variety of contexts. This section discusses health information exchanges, health knowledge management, e-health systems, e-public health systems, and m-health systems.

Health Information Exchanges (HIEs)

Health Information Exchange (HIE) (Overhage et al., 2005) is defined as the mobilization of healthcare information electronically across organizations within a region or community. HIE provides the capability to electronically move clinical information among disparate healthcare information systems while maintaining the meaning of the information being exchanged. Healthcare communities worldwide continue to adopt new approaches to better serve an increasingly complex patient population. Improved patient safety, streamlined provider workflow, more rapid and distributed access to medical information, and better clinical audits all place strains on healthcare infrastructures, which were originally designed for a single-entity approach (Jha et al., 2008).

With the maturation of EHRs and HIEs to address these business challenges, the focus most recently has shifted to patient-centered or "consumer-driven" healthcare, requiring a new level of integration between healthcare services and IT systems. As a result, clinical and business transformation of healthcare infrastructures has become central to business and political agendas, aiming to involve consumers, physicians, payers, and employers as never before.

Health institutions, governments, and coalitions worldwide are teaming to deliver fundamental transformation of healthcare IT and information services through three interrelated objectives. The impact of this effort is being felt across the entire healthcare continuum: a) clinicians are integrating their independent record and technology assets to create agile, patient-centered electronic health records, realizing new levels of patient safety and information exchange through organizational, regional, and national ways of working; b) HIEs are bringing together distributed enterprises and investing in standards for data sharing, integration, and information presentation across care settings; c) clinical transformation and interoperability of health information technologies on a national level is rapidly advancing health information exchange and driving public health initiatives, such as public health disease surveillance programs.

Health Knowledge Management

Knowledge management (KM) is a management paradigm that includes concerted, coordinated and deliberate efforts to manage the organizational knowledge through processes for identifying and leveraging it to enhance the organizations ability to compete. KM is purported to increase innovativeness and responsiveness. Liao classified such knowledge management technologies and applications into six categories: knowledge-based systems (KBS), data mining (DM), information and communication technology (ICT), artificial intelligence (AI) / expert systems (ES), database technology (DT), and modeling (Liao, 2003).

Quality care of patients requires evaluating large amounts of data at the right time and place and in the correct context. With the advent of electronic health records, data warehouses now provide information at the point-of-care and facilitate a continuous learning environment in which lessons learned could provide updates to clinical, administrative, and financial processes. Given the advancement of the information and communication tools and techniques of today's knowledge economy, utilizing these resources is imperative for effective healthcare. Thus KM techniques are now essential for quality healthcare management such that the healthcare industry is increasingly becoming a knowledge-based community. In this regard, knowledge based systems are assuming an increasingly important role in healthcare and medicine for assisting clinical staff in making decisions under uncertainty (e.g., diagnosis decisions, therapy and test selection, and drug prescribing).

Hsia et al. proposed a conceptual framework that integrates nursing process, KM activities, and enabling information technology (IT) for designing such a nursing knowledge management system. The framework indicates the critical knowledge management activities in nursing process and the enabling IT based on the task/technology fit theory. This framework would immensely help healthcare organizations to identify their IT needs and to plan for the KM activities and technical infrastructure of the nursing knowledge management system (Hsia et al., 2006).

To illustrate a feasible health knowledge management process that helps gather useful technology information and reduce many knowledge misunderstandings, Cheng et al. depicted the design of asynchronously sharing mechanism to facilitate the knowledge transfer, in which health knowledge management process can be used to publish and retrieve documents dynamically. It effectively creates an acceptable discussion environment and lessens the traditional meeting burden among development engineers (Cheng et al., 2008).

E-Health Systems

E-health is basically healthcare practice which is supported by electronic processes and communication. E-health can encompass a range of services that are at the edge of medicine/healthcare and information technology such as EMR, telemedicine, consumer health informatics, health knowledge management, virtual healthcare teams, m-health, e-healthgrids, healthcare information systems.

In general, e-health domains and applications can be divided into two primary clusters based on two key dimensions of systems integration characteristics. On one hand, systems that are characterized by a high degree of internal integration include applications such as the following: virtual patient records (VPR), document management (DM), geographical information systems (GIS), group health decision support systems (group HDSS), executive information systems (EIS), data warehouses (DW), and data mining. On the other hand, systems that are characterized by a high degree of external integration include the following: telecommunications, wireless and digital networks, community health information networks (CHIN), The Internet, Intranets and extranets, health informatics, and telemedicine or e-medicine (Raghupathi & Tan, 2002).

E-Public Health Systems

An e-public health information system must support the public health mandate of improving the health status of the community and the population at large. The information system must measure the health of the population against potential determinants of health. Community health assessment, for example, requires the collection, analysis, interpretation, and communication of key health statistics, data, and information (Araujo et al., 2009).

Emerging e-public health technologies include geographical information systems (GIS), data warehousing, and data mining methodology. These e-technologies, which have matured over the years, are now being applied to e-public health information systems.

M-Health Systems

Hospital environments inherently involve mobility due to the constant movement of medical professionals, support personnel and critical medical equipment. Given this intrinsic level of mobility, combined with the tremendous need for timely and accurate patient information and hospital efficiency, various wireless technologies are being adopted. Thus m-health can be defined as mobile communications network technologies for healthcare (Istepanian et al., 2006). This concept represents the evolution of "traditional" e-health systems from desktop platforms and wired connections to the use of more compact devices and wireless connections in e-health systems. The emerging development of m-health systems in the last decade was made possible due to the recent advances in wireless and network technologies, use of mobile technologies and devices such as cell phones and handheld devices, PDA. Although m-health can generally be considered to be an extension of electronic health, it has a number of unique characteristics and business models, as it embraces both emerging and enabling technologies (Varshney, 2006; Wu et al., 2007).

Kyriacou et al. reviewed wireless technologies and emerging wireless video systems used for m-health systems and also provided an overview of recently published wireless emergency healthcare systems, which clearly demonstrate the benefits and the need for their wider deployment. It is expected that m-health e-emergency systems will significantly affect the delivery of healthcare (Kyriacou et al., 2007).

Thus, the main wireless technologies that are used in m-health systems are GSM, 3G (W-CDMA, CDMA2000, TD-CDMA), satellite, and wireless LAN (WLAN). Emerging wireless technologies such as WiMax, Home/Personal/Body Area Networks, ad-hoc and sensor networks are also extensively used. Wireless PANs are defined with IEEE standard 802.15. The most relevant enabling technologies for m-health systems are Bluetooth and ZigBee.

For example, a variety of wireless technologies such as mobile computing and wireless networks have been applied to school-based health centers (Jen, 2009) and wireless healthcare using PDAs and handheld devices (Fontelo & Chismas, 2005).

ORGANIZATIONAL AND SOCIAL IMPLICATIONS OF HEALTH INFORMATION SYSTEMS

This section discusses community-based health systems, virtual communities, globalization, health level seven, health metric network, public health surveillance, human computer interaction, and health disparities.

Health informatics is an evolving field that considers health information technology at multiple levels of abstraction and complexity ranging from analysis of the impact of health information systems at the individual, organizational and regional level. Table 3 presents a conceptual framework for considering the interaction between humans and health information technologies (Kushniruk & Borycki, 2008).

Community-Based Health Systems

A community health information network (CHIN) may be conceived as a network that links health care stakeholders throughout a community or region. Such an integrated collection of telecommunication and networking capabilities can facilitate communication with patients as well as the exchange of clinical and financial information among multiple providers, employers, and related healthcare entities within a targeted geographical area. Central to a CHIN's success is the practical implementation of a computerized patient record system at the community or regional level. CHIN technology has become an important interactive research and communication tool, aiding both medical professionals and health consumers in search of health-related information and knowledge. Some example of community-based health systems can be given in Chiu et al., 2008 and Puri et al., 2009.

Table 3. Conceptual framework for considering the interaction between humans and HITs

Level 4	Healthcare system level (broader healthcare environment – eg national and international strategies and contexts)
Level 3	Organizational aspects of health information systems (social and organizational level)
Level 2	Users interacting with information system to carry out work task (level of workflow)
Level 1	Users interacting directly with IS (human-computer interaction)

Virtual Communities

Virtual communities serve as on-line support groups for both e-patients and e-caregivers. Numerous e-health companies are also promoting the concept of virtual communities as part of e-disease management programs. These communities provide consumers with general information, information about medical research on particular diseases, and information on available products and services specific to these diseases, as well as psychological support from affected patients facing the same condition (Forducey et al., 2005). Virtual patient records (VPR) are an integrated health database processing engine that links the accurate and rapid collection of various patient-related information and knowledge elements to generate an aggregated, well-classified, and organized set of administrative and clinical information and knowledge that e-health providers can retrieve, exchange, and disseminate as needed for e-clinical decision making, e-control, analysis, e-diagnosis, e-treatment planning and evaluation, and many other e-health-related cognitive activities. VPR enable the integration and sharing of healthcare information within large and heterogeneous organizations.

Globalization

Globalization refers to viewing the world as a single community for propagating the promotion of health and wellbeing through evolving virtual network and the sharing of e-health information and services. Globalization of e-healthcare will require effective use of individual, group, community, organizational, and societal resources. With the implementation of global call centers and Internet-enabled transactional services, e-health purchasers and providers can significantly streamline many administrative and financial processes, promoting global exchange of data for scheduling, shipping, billing, ordering, and purchasing healthcare products and services. Globalization of e-health services also has the potential to provide high-quality services to many underserved urban, rural, and remote areas (Haux, 2006).

Health Level Seven (HL7)

Health Level Seven (HL7) is an international community of healthcare subject matter experts and information scientists collaborating to create standards for the exchange, management and integration of electronic healthcare information, which is an all-volunteer, not-for-profit organization involved in development of international healthcare standards. HL7 and its members provide a framework (and related standards) for the exchange, integration, sharing and retrieval of electronic health information, which support clinical practice and the management, delivery, and evaluation of health services, are the most commonly used in the world. HL7 promotes the use of such standards within and among healthcare organizations to increase the effectiveness and efficiency of healthcare delivery for the benefit of all (HL7, 2009).

Health Metric Network

The Health Metrics Network (HMN) (WHO-HMN, 2009) is a global partnership that facilitates better health information at country, regional and global levels. HMN aims to increase the availability and use of timely and accurate health information by catalyzing the joint funding and development of core country health information systems. HMN has a single strategic goal—increasing the availability and use of timely and accurate health information by catalyzing the joint funding and development of core country health information systems. In pursuit of this goal, HMN lays out a vision and identifies strategies for health information system (HIS) development and strengthening, supporting countries in implementing such strategies, and generating new knowledge and global public goods through research, technical innovation, and sharing lessons learned.

Human Computer Interaction

The study of human computer interaction (HCI) is concerned with human, social, organizational and technical aspects of the interaction between human and machines. It is a broad area of study that deals with a broad range of phenomena, including the design evaluation and social implications of computer systems. There are a wide range of aspects of HISs that are related to cognitive that human information processing. The user interface to HISs can be defined as the component of the overall man-machine system responsible for communication with the user of the system. Thus HCI can be considered to be largely cognitive in that it involves processing of information by humans in close conjunction with computer systems. Therefore, the application of ideas, theories, and methods emerging from the field of cognitive psychology are highly relevant to the design and implementations of more effective HISs from the perspective of human users, for whom systems are designed to support and serve (Jacko & Sears, 2003).

Public Health Surveillance

Surveillance methods that can detect disease at an earlier stage are an important research direction for public health surveillance. These methods are referred to as syndromic surveillance because they have the goal of recognition of outbreaks based on the symptoms and signs of infection and even its effects on human behavior prior to first contact with the health care system. The Real-time Outbreak and Disease Surveillance system (RODS) is a computerized public health surveillance system for early detection of disease outbreaks, including those caused by bioterrorism. RODS processes clinical encounter data from participating hospitals and sales data of over-the-counter (OTC) healthcare products from participating stores and pharmacies (Tsui et al., 2003).

The role of public health surveillance is to collect, analyze, and interpret data about biological agents, diseases, risk factors, and other health events and to provide timely dissemination of collected information to decision makers.

Health Disparities

People have long recognized that some individuals are healthier than others and that some live longer than others do, and that often these differences are closely associated with social characteristics such as race, ethnicity, gender, location, and socio-economic status (Brach & Fraser, 2000).

Health disparities or healthcare inequalities refer to gaps in the quality of health and healthcare across racial, ethnic, and socioeconomic groups. There are several reasons for disparities in access to healthcare, which are as follows: lack of insurance coverage, lack of a regular source of care, lack of financial resources, legal barriers, the healthcare financing system, scarcity of providers, linguistic barriers, health literacy, lack of diversity in the healthcare workforce, and elderly age.

MANAGERIAL IMPACT OF HEALTH INFORMATION SYSTEMS

This section discusses contemporary coverage of managerial application and implications of HIS. The core concepts are such as health systems governance, interoperability, and healthcare strategy and evaluation.

Health Systems Governance

Governance is thought to be a key determinant of economic growth, social advancement and overall development. Assessment of governance as the gateway for promoting good governance of the health system is a key consideration that underpins this effort. Governance influences all other health system functions, thereby leading to improved performance of the health system and ultimately to better health outcomes.

Health systems governance is currently a critical concern in many countries because of increasing demand to demonstrate results and accountability in the health sector, at a time when increasing resources are being put into health systems where institutional contexts are changing rapidly.

Ten principles were proposed for the analytical framework for assessing governance of the health system. They are: strategic vision, participation and consensus orientation, rule of law, transparency, responsiveness, equity and inclusiveness, effectiveness and efficiency, accountability, intelligence and information and ethics (Siddiqi et al., 2009).

Interoperability

Interoperability means the ability to communicate and exchange data accurately, effectively, securely, and consistently with different information technology systems, software applications, and networks in various settings, and exchange data so the clinical or operational purpose and meaning of the data are preserved and unaltered. In the healthcare sector, interoperability is the ability of different information technology systems and software applications to communicate, to exchange medical data accurately, effectively, and consistently, and to use the information related to the patient that has been exchanged. Interoperability can also refer to legal interoperability (i.e., the regulatory issues of cross-border EMR implementations) (Bailey et al., 2008).

A study (Pirnejad et al., 2008) shows that in many studies heterogeneity of information systems and standards are referred as main impediments to building interoperable communication networks, however, social and organizational factors are also paramount. Lack of attention to how the technological artifact will affect and be affected by the organization in which it becomes embedded lies at the core of many technological failures.

Berler et al. illustrated that the integration of information systems represents one of the most urgent priorities of a Regional Healthcare Authority (RHA) in order to meet its clinical, organizational and managerial needs. Current practice shows that the most promising approach to achieve a Regional Healthcare

Information System (RHIS) is to use a HL7 message-based communication system implemented by an asynchronous common communication infrastructure between healthcare sites (Berler et al., 2004).

Strategies and Evaluations of Healthcare Systems

One of the critical aspects of healthcare systems is planning healthcare business strategies, healthcare technology management and diffusion, healthcare system implementation and evaluation, and envisioning and monitoring the impacts of health information technology. The planning aspect involves building a strategic vision to align the goals of senior management with the changing needs of the healthcare marketplace. Planning e-health strategies is crucial because it involves identifying e-consumer needs and business requirements, materializing telemarketing and virtual network management concepts, planning e-data warehouse mining and e-technology strategies, and championing sound methodologies for growing new and complex e-health applications. A major trend in planning e-health strategies is shifting responsibilities and power from traditional health providers and health system analysts to e-consumers, the people who ultimately determine the survival, use, and growth of the e-health business ventures (Tan, 2005).

It is important not only to focus on the impacts of healthcare systems on individuals, groups, communities, and societies, but also to realize how the implementation of healthcare system may ultimately affect the larger context of our healthcare delivery system both nationally and globally. Thus healthcare system implementation and evaluation that includes responsibility for overseeing the integration of health information technologies, the incorporation of transactional activities into the healthcare system, the incorporation of security and privacy mechanisms to ensure user acceptance and satisfaction, and the training and education of users migrating from legacy systems to the healthcare system needs to emphasized (Ammenwerth et al., 2004; Bradshaw & Urquhart, 2005).

CRITICAL ISSUES IN HEALTH INFORMATION SYSTEMS

This section discusses privacy and security issues as well as health ethical issues.

Privacy and Security Issues

Data security and confidentiality of health information are two of the most important concerns in the application of e-health technologies. Security access is a major concern as e-health technologies become available to a huge number of users spread across literally boundless geography. Appropriate firewall protection, data encryption, and password access can all be employed to manage security issues; however, computing viruses are getting more sophisticated as security technology increases.

The healthcare industry has also been facing pressing security challenges in the last few years. For one, EMR, among other systems, provides opportunities for care improvement as well as threats to the privacy of patients' information. Moreover, the Health Insurance Portability and Accountability Act (HIPAA) of 1996 outlines medical security and privacy rules and procedures to be applied by all healthcare providers in order to simplify and protect the administration of healthcare billing (Baumer et al., 2000; Mercuri, 2004). HIPAA aims at securing individuals' PHI (protected health information) and it only covers healthcare providers, health plans, and health care clearinghouses that transmit patient information in electronic form. However, other entities, such as secondary users (for example, researchers) who have access to such data, are not restrictedby HIPAA.

A number of technical protocols and methods have been proposed to resolve security issues. To enhance security, many e-health systems provide secure private channels over the Internet. The Secure Sockets Layer (SSL) protocol and Internet Protocol Security (IPSec) are the most widely used security protocols for PACS security (Dantu et al., 2007).

Privacy concerns are key barriers to the growth of health-based systems. Legislation to protect personal medical information was proposed and put in effect to help building a mutual confidence between various participants in the healthcare domain.

Access control is a preferred method for security management due to flexibility of assigning access privileges to roles rather than to individual users. Thus Wozak et al. showed that end-to-end security must be seen as a holistic security concept, which comprises the following three major parts: authentication and access control, transport security, as well as system security (Wozak et al., 2007).

Health Ethical Issues

Perhaps the most essential ingredient for vibrant e-health development is assurance for citizens and e-healthcare professionals that an e-healthcare system will in fact lead to improved health as opposed to fraud, medical misinformation, abuse of consumer data, marketing of products and services that are of little or questionable value, or e-care services that fail to satisfy their needs. Policies and mechanisms must be created to oversee the development and growth of e-health, including legislation against fraud and unethical practices and for protection of patient privacy and confidentiality of e-patient data (Harman, 2006).

Access to healthcare by low-income population can be hindered by legal barriers to public insurance programs. For example, in the United States federal law bars states from providing Medicaid coverage to immigrants who have been in the country fewer than five years.

EMERGING TRENDS IN HEALTH INFORMATION SYSTEMS

This section identifies seven emerging trends: Web services and semantic Web, Web 2.0, HealthGrid, Voice over IP, u-Health, Evidence-based Health Informatics, and e-health models and services.

Web Services and Semantic Web

Web services are software components or applications, which interact using open XML and Internet technologies. These technologies are used for expressing application logic and information, and for transporting information as messages (Wangler et al., 2003; Turner et al., 2004). Web services offer a platform-neutral interfacing and communication mechanism and have wide infrastructure support in terms of servers and development environments. They have significantly increased interest in Service-oriented architectures (SOAs) (Erl, 2005). The benefits of Web services include loose coupling, ease of integration and ease of accessibility.

In recent years, Web services technology has emerged as a set of standards for publishing, discovering, and composing independent services in an open network. Web services are also increasingly used in health information systems and electronic health records (Altmann et al., 2002; Bergmann et al., 2007; Wright & Sittig, 2008). Nevertheless, the application of SOAs and Web services is currently characterized by an abundance of alternative definitions, approaches and specifications.

Basically, two principle approaches can be applied to Web services (Alonso et al., 2004). The procedural approach focuses on bottom-up application integration. It is based on the architecture of the existing Remote Procedure Call (RPC) middleware, and the current Simple Object Access Protocol (SOAP), Web Service Definition Language (WSDL) and Universal Description, Discovery and Integration (UDDI) specifications. The document-oriented approach focuses on top-down business exchanges, and tries to describe in adequate detail the elements of this exchange, including the technology solutions. It is based on electronic commerce, documents and loosely coupled messaging, and includes specifications such as ebXML. The distinction between these two approaches is not merely related to the different messaging formats enabled by SOAP and WSDL, but rather to the entire design approach of the solutions. Indeed, technologies such as SOAP and WSDL can be used with both approaches (Mykkanen et al., 2007).

Furthermore, there are several overlapping Web services-related specifications available for features such as security, process description, transaction management and electronic contracts, which are required by interoperable complex systems and processes (Turner et al., 2004).

The semantic Web, which is an evolving extension of the World Wide Web, offers a united approach to knowledge management and information processing by using standards to represent machine-interpretable information. Thus semantic Web technology helps computers and people to work better together by giving the contents well-defined meanings. The semantic Web comprises the standards and tools of XML, XML Schema, Resource Description Framework (RDF), RDF Schema, and Web Ontology Language (OWL). The semantic Web has also drawn attention in the medical research communities (Cannoy & Iyer, 2007; Cheung & Stephens, 2009).

An important semantic Web application area is Web services. Semantic Web services aim to describe and implement Web services in order to make them more accessible to automated agents. Semantic web services can support a service description language that can be used to enable an intelligent agent to behave more like a human user in locating suitable Web services.

While the development of Web services and semantic Web has been impressive, numerous research opportunities exist. To realize these benefits, research and practitioner communities need to collaborate on standard and tool development to encourage the exploration and exploitation of semantic web technologies, and service-oriented application development to enhance inter-firm data sharing and collaboration. Ali and Kiefer presented an integrated approach of Web services and semantic Web into the field of medical devices and pervasive computing to build a new breed of medical devices, called Ambient Intelligent (AmI) medical devices. They illustrate the infrastructure, Semantic Medical Devices Space (SMDS), in which AmI medical devices can semantically interoperate not only with each other, but also with the legacy Hospital Information Systems (HISs) and Laboratory Information Systems (LISs) (Ali & Kiefer, 2006).

Web 2.0 Technologies

Web 2.0 refers to Web-oriented applications and services that use the Internet as a platform, with its unique features, relying on its strengths rather than trying to make the Internet suit a particular application. With its promise of a more powerful, engaging, and interactive user experience, Web 2.0 seems poised to revolutionize the way in which we interact with information resources. Web 2.0 is commonly associated with technologies such as weblogs (blogs), social bookmarking, wikis, podcasts, Really Simple Syndication (RSS) feeds (and other forms of many-to-many publishing), social software, and Web application programming interfaces (APIs) (Kristaly et al., 2008).

The collaborative concepts underpinning these Web 2.0 applications are very similar to the notion of Web-based, shareable and distributed electronic health/patient records. Patients and clinicians can securely and simultaneously access these records across multiple institutions and places, facilitating speedy information exchange, communication and collaboration among clinicians and between clinicians and patients to potentially improve clinical outcomes and cost reduction (Boulos & Wheeler, 2007)

Health 2.0 is term representing the possibilities between healthcare, e-health and Web 2.0. Health 2.0 refers to a number of related concepts including telemedicine, electronic medical records, and the use of the Internet by patients themselves such as through message boards, blogs, and other more advanced systems. A key concept is that patients themselves should have greater insight and control into information generated about them.

HealthGrid

A HealthGrid (HealthGrid, 2009) allows the gathering and sharing of many medical, health and clinical records/databanks maintained by disparate hospitals, health organizations, and drug companies. In other words, HealthGrid is an environment in which data of medical interest can be stored and made easily available to different actors in the healthcare system, physicians, allied professions, healthcare centers, administrators and, of course, patients and citizens in general. This large-scale sharing of medical records via network connections has the potential to bring us numerous benefits. It would enable real-time and remote access to large quantities of medical and clinical data regardless of the original healthcare setting in which they were acquired, and regardless of where and when the access is performed. This will, in turn, allow us to improve clinical decisions and diagnoses and to provide better patient care. HealthGrid aggregates longitudinal healthcare data, giving a more complete history of patients no matter where the care was provided and allowing real-time monitoring of trial results and research outcomes as well as early detection of disease and health problems. Applications in Healthgrids include areas such as microarray analysis, image analysis, in silico simulation, distributed database integration, and data mining, among others. HealthGrid is expected to reduce costs and improve healthcare efficiency (Breton et al., 2007). SHARE (Olive et al., 2009) was funded by the European Commission to define a research roadmap for a "HealthGrid for Europe," to be seen as the preferred infrastructure for biomedical and healthcare projects in the European Research Area.

Voice Over IP

Voice over Internet Protocol (VoIP) technologies have continued to evolve, including establishment of several important standards. The integration of different modes of communication is already happening and the increasing reliability of the network will foster the rate of adoption of VoIP. The driving forces for the individual and commercial adoption of the VoIP are the significant cost savings, portability, and functionality that can be realized by switching some or all of their voice services to VoIP. Chen et al showed the integration of mobile health information system with VoIP technology in a wireless hospital (Chen et al., 2008). However, there are risks associated with VoIP services, which may impact quality and security of the phone system for voice communications. If the VoIP user connects through an open wireless hotspot, there is also an increased risk of eavesdropping.

As VoIP technology and IP communication technology are still in an early stage, it would be interesting to investigate what factors are drivers and inhibitors for the adoption of these new technologies by firms and users, what value they create for health organizations, and how the technological features interact with users' characteristics.

Ubiquitous Computing and U-Health

Ubiquitous computing is a paradigm shift where technology becomes virtually invisible in our lives. The advancement of new technologies such as radio frequency identification (RFID) and sensor networks has initiated a trend towards ubiquitous computing, which is also called "anytime, anywhere" computing (Lyytinen et al., 2004). With the advent of the Internet and wireless technology, a worldwide communication system is available, enabling people to communicate at any time and anywhere and to exchange information online. Due to "anytime, anywhere" pervasive computing, organizational activities become more nomadic. The ubiquitous computing environment will make possible new forms of organizing, communicating, working and living. However, ubiquitous computing systems create new risks to security and privacy.

In general, u-healthcare can be divided into three sections depending on the transfer range of the patients' information: u-healthcare within medial institutions, between individuals and medical institutions, and among different medical institutions (Lee et al., 2009). Currently, newly built and large hospitals are trying to operate these hospital information systems by focusing on hospital information systems such as order communication systems (OCS), PACS, EMR, visual information system, and groupware.

In a ubiquitous computing environment, it is important that all applications and middleware should be executed on an embedded system. To organize the u-healthcare infrastructure, it is necessary to establish a context-aware framework appropriate for the wearable computer or small-sized portable personal computer in ubiquitous environment (Ko et al., 2007).

Evidence-Based Health Informatics

Evidence-based Health Informatics (EBHI) can be defined as the conscientious, explicit and judicious use of current best evidence when making decisions about the introduction and operation of IT in a given healthcare setting. Thus EBHI means integrating individual IT expertise with best available external evidence from systematic health informatics research. It has been argued that EBHI is an important step towards better healthcare IT.

Ammenwerth et al. discussed challenges found while conducting meta-analysis on computerized physician order entry (CPOE) and finally concluded that Evidence-Based Health Informatics is still in the beginning stage (Ammenwerth et al., 2009).

E-health Models and Services

E-health models and services can be various types such as Business-to-Consumer (B2C) and Business-to-Business (B2B) (Wen & Tan, 2005).

B2C models and services are among the most widely accepted and practiced service models currently proliferating the e-health marketplace. Examples include the following: virtual doctor visits, e-prescriptions, on-line medical suppliers, e-disease management, and health insurance services. B2B models and services include on-line medical suppliers, hospital and physician procurement, health insurance services, and automated services.

An emerging set of applications has been characterized by efforts to connecting e-consumers (consumer-to-consumer, or C2C) or e-providers (provider-to-provider, or P2P). The P2P model is a subset of the B2B models. Hybrids (for example, combinations of B2B and B2C; C2C and P2P; or B2C and C2C) and other models are used in the following applications and services: EMRs, connecting e-stakeholders, e-directories, medical digital libraries, on-line auctions, stakeholder health portals, and communities of e-health learners.

CONCLUSION

The aim of this chapter was to reflect on the past and current health information system (HIS) research trends and technological advancements and to identify emerging trends and research issues in HIS.

The foremost observations to be drawn from the previous studies include: (1) the realization of operational and strategic benefits was found to be contingent upon effective adaptation of health information system innovation, top management challenge, strategic planning rationale, and the extent of coordination; (2) the traditional ICT development methodologies and infrastructure became deficient in supporting the complex capabilities of emerging healthcare applications; (3) privacy and security issues as well as ethical issues are critical for the success of health information systems; (4) m-health has enormous potential to become a dominant form of market mechanism; (5) virtual communities and globalization have potential to become prominent e-health business models structured around user interests and needs. These observations should be taken into account in the design of future research in emerging trends in e-health systems.

ACKNOWLEDGMENTS

Part of this work has been supported by the *Instituto de Telecomunicações*, Next Generation Networks and Applications Group (NetGNA), Portugal.

REFERENCE

Alonso, G., Casati, F., Kuno, H., & Machiraju, V. (2004). Web services concepts, architectures and applications. Springer.

Altmann, U., Tafazzoli, A.G., Katz, F.R., & Dudeck, J. (2002). XML-based application interface services—a method to enhance integrability of disease specific systems. *International Journal of Medical Informatics, 68,* 27-37.

Araujo, J., Pepper, C., Richards, J., Choi, M., Xing, J., & Li, W. (2009). The profession of public health informatics: Still emerging? *International Journal of Medical Informatics, 78,* 375-385.

Ammenwerth, E., Brender, J., Nykanen P, Prokosch, H.U., Rigby, M., & Talmon, J. (2004). Visions and strategies to improve evaluation of health information systems: Reflections and lessons based on the HIS-EVAL workshop in Innsbruck. *International Journal of Medical Informatics, 73*, 479-491.

Ammenwerth, E., Schnell-Inderst, P., & Siebert, U. (2009). Vision and challenges of evidence-based health informatics: A case study of a CPOE meta-analysis. *International Journal Medical Informatics*.

Ayres, D., Soar, J., & Conrick, M. (2006). Health information systems. In M. Conrick (ed.), *Transforming healthcare with technology: Informatics in healthcare* (pp. 197-211). Thomson Social Science Press.

Ali, S., & Kiefer, S. (2006, October). Semantic medical devices space: An infrastructure for the interoperability of ambient intelligent medical devices. In *Proceedings of the International Special Topic Conference on Information Technology in Biomedicine (ITAB 2006)*.

Bai, G. (2004). Activity system theory approach to healthcare information system. In *Proceedings of International Conference on Service Systems and Service Management (ICSSSM04)*.

Baumer, D., Brande Earp, J., Cobb Payton, F. (2000). Privacy of medical records: IT implications of HIPAA. *Computer & Society 30*(4), 40-47.

Bailey, C., Boucher, P., Kibbe, D., Lubinski, D.J., Spohr, M., & Whitaker, P. (2008). *Interoperability standards for health information systems*. Paper presented at the Conference on Making the eHealth Connection.

Berler, A., Pavlopoulos, S., & Koutsouris, D. (2004). Design of an interoperability framework in a regional healthcare system. In *Proceedings of 26th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, (IEMBS'04) vol. 2* (pp. 3093-096).

Bertalanffy, L. (1968). General systems theory: Foundations, development, applications. New York: Braziller.

Bergmann, J., Bott, O.J., Pretschner, D.P., & Haux, R. (2007). An e-consent-based shared EHR system architecture for integrated healthcare networks. *International Journal of Medical Informatics, 76,* 130-136.

Bradshaw, K., & Urquhart, C. (2005, March). Theory and practice in strategic planning for health information systems. In *Proceedings. of 10th conference on UK Academy for Information Systems*.

Breton, V., Blanquer, I., Hernandez, V., Jacq, N., Legre, Y., Oliver, M., & Solomonides, T. (2007). Roadmap for a European Healthgrid. *HealthGrid 2007*.

Blazona, B., & Koncar, M. (2007). HL7 and DICOM based integration of radiology departments with healthcare enterprise information systems. *International Journal of Medical Informatics, 76S,* S426-S435.

Boulos, M.N.K. (2004). Towards evidence-based, GIS-driven national spatial health information infrastructure and surveillance services in the United Kingdom. *International Journal of Health Geographics, 3*(1).

Boulos, M.N.K., & Wheeler, S. (2007). The emerging Web 2.0 social software: An enabling suite of sociable technologies in health and health care education. *Health Information and Libraries Journal, 24*, 2-23.

Brach, C., & Fraser, I. (2000). Can Cultural competency reduce racial and ethnic health disparities? A review and conceptual model. *Medical Care Research and Review, 57*, 181-217.

Cannoy, S., & Iyer, L. (2007). Semantic Web standards and ontologies in the medical sciences and healthcare. In A.F. Salam & J.R. Stevens (Eds.), *Semantic Web technologies and e-business*. Hershey, PA: Idea Group.

Chen, H.S., Luh, J.J., Cheng, P.H., Chen, S.J., Chen, C.L., & Lai, F. (2006, August). Mobile Health information system integrated with VoIP technology in a wireless hospital. In *Proceedings of the IEEE 8th International Workshop on Enterprise Networking and Computing in Healthcare Industry (Healthcom-2006), India* (pp. 19-23).

Cheung, K.H., & Stephens, S. (2009). Semantic Web for health care and life sciences: A review of the state of the art. *Briefings in Bioinformatics, 10*(2), 111-113.

Conrick, M. (2006). Health informatics: Transforming healthcare with technology. Thomson Social Science Press.

Cohen, M.E., & Hudson, D.L. (2002). Meta neural networks as intelligent agents for diagnosis. In *Proceedings of 2002 International Joint Conference on Neural Networks*.

Coffin, C., Saunders, C., Thomas, C., Loewen, A., Campbell, N., & Ghali, W. Using intelligent agents to repurpose administrative data in fostering disease prevention in an outpatient context: The case of pneumococcal vaccination. In Proceedings of 37th Annual Hawaii International Conference on System Sciences.

Coiera, E. (2003). *Guide to health informatics* (2^{nd} ed.).

CEN-TC (2009). Comitée Européen de Normalisation, Technical Committee 251—Health informatics (CEN/TC251). Retrieved June 2009, from http://www.centc251.org

Chiu, Y.H., Chen, L.S., Chan, C.C., Liou, D.M., Wu, S.C., Kuo, H.S., Chang, H.J., & Chen, T.H.H. (2006). Health information system for community-based multiple screening in Keelung, Taiwan. *International Journal of Medical Informatics, 75*, 369-383.

Choe, J., & Yoo, S.K. (2008). Web-based secure access from multiple patient repositories. *International Journal of Medical Informatics, 77*, 242-248.

Cheng, P.H., Chen, S.J., Lai, J.S., & Lai, F. (2008). A collaborative knowledge management process for implementing healthcare enterprise information systems. *IEICE Transactions on Information and Systems, E91-D*(6), 1664-1672.

Dantu, R., Oosterwijk, H., Kolan, P., & Husna, H. (2007). Securing medical networks. *Network Security* (pp. 13-16).

Delpierre, C., Cuzin, L., Fillaux, J., Alvarez, M., Massip, P., & Lang, T. (2004). A systematic review of computer-based patient record systems and quality of care: More randomized clinical trials or a broader approach. *International Journal for Quality in Health Care*, *16*(5), 407-416.

Erl, T. (2005). Service-oriented architecture: Concepts, technology, and design. Prentice Hall.

Foster, D., McGregor, C., & El-Masri, S. (2005, July). A survey of agent-based intelligent decision support systems to support clinical management and research. In *Proceedings of the First International Workshop on Multi-Agent Systems for Medicine, Computational Biology, and Bioinformatics (MAS*BIOMED'05)*.

Fonseca, J.M., Mora, A.D., & Marques, A.C. (2005). MAMIS–A multi-agent medical information system. In *Proceedings of the IASTED International Conference on Biomedical Engineering (BioMED 2005)*.

Favela, J., Rodriguez, M., Preciado, A., & Gonzalez, V.M. (2004). Integrating context-aware public displays into a mobile hospital information system. *IEEE Transactions on Information Technology in Biomedicine, 8*(3), 279-286.

Fontelo, P.A., & Chismas, W.G. (2005). PDAs, handheld devices and wireless healthcare environments: Minitrack introduction. In *Proceedings of the 38th Hawaii International Conference on System Sciences*.

Forducey, P., Kaur, K., Scheideman-Miller, C., & Tan, J. (2005).Surveying the E-Health landscape: Cases and applications. In J. Tan (Ed)., E-health care information systems: An introduction for students and professionals. Jossey-Bass.

Goldschmidt, P.G. (2005). HIT and MIS: Implications of health information technology and medical information systems. *Communications of the ACM, 48*(10), 69-74.

Harman, L.B. (2006). *Ethical challenges in the management of health information* (2nd ed.). Jones & Bartlett Publishers.

HealthGrid Initiative (2009). Retrieved June 2009, from http://www.healthgrid.org

HL7. (2009). *Health Level Seven, Devices Special Interest Group*. Retrieved May 2009, from http://www.hl7.org

HIS2015 (2006, March). Health Information Systems 2015, Biomonitoring Futures Project, Background Report (BFP 5). *Institute for Alternative Futures*.

Hsia, T.L., Lin, L.M., Wu, J.H., & Tsai, H.T. (2006). A framework for designing nursing knowledge management systems. *Interdisciplinary Journal of Information, Knowledge, and Management, 1*.

Haux, R., "Individualization, globalization and health – about sustainable information technologies and the aim of medical informatics", International Journal of Medical Informatics 75 (2006) 795-808.

Istepanian, R.H., Laxminarayan, S., & Pattichis, C.S. (Eds.) (2006). M-Health: Emerging mobile health systems. Springer.

Jacko, J.A., & Sears, A. (2003). The human-computer interaction handbook: Fundamentals, evolving technologies, and emerging applications.

Jha, A.K., Doolan, D., Grandt, D., Scott, T., & Bates, D.W. (2008). The use of health information technology in seven nations. *International Journal of Medical Informatics, 77*, 848-854.

Jen, W.Y. (2009). Mobile healthcare services in school-based health center. International *Journal of Medicine Informatics, 78*,425-434 .

Kushniruk, A.W., & Borycki, E.M. (2008). *Human, social, and organizational aspects of health information systems*. Hershey, PA: IGI Global.

Kaplan, B. (2001). Evaluating informatics applications — Clinical decision support systems literature review. *International Journal of Medical Informatics, 64*, 39-56.

Kaur H., & Wasan, S.K. (2006). Empirical study on applications of data mining techniques in healthcare. *Journal of Computer Science, 2*(2), 194-200.

Kebair, F., & Serin, F. (2006). Multiagent approach for the representation of information in a decision support system (LNCS 4183, pp. 98-107).

Ko, E.J., Lee, H.J., & Lee, J.W. (2007). Ontology-based context modeling and reasoning for u-healthcare, *IEICE Transactions on Information and Systems 2007 E90-D*(8), 1262-1270.

Kyriacou, E., Pattichis, M.S., Pattichis, C.S., Panayides, A., & Pitsillides, A. (2007).,m-Health e-emergency systems: Current status and future directions. *IEEE Antennas and Propagation Magazine, 49*(1).

Kristaly, D.M., Sisak, F., Truican, I., Moraru, S.A., & Sandu, F. (2008). Web 2.0 technologies in web application development. In *Proceedings of the 1st International Conference on Pervasive Technologies Related to Assistive Environments (PETRA'08)*.

Kruchten, P. (2003). *The Rational Unified Process. An Introduction* (3rd ed.). Boston: Addison Wesley.

Lee, H.J., Lee, S.H., Ha, K.S., Jang, H.C., Chung, W.Y., Kim, J.Y., Chang, Y.S., Yoo, & D.H. (2009). Ubiquitous healthcare service using Zigbee and mobile phone for elderly patients. *International Journal of Medical Informatics, 78*, 193-198.

Liao, S.H. (2003). Knowledge management technologies and applications - Literature review from 1995 to 2002. *Expert Systems with Applications, 25*, 59-71.

Liu, L., Qian, L., & Song, H. (2006). Intelligent group decision support system for cooperative works based on multi-agent system. In *Proceedings of the 10th international conference on CSCW in design CSCWD 2006* (pp. 574-578).

Lyytinen, K.J., Yoo, Y., Varshney, U., Ackerman, M., Davis, G., Avital, M., Robey, D., Sawyer, S., & Sorensen, C. (2004). *Surfing the next wave: design and implementation challenges of ubiquitous computing*. *Communications of Association for Information Systems, 13*(40), 697-716.

Lopez, D.M., & Blobel, B.G.M.E. (2009). A development framework for semantically interoperable health information systems. *International Journal of Medical Informatics, 78,* 83-103.

Kushniruk, A.W., & Borycki, E.M. (2008). *Human, social, and organizational aspects of health information systems*. Hershey, PA: IGI Global.

Mercuri, R.T. (2004). The HIPAA-potamus in health-care data security. *Communications of the ACM, 47*(7), 25-28.

Mykkanen, J., Riekkinen, A., Sormunen, M., Karhunen, H., & Laitinen, P. (2007). Designing web services in health information systems: From process to application level. *International Journal of Medical Informatics, 76*, 89-95.

Nicholson, L., Vakharia, A.J., & Erenguc, S.S. (2004). Outsourcing inventory management decisions in healthcare: Models and application. *European Journal of Operational Research, 154,* 271-290.

Overhage, J.M., Evans, L., & Marchibroda, J. (2005). Communities' readiness for health information exchange: the National Landscape in 2004. *J Am Med Inform Assoc, 12*(2), 107-12.

Obenshain, M.K. (2004). Application of data mining techniques to healthcare data. *Infect Control Hosp. Epidemiol., 25,* 690-695.

OMG (Object Management Group) (2009). *Healthcare Domain Task Force*. Retrieved June 2009, from http://healthcare.omg.org

OpenEHR Foundation (2009). Retrieved June 2009 from, http://www.openehr.org/home.html

Olive, M., Rahmouni, H., Solomonides, T., Breton, V., Legre, Y., Blanquer, I., & Hernandez, V., SHARE road map for HealthGrids: Methodology. *International Journal of Medicine Informatics 78S,* S3-S12

Protti, D., Johansen, I., & Perez-Torres, F. (2009). Comparing the application of health information technology in primary care in Denmark and Andalucia, Spain. *International Journal of Medical Informatics, 78,* 270-283

Pirnejad, H., Bal, R., & Berg, M. (2008). Building an inter-organizational communication network and challenges for preserving interoperability. *International Journal of Medical Informatics, 77,* 818-827.

Puri, S.K., Sahay, S., & Lewis, J. (2009). Building participatory HIS networks: A case study from Kerala, India. *Information and Organization*.

Raghupathi, W., & Tan, J. (2002). Strategic IT applications in health care. *CACM, 45*(12), 56-61.

Sahama, T.R., & Croll, P.R. (2007). A Data warehouse architecture for clinical data warehousing. In *Proceedings Of the First Australasian Workshop on Health Knowledge Management and Discovery (HKMD 2007), Ballarat, Australia* (pp. 227-232).

Sokolova, M.V., & Fernandez-Caballero, A. (2009). Modeling and implementing an agent-based environmental health impact decision support system. *Expert Systems with Applications, 36,* 2603-2614.

Silver, M., Su, H.C., & Dolins, S.B. (2001). Case study: how to apply data mining techniques in a healthcare data warehouse. *J. Healthc. Inf. Manag. 15,* 155-164.

Siddiqi, S., Masud, T.I., Nishtar, S., Peters, D.H., Sabri, B., Bile, K.M., & Jama, M.A. (2009). Framework for assessing governance of the health system in developing countries: Gateway to good governance. *Health Policy, 90*, 13-25.

Tan, J., & Sheps, S.B. (1998). *Health decision support systems*. Aspen Publishers.

Tan, J. (2001). *Health management information systems: Methods and practical applications* (2nd ed.). Sudbury, MA: Jones & Bartlett.

Tan, J., Wen, H.J., & Awad, N. (2005). Health care and service delivery systems as complex adaptive systems. *Communications of the ACM, 48*, 36-44.

Tan, J. (2005). The next health care frontier. In J. Tan (Ed.), *E-health care information systems: An introduction for students and professionals* (pp. 3-26). Jossey-Bass.

Turner, M., Zhu, F., Kotsiopoulos, I., Russel, M., Budgen, D., Bennet, K., Brereton, P., Keane, J., Layzell, P., & Rigby, M. (2004). Using web service technologies to create an information broker: an experience report. In *Proceedings of the 26th International Conference on Software Engineering (ICSE'04)* (pp. 552-561). IEEE.

Tsui, F.C., Espino, J.U., Dato, V.M., Gesteland, P.H., Hutman, J., & Wagner, M.M. (2003). Technical description of RODS: A real-time public health surveillance system. *J Am Med Inform Assoc, 10*(5), 399-408

van de Wetering, R., & Batenbur, R. (2009). A PACS maturity model: A systematic meta-analytic review on maturation and evolvability of PACS in the hospital enterprise. *International Journal of Medical Informatics, 78*, 127-140.

Varshney, U. (2006). Using wireless technologies in healthcare. *International Journal of Mobile Communications, 4*(3).

Wangler, B., Ahlfeldt, R.M., & Perjons, E. (2003). Process oriented information systems architectures in healthcare. *Health Informatics Journal,. 9*(4), 253-265.

Wen, H.J., & Tan, J. (2005). Reshaping the Traditional Health Care System. In J. Tan (Ed.), *E-health care information systems: An introduction for students and professionals* (pp. 365-392).

W3C. Worldwide Web Consortium (2009). Extensible Markup Language. Retrieved May 2009, from http://www.w3.org/XML

WHO-HMN. (2009). *World Health Assembly: Health Metric Network (HMN)*. Retrieved May 2009, from http://www.who.int/healthmetrics/about/whatwillhmndo/en/index.html

Wozak, F., Schabetsberger, T., & Ammmenwerth, E. (2007). End-to-end security in telemedical networks – A practical guideline. *International Journal of Medical Informatics, 76*, 484-490.

Wright, A., & Sittig, D.F. (2008). SANDS: A service-oriented architecture for clinical decision support in a National Health Information Network. *Journal of Biomedical Informatics, 41*, 962-981.

Wu, J.H., Wang, S.C., & Lin, L.M. (2007). Mobile computing acceptance factors in the healthcare industry: A structural equation model. *International Journal of Medical Informatics, 76*, 66-77.

Yusof, M.M., Papazafeiropoulou, A., Paul, R.J., & Stergioulas, L.K. (2008). Investigating evaluation frameworks for health information systems. *International Journal of Medical Informatics, 77*, 377-385.

About the Editor

Joel J. P. C. Rodrigues is a Professor at the Department of Informatics of the University of Beira Interior, Covilhã, Portugal, and researcher at the Institute of Telecommunications (IT), Portugal. He received a PhD degree in Informatics Engineering and a MSc degree from the University of Beira Interior, Portugal, and a 5-year B.S. degree (licentiate) in Informatics Engineering from University of Coimbra, Portugal. His main research interests include e-health, vehicular delay tolerant networks, sensor networks, body sensor networks, high-speed networks, e-Learning technologies, information and knowledge management, mobile and ubiquitous computing, and supervising several PhD and Master of Science candidates in these areas. He participated in several PhD and MSc juries. He has authored or co-authored over 80 papers in refereed international journals and conferences, book chapters, a book and a patent. He is the leader of NetGNA Research Group from IT (http://netgna.it.ubi.pt) and the founder and leader of the IEEE ComSoc CSIM Special Interest Group on Modeling and Simulation Tools (http://mst.it.ubi.pt). He is the Secretary of the IEEE ComSoc Technical Committee on Communications Software and the Secretary of the IEEE ComSoc Technical Sub-Committee on eHealth. He is member of many IARIA Workgroups and ComSoc Technical Committees related with his research areas and regularly participates on their meetings. Joel is the Editor-in-Chief of the *International Journal of E-Health and Medical Communications* (from IGI Global), and he has served as a guest editor for a number of journals including the *Journal of Communications* and the *Journal of Communications Software and Systems*. He is Co-chair of the Communications Software, Services and Multimedia Applications Symposium (CSSMA) at IEEE Globecom 2010, Organizer and General Chair of the IEEE ICC 2009 Workshop on Medical Applications Networking (http://man.it.ubi.pt/), Chair of the Symposium on Ad-Hoc and Sensor Networks of the SoftCom Conference, Workshop Program Chair of the 2009 International Workshop on Wireless Multimedia Computing and Security Services (WIMUCS 2009), Workshop Program Chair of the 2009 International Workshop on Network Assurance and Security Services in Ubiquitous Environments (NASSUE-2009), TPC Chair of IARIA International Conference on Communication Theory, Reliability, and Quality of Service (CTRQ 2008, CTRQ 2009), and chaired other conferences committees in the recent past years. He is and was member of many international program committees (IEEE ICC, IEEE Globecom, IEEE WCNC, IEEE CCNC, IEEE ISCC, IEEE ICCCN, ICTTA, SoftCOM, CTRQ, ICN, ICNS, ACHI, CONTENT, PATTERNS, ECUMN, ICSNC, CENTRIC, MMEDIA, SENSORCOMM, IPC, IWT, SSDU, CNSR, NGI, WLN, IPC, NGMAST, etc.) and several editorial review boards (*IEEE Communications Magazine*, *Journal of Communications Software and Systems*, *International Journal of Communications Systems*, *International Journal of Business Data Communications and Networking*, *IARIA International Journal On Advances in Life Sciences*, *IARIA International Journal On Advances in Internet Technology*, *IARIA International Journal On Advances in Telecommunications*, etc.). He chaired many technical sessions and gave tutorials at major international conferences. He is a licensed Professional Engineer and he is member of the ACM SIGCOMM, a member of the Internet Society, and a Senior Member IEEE Computer Society, IEEE Communications Society and IEEE Education Society, and an IARIA Fellow.

Section I

Fundamental Concepts and Theories

This section serves as the foundation for this exhaustive reference tool by addressing crucial theories essential to the understanding of health information systems. Chapters found within these pages provide an excellent framework in which to position health information systems within the field of information science and technology. Individual contributions provide overviews of the future of e-health, telemedicine barriers, electronic health records, and data protection. Within this introductory section, the reader can learn and choose from a compendium of expert research on the elemental theories underscoring health information systems research

Chapter 1.1

Inventing the Future of E-Health

José Aurelio Medina-Garrido
University of Cadiz, Spain

María José Crisóstomo-Acevedo
Jerez Hospital, Spain

INTRODUCTION

E-health involves the use of information and communications technologies to improve health in general and the healthcare system in particular (Alvarez, 2002; Chau & Hu, 2004; Roger & Pendharkar, 2000).

Healthcare, one of the largest industries in the world, suffers from some inefficiencies and inequities in both service provision and quality. Some of these problems are due to the poor management of the information flows (Kirsch, 2002). In this respect, there are business opportunities for e-health. But to understand what the future holds for e-health, we need to find a precise definition of the concept and identify the possible sources of business.

This article is structured as follows. The second section, the background, defines the concept of e-health. The third section outlines some of the business opportunities in the area of e-health based on the communications platform that is the Internet, and discusses some practical guidelines for e-health businesses to create value. The fourth section discusses the low level of adoption of e-health at present, as well as the future trends, in which e-health will presumably grow. e-health is also expected to be used to reduce the disparities in the population in access to healthcare, and for the treatment of the chronically ill. The fifth section is dedicated to the final conclusions.

DOI: 10.4018/978-1-60566-026-4.ch355

BACKGROUND

The term *e-health* is relatively recent and refers to healthcare practice that is supported by electronic processes and communications. The term has many definitions, depending on the functions, stakeholders, context, or the theoretical framework referred to. It includes a wide range of medical informatics applications, both specific (for example, decision support systems, citizen health information) and general (for example, management systems, healthcare services provision, etc.). But the increased importance of the communication function in e-health, and the use of electronic networks (particularly the Internet), differentiate e-health from traditional medical informatics (Pagliari, 2005).

Thus, e-health goes beyond healthcare informatics and incorporates the most advanced information technologies to medicine and healthcare. Among the most significant applications of the technologies to healthcare are the following:

- **Electronic medical records,** which allow different healthcare professionals to share information about a particular patient.
- *Telemedicine*, which uses information and communications technology (ICT) to enable physician-patient contact at a distance.
- **Evidence-based medicine,** in which a system updates information about the most appropriate treatments for each patient, thereby enhancing physicians' treatment possibilities.
- **Citizen-oriented information,** through which citizens are provided with information about health topics.
- **Specialist-oriented information,** whereby a system distributes information to specialists about medical journal articles, practices and protocols in the area of health, new medical advances, epidemiological alerts, etc.
- **Virtual healthcare teams**, made up of healthcare professionals sharing information about patients electronically to improve their knowledge and decision-making.
- **Health e-commerce,** which involves providing value-added electronic services to both professionals and citizens, and economically exploiting some or all of the services. In this respect, e-health is supported by the Internet and related technologies and combines medical informatics, public health, and business. This type of e-health does not exclude the previous ones. To the contrary, it includes them or complements them. The following section discusses the concept of Health e-commerce, indicating what types there are, what they consist of, and how they obtain their revenues.

Some authors go further than the concepts explained in this section and predict a change of mentality and culture among both citizens and practitioners. One author goes so far as to argue that e-health "..characterizes not only a technical development, but also a state-of-mind, a way of thinking, an attitude, and a commitment for networked, global thinking, to improve healthcare locally, regionally, and worldwide by using information and communication technology" (Eysenbach, 2001).

BUSINESS OPPORTUNITIES BASED ON E-HEALTH

As we mentioned above, the inadequate management that a large part of the healthcare sector makes of its information flows (Kirsch, 2002) and processes, as well as the new advantages offered by present-day ICT, mean that e-health opens up significant business opportunities.

One of the most notable business opportunities offered by e-health is e-commerce. The most important forms that *e-commerce* can adopt on the Internet include (Parente, 2000): portals, connectivity sites, business-to-business applications, and business-to-consumer applications.

Portals dedicated to health tend to provide all types of information, guidance, and medical advice to consumers and professionals. Portals generally represent starting points for consumers, offering them various online activities as well as diverse information. Their general objective is to be the first place that customers go to when they are looking for something on the Internet. For this, they need to establish a brand that attracts visits and creates loyal customers. Their main sources of income come from the advertising they contain and occasionally from users' subscriptions.

Table 1. Examples of business models in e-health (Source: Adapted from Parente (2000))

Portal	Connectivity	B2B	B2C
Medscape drkoop.com OnHealth HealthGrades.com	Healtheon/WebMD TriZetto XCare.net Claimsnet.com	Neoforma.com Medical Manager Allscripts eBenx	drugstore.com PlanetRx HealthExtras

Sites dedicated to facilitating connectivity in the healthcare sector have the objective of linking and integrating the various information systems seamlessly. The income of this business model comes from the company's external users, who pay fees to obtain information. Health e-commerce connectivity initiatives involve accessing electronic medical records on the Internet, evaluating the quality of providers according to their clinical results, and using quality information in the selection of physicians. For example, some hospitals provide their patients with directories of their physicians on the Internet, which are searchable by zip code and clinical specialty (Coile, 2000). Because these sites obtain their revenues from the fees generated by each information transaction, their objective is to maximize the number of transactions. These companies obtain transaction fees from health plan providers, physicians, hospitals, clinical laboratories, pharmacies, consumers, and companies offering financial, marketing, or delivery services in the healthcare sector.

Business-to-business (B2B) e-commerce involves selling products and services to other firms on the Internet. The income from this business model comes from the sale of the product or service itself. *B2B Health e-commerce* includes businesses dedicated to selling refurbished medical equipment or pharmaceutical refills on the Internet. Indeed, pharmaceutical refills are a large market with a high turnover, and are ideally suited to be traded on the Internet at competitive prices offering next-day home delivery (Coile, 2000). Apart from the products sold in this way, some companies are now beginning to offer services such as online management consultancy.

Business-to-consumer (B2C) e-commerce sells products and services directly to the consumer via the Internet. As in the previous model, the income comes from the sales themselves. The B2C business model in the healthcare area allows consumers to acquire products and services such as health insurance, prescription drug refills, over-the-counter drugs, medical supplies for the chronically ill, vitamins, homeopathic medicines, and home fitness equipment (Coile, 2000).

Table 1 shows examples of some of the most important firms in the e-health sector. The firms are classified under the business model that most closely matches their main activities or sources of income. But the limits are often hazy, and the firms can often be classified in more than one category.

After the bursting of the Internet bubble it became clear that an e-business, such as one based on e-health, should in the first place be a business venture, and not just a technological one. e-health firms are businesses, and so they must seek to create value. In this respect, some authors offer *practical guidelines to e-businesses* about how to generate value (Earle and Keen, 2000; Shapiro and Varian, 1999), and these are also valid for the particular case of e-health:

- Cultivate stable relationships with customers. Building a critical mass of loyal customers allows firms to avoid customer acquisition costs for each transaction. The idea is to build solid relationships with strong ties. For this reason, some firms offer some services for free on their Web sites.

- Build a powerful brand. The concept of brand is redefined on the Internet. It is a relationship brand. Customers cannot see the product or service until they pay for it. Thus, e-health firms need to have a good reputation. This reputation, which takes substantial time and money to build, can be quickly acquired working together or allying with another firm that already has a good reputation.•
- Improve the logistics. This is important for e-health firms that distribute physical products such as medical equipment or drugs. Logistics capabilities are critical for the generation of value. But some firms have opted to focus on those core activities they know how to do well, in order not to spread efforts or resources too thinly, and have allied with top logistics firms that can undertake this function.
- Harmonize the channels in the name of the customer. Customers choose the communication channel that offers them most advantages. Firms need to provide the option that best helps to build and maintain the relationship, and that choice is for the customer to make, not the firm. In this respect, customers need to be offered a number of communications channels (Web forms, e-mail, telephone, fax, post, cell phone SMS, personal digital assistants (PDAs), a combination of physical and virtual branches, etc.).
- Become an intermediary that provides value, or use one that does. Business on the Internet is dominated by nerve centers such as portals with powerful brands and other intermediaries that bring the supply and the demand together. These will control the interaction between providers and customers, and will advise customers about the Web sites they should visit when looking for a particular product or service. Only the intermediaries that offer consumers or firms value will survive and prosper. Intermediaries that do not provide value must use one that does if they wish to be profitable.
- Analyze how much the firm invests in producing and selling information. Information is expensive to produce, but extremely cheap to copy. In this respect, trading data electronically allows firms to distribute information enjoying economies of scale, which means they can cut unit costs and consequently the price of their product or service.
- When firms compete in commodity markets they need to create economies of scale that cut costs (and prices), be flexible to adapt to any change and quick, both to enter a market and exploit the business opportunity and to exit when this is no longer profitable.

FUTURE TRENDS

E-health tools show plenty of potential, but they are relatively undeveloped and have not yet been adopted to a great extent (Wilson, 2005). Some authors have predicted that some of the new technologies applicable to e-health will be adopted very quickly and massively (for example, telemedicine or PDAs), but there remain problems in this respect. Occasionally, the main *source of income of the business model* has seen undermining. This has been the case, for example, of the supply of information to the consumer, as they are not used to paying for this. On the other hand, some technologies do not have a large enough potential market to grow very quickly, for example, applications for supply-chain management (SCM) or procurement. Consequently, firms do not find them so attractive to invest in (Kirsch, 2002).

Electronic medical records are also expected to take off in the future. No paperless hospitals can be found just yet, but some authors predict that some hospitals will be completely paperless in the not-too-distant future (Coile, 2000). If these predictions prove right, extreme care will be needed to protect patients' privacy and interests.

A proper implementation of *e-health will require political commitment*, an adequate legal framework, and R&D and Innovation (Wilson, 2005). The political commitment should be reflected in the development of electronic health cards and health information networks and online health services. The legal framework must offer adequate coverage in terms of data protection, digital signatures, e-commerce regulations, and the professional qualifications required to use telemedical applications. The R&D and Innovation needs to promote the development of new technological tools and help to spread best practices in this new field.

Another potential future trend for *e-health is to apply information and communications technologies to reduce the disparities in the population* in access to the healthcare system (Ahern, Kreslake, & Phalen, 2006; Cashen, Dykes, & Gerber, 2004; Gibbons, 2005). Demographic and socio-economic factors are arguably behind these disparities, such as: ethnic origin (whites vs. minorities), geographic (urban vs. rural) (Galea & Vlahov, 2005), gender (masculine vs. feminine) (Mcgrath & Puzan, 2004; Quinn & Overbaugh, 2005), income level (poor vs. non-poor) (Federico & Liu, 2003), and age (elderly vs. non-elderly) (Pyle & Stoller, 2003).

In the future, *e-health is also expected to increasingly facilitate the treatment and monitoring of patients with chronic illnesses* (Ahern, Kreslake & Phalen, 2006). This will reduce the constant and inconvenient traveling to and from medical centers that these patients are subjected to, not to mention the healthcare system's work overload in this respect.

CONCLUSION

E-health will lead to a behavior change in the area of healthcare, through which the use of information technologies, the Internet and communications technologies enable improved and more effective healthcare (Eng, 2002).

One of the main areas of interest in e-health is to improve health communications by using technologies. In this respect, both healthcare organizations and public healthcare agencies are increasingly using the Internet in their communications and to transfer information.

These efforts are generating various socio-economic phenomena, in particular e-health as a business opportunity – the chance to create an e-business. Four models familiar from traditional e-businesses have also been adopted by e-health businesses: portals, connectivity sites, business-to-business applications, and business-to-consumer applications.

Although more attention is commonly paid to technological questions, we must also remember that an e-business is first of all a business. E-health businesses, as businesses, need to create value for their customers. In this respect, they are advised to cultivate stable relationships with their customers, build a powerful brand, consider the logistics carefully, offer a number of channels to their customers, be an intermediary that provides value, seek economies of scale when they produce and sell information, and be quick and flexible and create economies of scale when they compete in commodity markets.

At present, e-health activities are defusing only gradually, and have been slow to be accepted. But a greater development is forecast for the future; in particular, we will conceivably see phenomena such as paperless hospitals and a more complete coverage of the population's healthcare needs (education about health, treatment of chronically ill patients, and reduction in the disparities in access to healthcare).

REFERENCES

Ahern, D. K., Kreslake, J. M., & Phalen, J. M. (2006). What Is E-health: Perspectives on the Evolution of E-health Research. *Journal of Medical Internet Research*, *8*(1), e4. doi:10.2196/jmir.8.1.e4

Alvarez, R. C. (2002). The promise of e-Health - a Canadian perspective. *Ehealth International*, *1*(1), 4. doi:10.1186/1476-3591-1-4

Cashen, M. S., Dykes, P., & Gerber, B. (2004). E-health technology and Internet resources: barriers for vulnerable populations. *The Journal of Cardiovascular Nursing*, *19*(3), 209–222.

Chau, P. Y. K., & Hu, P. J. (2004). Technology Implementation for Telemedicine Programs. *Communications of the ACM*, *47*(2), 87–92. doi:10.1145/966389.966396

Coile, R. C. (2000). E-health: Reinventing healthcare in the information age. *Journal of Healthcare Management*, *45*(3), 206–210.

Earle, N., & Keen, P. (2000). From. com to. profit. *Inventing Business Models that Deliver Value and Profit*. San Francisco, California: Jossey-Bass Inc.

Eng, T. R. (2002). E-health research and evaluation: challenges and opportunities. *Journal of Health Communication*, *7*(4), 267–272. doi:10.1080/10810730290001747

Eysenbach, G. (2001). What is e-health? *Journal of Medical Internet Research*, *3*(2), e20. doi:10.2196/jmir.3.2.e20

Federico, M. J., & Liu, A. H. (2003). Overcoming childhood asthma disparities of the inner-city poor. [vii.]. *Pediatric Clinics of North America*, *50*(3), 655–675. doi:10.1016/S0031-3955(03)00045-2

Galea, S., & Vlahov, D. (2005). *Handbook of Urban Health: Populations, Methods and Practice*. New York: New York Academy of Medicine.

Gibbons, M. C. (2005). A Historical Overview of Health Disparities and the Potential of E-health Solutions. *Journal of Medical Internet Research*, *7*(5), e50. doi:10.2196/jmir.7.5.e50

Kirsch, G. (2002). The business of e-health. *International Journal of Medical Marketing*, *2*(2), 106–110. doi:10.1057/palgrave.jmm.5040062

Mcgrath, B. B., & Puzan, E. (2004). Gender disparities in health: attending to the particulars. *The Nursing Clinics of North America*, *39*(1), 37–51. doi:10.1016/j.cnur.2003.11.003

Pagliari, C., Sloan, D., Gregor, P., Sullivan, F., Detmer, D., & Kahan, J. P. (2005). What Is E-health (4): A Scoping Exercise to Map the Field. *Journal of Medical Internet Research*, *7*(1), e9. doi:10.2196/jmir.7.1.e9

Parente, S. T. (2000). Beyond the hype: A taxonomy of e-health business models. *Health Affairs. Chevy Chase*, *19*(6), 89–102.

Pyle, M. A., & Stoller, E. P. (2003). Oral health disparities among the elderly: interdisciplinary challenges for the future. *Journal of Dental Education*, *67*(12), 1327–1336.

Quinn, T. C., & Overbaugh, J. (2005). HIV/AIDS in women: an expanding epidemic. *Science*, *308*(5728), 1582–1583. doi:10.1126/science.1112489

Rodger, J. A., & Pendharkar, P. C. (2000). Using telemedicine in the Department of Defense. *Communications of the ACM*, *43*(3), 19–20. doi:10.1145/330534.330551

Shapiro, C., & Varian, H. R. (1999). *Information Rules. A Strategic Guide to the Network Economy*. Boston, Massachusetts: Harvard Business School Press.

Wilson, P. (2005). *My Health / My E-health. Meeting the challenges of making e-health personal*. Presented at ICLM9. Brazil, September.

KEY TERMS AND DEFINITIONS

Business-to-Business (B2B) E-Commerce: Economic transactions between firms using information systems and technologies.

Business-to-Consumer (B2C) E-Commerce: Commercial transactions and activities between firms and the end-consumer using information systems and technologies.

Commodities: Raw materials, unfinished products, or products sold loose, or any other product characterized by being undifferentiated. Such products cannot be differentiated from other products in function of the producer that manufactures them or the supplier that sells them.

E-Health: The provision of any healthcare service that is supported by electronic processes and communications.

Electronic Medical Records: Computer-based patient medical records. Patient medical records are a systematic documentation of a patient's medical history and care.

Evidence-Based Medicine: Medical practice involving the sharing, updating and consultation of a system containing information about the most appropriate treatments for each patient. This helps to improve the treatments chosen by the physicians who use this system.

Health E-Commerce: E-business based on the economic exploitation of health-related information and services.

Health Plan: An individual or group plan that provides, or pays the cost of, medical care.

Over-the-Counter (OTC) Medicine: A medicine that can be bought without a doctor's prescription, such as some analgesics.

Telemedicine: The use of information and communications technologies to exchange information between practitioners, or to deliver medical services to a patient remotely.

Virtual Healthcare Teams: Teams made up of healthcare professionals that share information about patients electronically in order to improve their knowledge and decision-making.

This work was previously published in Encyclopedia of Information Science and Technology, Second Edition, edited by M. Khosrow-Pour, pp. 2244-2248, copyright 2009 by Information Science Reference (an imprint of IGI Global).

Chapter 1.2

Multi-Dimensional Criteria for the Evaluation of E-Health Services

Alalwany Hamid
Brunel University, UK

Alshawi Sarmad
Brunel University, UK

ABSTRACT

E-health is an emerging field in the intersection of information systems, healthcare and business, referring mainly to healthcare services delivered and enhanced through the use of information and communication technologies (ICT). An important area of research is the evaluation of e-health services. A holistic e-health evaluation framework should address the aspects that are hampering healthcare services from embracing the full potential of ICT towards successful e-health initiatives. In order to build a holistic evaluation framework for e-health services, this article suggests framework characteristics for the appropriate evaluation for e-health services. The article argues that e-health services evaluation framework should be criteria based. The criteria have to be multi-dimensional that grounded in, or derived from, one or more specific perspectives or theories. The proposed evaluation criteria in this article can serve as part of an e-health evaluation framework, improve our understanding of the role of information systems in health care, and develop our ability to deliver high quality services. [Article copies are available for purchase from InfoSci-on-Demand.com]

BACKGROUND

E-health is a very broad term encompassing various activities in an evolving field. This is reflected in the broad and various definitions of the term. An example of these definitions is the one that has been adopted by the World Health Organization. According to the Organisation, E-health can be defined as ‘being the leveraging of the information and communication technology (ICT) to connect provider and patients and governments;

to educate and inform healthcare professionals, managers and consumers; to stimulate innovation in care delivery and health system management; and, to improve our healthcare system' (Hans Oh et al., 2005).

The variety of e-health applications is considerable, ranging from a self-help guide about treating common health problems at home to a virtual clinic which allows diagnostic consultations between patients and practitioners at separate sites. In light of the dynamic and evolving meaning of e-health concept and the wide range of applications that the term e-health has covered, the questions are what the term e-health means and what is the e-health application that should be considered. In this paper although we employ e-health as a broad term, the scope will be limited to the service delivery aspect by electronic means of information, advice, and consultation.

E-health, which are basically enabled and driven by the use of information and communication technologies in healthcare, have the potential to change the healthcare industry worldwide in terms of their infrastructures, and the costs and quality of services (Wickramasinghe & Misra, 2004; Wickramasinghe & Goldberg, 2004). Despite the potential that e-health may bring to the healthcare sector, the sector is the slowest in moving to the form of e-health among other government services. Skinner (2003) argues that the slow progress is related to the fact that healthcare does not have the standards in place that other sectors do. Holliday and Tam (2004) have a broader explanation; they see that slow progress is more related to institutional, cultural and financial factors.

An important area of research is that of the evaluation of e-health services. It could contribute to important knowledge that can be used to support the value of existing e-health projects, and to increase the quality and efficiency of future e-health initiatives. Despite its importance, the evaluation of e-health services as many researchers agree, is both an under developed and under managed area in theory and practice (Brender, 2006; Friedman & Wyatt, 2000).

This study forms a part of a research that aims to develop, and assess a holistic evaluation framework for e-health services. Towards this aim, the objectives of this paper are; addressing the challenges in developing such a framework, suggesting framework characteristics for the appropriate evaluation for e-health services, and proposing a multi dimensional criteria for e-health evaluation. The proposed multi-dimensional criteria can serve as part of e-health evaluation framework, and also to provide useful and necessary tools to allow the development of successful e-health initiatives by assisting the healthcare organisation to identify and thus address areas that require further attention. The selection process of the proposed criteria will take into account the challenges faced at the intersection of the three areas, healthcare services, information systems, and evaluation methodologies.

THE RESEARCH APPROACH

According to Lowery & Evans (2004) and Myers & Avison (2002) that selecting an appropriate research approach is about setting a research strategy considering the underlying characteristics or assumptions about what constitutes valid research. Such strategy should guide the researcher through the research process by embodying a particular style and employing different research methods.

The process of selecting and deploying appropriate research approach for this study, is an important and critical issue, and should only be decided on after considering a number of factors including;

- The research question and its context (how to identify the key factors for the evaluation of e-health services?)

- The multi-dimensional aspects of e-health, as it has different roots and complex relationships associated with using information communications technologies, management as well as health regulations, and governments policies.
- The large number of stakeholders involve in e-health evaluation, each with their own particular needs, values and objectives.

As this study forms a part of a research project which will progress through a number of phases, the research will be based on a sequential multi-method approach (Creswell, 2003). Adopting the sequential multi-method approach paves the way to the use of the appropriate method for each research phase and creates the opportunity for multiple analyses about the same collected data.

This study represents one phase of the research project, and will be based partially on two lines of studies relating to the behaviour of users of new products or services. These studies are: diffusion of innovations (Rogers, 1995) and technology acceptance (Davis, 1989). The aim of using both studies is to build theoretical framework that aids in the selection process of the multi dimensional criteria. Broad examining and critical analysis of the existing evaluations initiatives specifically those who were based on e-health services case studies was also used to overcome the limitation of the theoretical framework.

In the next phase of the research project the authors will carry out an empirical validation and examination of the proposed evaluation criteria, the validation will be performed through case study methodology (Yin, 2003). This process is very important; it will address potential improvements, and verify the adaptability of the proposed criteria to various e-health contexts.

E-HEALTH EVALUATION CHALLENGES

The research in the area of e-health evaluation is a complicated and difficult subject (Brender, 2006; Friedman & Wyatt, 2000). The complexity and difficulty lies in the challenges encountered at the intersection of three research fields, each well-known for its complexity; healthcare services, information systems, and evaluation methodologies.

Healthcare services are characterized by having many stakeholders which are working in different disciplines and pursuing different goals (Alvarez, 2003; Connell & Young, 2007; Ray, 2007). Healthcare services are also dictated by complex regulations, especially those that apply to directly manage patients' information. The medical knowledge itself and methods of healthcare delivery are changing rapidly and require a high degree of formalized working practices (Friedman & Wyatt, 2000). The regulations of healthcare services particularly in developed countries is complex in its diversity and wide ranging in its scope, ruling the relation with patients, health professionals, the public, taxpayers, employers, educators, regulators, and many others across the country. The medical knowledge is an enormous and dynamic field, Mcconaghy (2006) states that the medical knowledge doubles approximately every five years. Moreover the main aspects of this knowledge require an interactive environment to be transferred or practiced.

Information systems and its evaluation as many researcher (Serafeimidis & Smithson, 2000; Jones & Hughes, 2001) assent is another complicated and difficult research field. Symons and Walsham (1988) argue that the complexity is due to the multiple perspectives involved, and the difficulties of quantifying benefits. Willcocks (1992) has a similar view but he also believes that the complexity of information systems evaluation is changing and becoming more and more complex nowadays. This is because the nature of information systems investments is changing both in terms of technological capability and the benefits they can deliver, as well as in terms of diffusion in most aspects of society. The evaluation of information systems in public sector has proved to be even more complex as an accurate evaluation requires conducting the evaluation process in more challenging context. To overcome the complexity and difficulty of information systems evaluation in public sector, it is necessary to address and consider a number of evaluation challenges in the development of the required evaluation framework. The first of these challenges is the investigation of various perspectives (Jansen, 2005), which may not only require addressing and meeting the general needs of a target group such as citizens, but also requires including the specific needs of the specific target groups of citizens that are using a particular service. The second challenge in evaluating information systems in public sector is in identifying and quantifying benefits. Beynon-Davies, (2005) states that it is difficult to determine the precise benefits associated with information systems in public sector. An explanation to this lies in the different goals and objective of the information systems investments in public sectors, the benefits gained by these initiatives will be different as well, and the assessment of these benefits also vary according to the different perspectives of the stakeholders for the value of these benefits. The third challenge in evaluating information systems in public sector is the fact that in order for the evaluation to be proper, it should consider the social and technical context of use. This is a result of the opinion that information systems research is as much a social science as an information systems science (Mingers & Stowell, 1997).

The establishment of an evaluation methodology is the last complex and difficult research field. The field is suffering from the limited experience of using methods, the unfamiliarity with evaluation techniques and the difficulty in interpreting results (Ballantine et al., 1999; Farbey et al., 1999; Powell, 1999). The limited experience of using methods in e-health evaluation is related to a certain extent to the gap between the theory and practice. Eng (2002) argues that this gap is a result of the tension between e-health research efforts in academic institutions and commercial organizations. He believes that the academic sector succeeds in developing scientifically rigorous evaluation methodologies, but these methodologies are not designed to answer real-world concerns. On the other hand, when commercial organizations conduct evaluations of e-health applications, they usually adopt methodologies with limited applicability to other situations. In adopting such methodologies, they maintain obtaining quick and practical answers because of market pressures.

Table 1 summarizes the challenges encountered at the intersection of healthcare services, information systems, and evaluation methodologies.

DEVELOPING AN EVALUATION FRAMEWORK FOR E-HEALTH SERVICES

The evaluation in the area of e-health services as many researchers argue, is dominated by economic and organizational aspects, has no standard framework for evaluating the effects and outputs of implementation and use, and the area in general is both under developed and under managed in theory and practice (Brender, 2006; Eng, 2001; Friedman & Wyatt 2000; Rahimi & Vimarlund, 2007). Nevertheless, there is a wide range of information system evaluation frameworks, some of them were proposed and used in a healthcare context.

Existing evaluation frameworks that have been proposed or used in e-health context are suffering from many limitations. These limitations include, that they are either designed to focus particularly on the supply side of the healthcare

Table 1. The challenges encountered at the intersection of healthcare services, information systems, and evaluation methodologies

The Research Field	The challenges Encountered	References
Healthcare Services	• Healthcare services are characterized by having many stakeholders which are working in different disciplines and pursuing different goals. • Healthcare services are dictated by complex regulations. • The medical knowledge is an enormous and dynamic field. • The main aspects of medical knowledge require an interactive environment to be transferred or practiced.	Alvarez (2003) Connell and Young (2007) Ray (2007) Friedman and Wyatt (2000) Mcconaghy (2006)
Information Systems	• The multiple perspectives involved. • The difficulties of quantifying benefits. • The nature of information systems investments is changing both in terms of technological capability and the benefits they can deliver, as well as in terms of diffusion in most aspects of society. • Consider the social and technical context of use.	Walsham (1993) Beynon-Davies (2005) Jansen (2005) Willcocks (1992) Mingers, and Stowell (1997)
Evaluation Methodologies	• The limited experience of using methods. • The unfamiliarity with evaluation techniques. • The difficulty in interpreting results.	Ballantine et al. (1999) Eng (2002) Farbey et al. (1999) Powell (1999)

services (organizational perspective) or they are designed to target a specific user or a specific application of an e-health initiative. Moreover, the healthcare dimension is either ignored or not fully considered in the design and the implementation of these evaluation frameworks.

Though the development of a comprehensive evaluation framework for e-health services is beyond the remit of this study, it is vital to examine the current evaluation frameworks in order to choose the appropriate evaluation approach and select the suitable framework that can accommodate the proposed criteria. We have selected for our analysis a number of evaluation approaches that we believe are more suitable for the evaluation in the healthcare context.

One of these approaches is focused mainly on the evaluation criteria, which can be called criteria-based evaluation approach. What is typical for this approach is that the information systems interface and the interaction between users and the systems work as a basis for the evaluation together with a set of predefined criteria. The chosen criteria rule the evaluation process and its results (Cronholm & Goldkuhl, 2003). In the same direction and based on what drives the evaluation, Cronholm and Goldkuhl (2003) identified another two approaches named goal-based and goal-free evaluations. The goal-based evaluations use goals from the organisational context to assess the information system. Goal-free evaluation is based on gathering data about a broad range of actual effects of the system and evaluating the importance of these effects in meeting demonstrated needs (Patton, 1990). Among the three previous approaches, the criteria based one is the most appropriate for e-health services evaluations. The appropriateness stems from the fact that e-health applications are principally complex in nature, hence they require an approach that can be derived from a multitude of perspectives and theories such as TAM or DOI.

Another group of evaluation approaches were introduced to address one or more of the perspectives of the system stakeholders. Freeman (1984) was among the first, who introduced the stakeholders' concept. Since then, several researchers have adopted the stakeholders approach in their research of information systems evaluation. However, there is only limited literature that recognizes healthcare stakeholders and their changing role in the evaluation of e-health services.

Moreover, even in the limited literature available on healthcare stakeholders, the description and identification of these stakeholders seems to be generally ignored (Mantzana & Themistocleous, 2006).

One of the popular and general approaches in categorizing e-health stakeholders is dividing them between supply side stakeholders (organizational perspective) and demand side stakeholders (users' perspective). According to Löfstedt (2007) most research in the area of e-government, and also in the development of e-services in public sector is dominated by supply side factors and there where none or a few efforts that focused on the demand side. Gustafson and Wyatt, 2004, acknowledged the dominant of supply side factors in the field of e-health as well. They stated that despite the fact that users are the most important stakeholder in the e-health evaluation, assessing e-health from users' perspective and addressing the key factors that influence the users' acceptance to the new adopted technologies is still lacking behind.

For practical reasons this study will focus on the demand side stakeholders. We believe that the acceptance and satisfaction of e-health services are dependent primarily on users' motivation to adopt and utilize these services, user utilization being important for the success of e-health services.

The stakeholder's evaluation approach is part of the school which suggested five levels of evaluation approaches for healthcare information systems, which are macro, sector, firm, application, and stakeholder. This suggests that different criteria would inevitably apply to each of these approaches (Connell & Young, 2007).

There is also another group of evaluation studies which is defined by the basis on which the evaluation is performed. In this direction Grover et al. (1996) categorize three approaches: Comparative, normative and improvement. In the comparative approach, the evaluation is based on comparing a particular system with other similar systems. The normative approach compares the system against a theoretical ideal system or, in essence, against best practice. The improvement approach is intended to assess how much the system has improved over time. In this study we intend to use only the comparative and normative approaches because the main aim is toward proposing evaluation criteria for proposed implementations rather than historical ones.

Furthermore, another group of evaluation studies classified evaluations based on when the assessment is performed (Brender, 2006; Cronholm & Goldkuhl, 2003; Grover et al., 1996). According to these studies the evaluation can be carried out during the analysis and planning phase, or during the development and the adaptation phases, or after the development has completed and the system is in use. An example of this kind of evaluation is process evaluation approach which is intended to evaluate the efficient use of resources, and is normally performed during the analysis and planning phase. There is also the response evaluation approach which assesses the users reaction to the system, and is usually performed during the final stage of implementation, or while the system is in use. The equity implementation model presented by Lauer et al. (2000) is an example of the response evaluation approach. The model was based on the equity theory (Adams, 1965), a well-established theory in the social sciences and was adopted in e-health assessments to examine and understand user reaction to the implementation of a system. Lauer et al. (2000) stated that the focus of this approach is on the effect of the changes that such a system brings about on the system users.

The last example in this group is the impact evaluation approach, which is intended to assess the overall social and technical impact of the system on users and organisations, and is normally performed while the system is in use. According to Grover et al. (1996), because the impact evaluation is the most comprehensive, it is the most difficult approach to undertake. The impact evaluation approach can be quite beneficial in evaluating e-health services because it would comprehensively recognize users and organisations needs, by measuring the acceptability as well as the risks and benefits of e-health services (Gustafson & Wyatt, 2004). In this study, the focus will be on the criteria that influence the user's reaction to the e-health services and the social, economical and technical effects of these services.

To conclude, we suggest that the appropriate evaluation framework for e-health services which can accommodate the proposed evaluation criteria would have the following characteristics:

- The framework has to be sufficiently generic to be applicable to a wide range of applications but also sufficiently detailed to provide effective guidance
- The framework has to support the evaluator in making precise and effective choices at various stages of the evaluation process
- The framework is criteria-based. The criteria can be grounded in, and derived from, one or more specific perspectives or theories
- The framework only considers one stakeholder or a group of stallholders with a common perspective in an evaluation process. For example, as in the case of this study, the framework may consider the demand side perspective and specifically the criteria that influence the user's reaction to e-health services, and the impact of these services on the users
- The framework combines both comparative and normative approaches toward proposing evaluation criteria for e-health services.

USERS' BEHAVIOUR TOWARDS NEW PRODUCTS OR SERVICES

There are many studies on the behaviour of consumers of new products and services, these studies were adopted in research to predict user's acceptance of innovations including e-health services. Towards aiding the selection process of the multi-dimensional evaluation criteria, this study will make use of two lines of these studies

The first one is Diffusion of Innovations Theory (DOI). DOI is one of the popular theories which were introduced by Rogers (1995) to explain how a new idea or innovation propagates in a social system. The theory is based on 50 years of research, and was adopted by many researchers in different research fields including the e-government research. For example, the theory was used by Carter and Belanger (2004) to assess the citizen adoption of e-government initiatives. Since being introduced, the diffusion of innovations theory was adopted in different ways in many studies including the use of the important part of the theory and the well-known S-shaped curve of adoption and the categorization of adopters.

In applying diffusion theory to e-health services evaluation, the most relevant points to recognize are the innovation perceived attributes identified by Rogers' study and their applicability to e-health services: Rogers (1995) describes the characteristics of an innovation in terms of its perceived attributes, and these attributes are responsible in controlling the rates of diffusion of the innovation. Rogers (1995) identified three primary perceived attributes, which are relative advantage, compatibility, and complexity. He added two other innovation attributes, which are trialability and observability.

From the five factors of DOI theory, we will only include in this study the primary ones, which are relative advantage, compatibility, and complexity. We believe that the other two, trialability and observability, are not pertinent for e-health services. Rogers (1995) considers trialability and observability as less important than the other three. Tornatzky and Klein (1982) have the same view, and they conclude that relative advantage, compatibility, and complexity are the most relevant factors to adoption research.

The second line of studies relating to the behaviour of users to new products or services is Technology Acceptance Model (TAM) (Davis, 1989). TAM is widely used to study user acceptance of technology. It was designed to examine the mediating role of perceived ease of use and perceived usefulness in their relation between systems characteristics as external variables and the probability of system use as an indicator of system success. However, as noted by several researchers (Hufnagel & Conca, 1994; Melone, 1990; Paul et al., 2003), TAM suffers from the absence of significant factors, including considering both human and social change processes and their affects on the adoption and utilization of new information systems. Paul et al. (2003) added that although technology acceptance model is useful, using TAM specifically in empirical research may give inconsistent results.

The technological acceptance model was used in the evaluation of e-services in the public sector by many research studies (Al-adawi et al., 2005; Carter & Belanger, 2004). The model was also applied to healthcare by Lapointe et al. (2002). In applying technology acceptance model to e-health services evaluation in this study, we will consider the mediating role of both perceived ease of use and perceived usefulness.

PROPOSED MULTI-DIMENSIONAL CRITERIA

E-government services evaluation and e-health services evaluation in particular are unable to reveal the full value of e-government projects without considering the perspectives of all the e-government services stakeholders and the e-government value measures presented by evaluation criteria consisted of all the key issues perceived by each of the stakeholders.

As mentioned earlier healthcare services are known to be a complex domain. This is related to the fact that healthcare is a safety critical area, dictated by a complex regulations. These regulations should be carefully considered in the selection process of the evaluation criteria, and in the description of the criteria used for a specific e-health service.

Hence, the proposed criteria are derived from two sources. The first source is two lines of studies relating to the behaviour of users of new products or services. The second source is a broad examination of the existing evaluations initiatives specifically those who were based on e-health services case studies. The first source represented by DOI and TAM which are popular and widely used theories, but still have their own merits and limitations. One of the main limitations of both theories is that they are not conclusive models and they suffer from the absence of significant factors. To adapt both theories for e-health context and overcome their limitations, critical analysis of e-health services case studies were used.

Considering the technical dimension, the economic dimension, and the social dimension in selecting and grouping the proposed evaluation criteria for this study, the criteria will be grouped in three sets of criteria, which are usability, direct costs and benefits, and trust. This classification should serve the deployment of the evaluation framework.

The Usability Criteria

The first set of evaluation criteria is the usability criteria. Usability in the proposed criteria may represent perceived ease of use and perceived usefulness as depicted by Davis (1989) technology acceptance model (TAM), or complexity as defined by Rogers (1995) diffusion of innovation.

Davis (1989) defines perceived usefulness as "the degree to which a person believes that using a particular system would enhance his or her job performance". He also defines perceived ease of use as "the degree to which a person believes that using a particular system would be free of effort". Rogers (1995) defines complexity as the "degree to which an innovation is perceived as difficult to understand and use"

We believe that perceived ease of use is predicted to influence perceived usefulness, since the easier a system is to use, the more useful it can be. We also believe that complexity and perceived ease of use are measures for the same issue. Therefore we are considering the three issues belonging to the same set and they will be represented by the usability criteria.

Usability has different interpretations and meanings depending on the context of use. Bevan and Macleod (1993) define usability as the quality of interaction within a particular context. Another description of usability which considers user's perspective is proposed by Nielson (1993), according to him, usability relates to how well users can use the functionality of a system or service in terms of what it can do. Researchers have provided broad dimensions and introduced long lists of aspects by which the usability can be assessed. These include accessibility (Steinfeld & Danford, 1999), functionality (Melander-Wikman et al., 2005; Nielson, 1993; Steinfeld & Danford, 1999), compatibility (Bevan et al., 2007; Chau & Hu 2001), user' satisfaction, easy to learn and use (Melander-Wikman et al., 2005; Nielson, 1993), and user interface (Melander-Wikman et al., 2005).

Accessibility is an important subset of usability. According to Terry, Ma, and Zaphiris (2003), accessibility means an effective and efficient user interface which is inclusive of more people in more situations and can achieve user satisfaction. Those people are different in their accessibily requirments and needs. A high percentage of them particularly those who suffer from disabilities or cronic illness are more likely in need than others for accessible and effective e-health services. Mont (2007) reported that an estimated 20 percent of American and Australian populations and 12.2 percent of British population have disabilities. Another research by Lenhart et al. (2003), shows a high percentage of about 38 percent of Americans with disabilities are using the Internet. The same research also shows that users with disabilities are more likely than the general population to use e-health services and have access to these services only from home.

Accessibility requirements for e-health services should generally accommodate all people, but particularly remove or reduce all the barriers that can hamper disabled people from fully benefiting from e-health services. One of the efforts for determining accessibility is the guidelines developed by the "Web Accessibility Initiative", a working group of the World Wide Web Consortium (Caldwell et al., 2007)

Despite the importance of accessibly in the evaluation of e-services in public sector and e-health services in particular, studies show that governments either ignored or did not pay enough attention to the accessibility importance. According to the Global e-government Survey conducted by World Market Research Centre and Brown University (2001), only 2% of government websites worldwide have some form of disability access and only 7% of the e-government websites were accessible. Another study by West (2000) show that only 15 percent of American government websites offer some form of disability access, such as TTY (Text Telephone) or TDD (Telephone Device for the Deaf) or are approved by disability organizations. The study also revealed that only 4 percent of American government websites offer foreign language translation features on their websites. Another example for ignoring accessibly in healthcare services is a cross-sectional study by Zeng and Parmento (2004). The study was aiming to evaluate the accessibility of consumer health information of 108 Web sites, and reported that no Web site met all the accessibly criteria in their assessing framework.

Compatibility is another important criterion to be included in the usability criteria. According to Rogers (1995), compatibility is measured by the degree to which an innovation is perceived as being consistent with the existing values, past experiences, and needs of potential users. Chau and Hu (2001) argued that compatibility is positively affecting user's attitude toward accepting new technologies in healthcare environments. They based their argument on the assumption that users would be more likely to consider technology useful if they perceived it to be compatible with their existing practices. In addition, users would consider technology easy to use if they did not need to change their practices significantly in an environment that can not cope with radical change.

Functionality is a broad criterion of the usability criteria which supposes to cover the user's requirements from a system to perform specific tasks in a specific situation; this includes accuracy, validity, robustly, speed and availability (Melander-Wikman et al., 2005).

User satisfaction is generally regarded as one of the most important measures of system or service success and should be included in the proposed usability criteria. The user satisfaction criterion can be measured by various dimensions including utility, reliability, efficiency, customization and flexibility (Horan et al., 2006).

Table 2 summarizes the proposed usability criteria, list of measuring aspects by which the criteria can be assessed and suggestions for measuring descriptions. The aim of proposing the measuring descriptions is to provide general guide for assessing these aspects. The applicability of the descriptions for specific context is out of the scope of this study.

The Direct Costs and Benefits Criteria

The second set contains the direct costs and benefits criteria. The criteria in this set are primarily based on Rogers's relative advantage. According to Rogers (1995), relative advantage is "the degree to which an innovation is seen as being superior to its predecessor". It is essentially a cost–benefit analysis of how useful a given innovation when compared with what is already available. Relative advantage represents mostly the economic return involved in the adoption of an innovation, but could also include the immediacy of reward, social prestige, or savings in time and effort (Rogers, 1995). The direct costs and benefits criteria have traditionally dominated the traditional information system evaluation process, and they were criticized by many authors (Farbey et al., 1995; Serafeimidis & Smithson, 2000) for their limited relevance to the role of information systems. This limitation is in their definition of stakeholders, targeting only direct tangible costs and benefits and being only based on accounting and financial instruments. On the other hand, many authors (Eng, 2002; Glasgow, 2007; Gustafson & Wyatt, 2004; Smaglik et al., 1998) argue that direct costs and benefits are important and should be

Table 2. The usability criteria and suggestions for measuring descriptions

Evaluation Criteria	Measuring Aspects	Suggestions for Measuring Descriptions
Easy to learn and use	Easy to learn	Measured by the time needed to learn to work with a service.
	Easy to use	Assessed by the simplicity of the service and how easy it is to understand and comprehend its functions
Accessibility	Content Accessibility	Measured by the degree of compliance with the Web Content Accessibility Guidelines
	User interface	Judged by the available options of user interfaces (e.g. Graphical interface, Multi-screen interface, Attentive User Interface).
	Disability access & translation	Is the system offering some form of disability access and foreign language translation features?
Compatibility	Compatibility	Assessed by how quickly and easily the e-service can fit into the whole healthcare system.
Functionality	Accuracy	Measured by the degree to which information provided by the service is free of errors.
	Validity	Measured by the clarity and regularity of information updating.
	Robustly	Judged by the technical functionality of the service.
	Speed	Judged by the system response time; web page load time; download time.
	Availability	Assessed by the availability of the service 24hrs/7days per week and the existing of alternative choices.
User satisfaction	Utility	Assessed by the completeness and usefulness of the service content (Loiacono et al., 2002)
	Reliability	Judged by the appropriately of the service functions in terms of the technology as well as the accuracy of the content (Zeithaml et al. 2000).
	Efficiency	Judged by the time spent to complete the information task, quality of the information found, appropriateness of information found, and satisfaction with the outcome (Wang et al., 2005).
	Customization	Measured by the degree of service tailrarity to meet the needs of individual user (Burgess, 2004).
	Flexibility	Assessed by whether a system or a service provides choice of ways to state a need and delivers dynamic information (Zeithaml et al. 2000).

considered in evaluating e-health services. Despite the above mentioned opinions regarding the limitations of using the economic issues in the evaluation; we tend to support the opinion of including them as part of the evaluation criteria because healthcare services have a high economic impact on governments and users comparing to any other services (Bower, 2005; Friedman & Wyatt, 2000; Gustafson et al., 2001).

One of the efforts in assessing the direct financial cost and benefits of e-health is the e-health impact project which was commissioned by the European Commission (DG Information Society and Media) (Stroetmann et al., 2006). The main aim of the project was to evaluate the economic and productivity impact of e-health services. The research project developed a generic economic assessment and evaluation framework for e-health applications, and was mainly focused on citizens' perspective in assessing ten e-health application cases. The ten cases were selected from across the European Union for their proven, sustainable e-health application. The result of the assessment, which was carried over a period of 15 years, indicates a positive, sustainable economic impact of these e-health services.

Table 3 summarizes the proposed direct costs and benefits criteria and suggestions for measuring descriptions for e-health services evaluation. Adopting the proposed evaluation criteria and their descriptions for a specific e-health service should take into account the relevancy of each of the evaluation criterion to the prevailing situation. This mainly depends on the maturity of the e-health initiative, and could lead to partial use of the evaluation criteria.

The Trust Criteria

The third set of the proposed evaluation criteria is the trust criteria. Trust has been acknowledged as a crucial property of information systems that provide e-services in a variety of contexts, because failing to address the trust aspects correctly may have a profound impact on the e-services (Fruhling & Lee, 2004; Presti et al., 2006). The aspects of trust must be tackled properly during the development and use of e-services. Trust can be defined as "the willingness of a party to be vulnerable to the actions of another party based on the expectation that the other will perform a particular action important to the trustor, irrespective of the ability to monitor or control that other party" (Mayer et al., 1995). Trust in e-health services is associated with data security and privacy of personal health data (Rodrigues, 2003). Given the sensitive nature of healthcare information, trust requires maintaining security in handling of patients' information, protecting their privacy, and assuring them that their personal information will be treated confidentially. Without this assurance, it will be difficult to promote the use of e-health services.

Enhancing trust involves enhancing security measures. This requires a large variety of measures and principles. Slaymaker et al. (2004) identified several aspects for security to be considered in any e-health project. These aspects include: user authentication, encrypted data movement, data integrity, security breach detection, physical security, audit trails, client and server authentication, and availability.

Trust in e-health services is also associated with the privacy of personal health data. According to Davis et al. (1999) "Privacy is the state of being free from intrusion, and in the context of health care, it concerns the responsibility of a care provider to protect a patient from any disclosure (i.e., discovery by others), even unintentional, of

Table 3. The direct costs and benefits criteria and suggestions for measuring descriptions

Evaluation Criteria	Measuring Aspects	Suggestions for Measuring Descriptions
Costs	Money Saving	How much money the citizens are saving by using the e-health service.
	Time Saving	How much time the citizens are saving by using the e-health service.
Benefits	Effort Saving	Measured by the degree of convenience in using a particular e-health service.
	Quality	Assessed by the added value to the Citizens information and knowledge about their conditions, diagnoses, treatment options and healthcare facilities, as well as the appropriate timing of the service
	Access	Judged by access level comparing to the same quality of services through alternative channel.

personal health data by providing security to the patient and the patient's records".

Moor (1997), stated that the main consideration in developing policies for protecting privacy is to make sure that the right people, and only the right people, have access to relevant information at the right time. Moor (1997) also proposed a controlled and restricted access technique for managing privacy. The technique is based on setting up zones of privacy and provides the opportunity for different people to be authorized for different levels of access to different kind of information at different times.

In practice, studies show that governments and health organizations have different levels of consideration for trust, security and privacy in their initiatives. An example is the study of Jarvinen (2005) which concludes that governments and health organizations have low levels of consideration for privacy. The study which covers 39 American health organizations reveals numerous examples of practices that make the customer vulnerable can be found in the analysed healthcare privacy policies. These practices include the absence of an adequate privacy notice, not give the users reasonable control over their information and the use of technical and confusing language in the privacy policies that make it difficult for the user to fully understand them. Another study by West (2000) also confirms similar finding. The study shows that there is very low consideration to the security and privacy in the American e-government websites. The study reveals that only 7 percent of American government websites have a privacy policy, and another 5 percent show some form of security policy. On the other hand, there are positive examples for the consideration of security and privacy such as the privacy provisions in Canada or quality seals for e-government services which was introduced in Austria (Aichholzer, 2003).

Table 4 summarizes the proposed trust criteria and suggestions for measuring the aspects of the criteria. Although the table provides clear and useful set of criteria, the criteria are general

Table 4. The trust criteria and suggestions for measuring descriptions

Evaluation Criteria	Measuring Aspects	Suggestions for Measuring Descriptions
Security	User authentication	Measured by how strong the user authentication is and if its key capabilities are sufficient for e-Health services
	Encrypted data movement	Assessed by the suitability of the technology used to protect the transfer of data.
	Data integrity	Determined by if the information is complete, whole, valid and digitally signed when required
	Security breach detection	Judged by the ability of the system to monitor and look for suspicious activity on the network.
	Physical security	Assessed by how secure is the area that holding the database equipments and if it is located in an area with limited and controlled access.
	Audit trails	Judged by the ability of the system to record the modification of data, to keep the most up to date version of data and to retrieve old versions of data.
Privacy	Responsibility	Measured by the degree of protection supplied by the healthcare organization for patient information from any disclosure.
	Access Control	Assessed by the degree of control on different level of access to different kind of information at different time.
	Confidentiality	Measured by the degree of compliance with the UK Data Protection Act (1998)

and it may be necessary to modify them to suite specific e-health initiative. The aim of proposing the measuring descriptions is to provide general guide for assessing the criteria aspects. The applicability of the description for specific context is out of the scope of this study.

CONCLUSION

This paper argues that the first requisite towards developing a holistic evaluation framework for e-health services is to deal effectively with the complexities, and overcoming the barriers through a multi stage strategy. The e-health services evaluation complexities are correlated mainly to the multi-disciplinary nature of the field and the challenges at the intersection of three areas, each well-known for its complexity, healthcare services, information systems, and evaluation methodologies. The paper starts with a summarization for these challenges.

Working towards building a holistic evaluation framework through a multi stage strategy, the paper suggests framework characteristics for the appropriate evaluation for e-health services. The paper argues that e-health services evaluation framework should be criteria based, while the criteria have to be multi-dimensional that grounded in, and derived from, one or more specific perspectives or theories, and cannot be entirely framed within the bounds of a single theory or perspective. Understanding the multi-disciplinary nature of e-health services evaluation and the challenges that it faces is the first requisite towards dealing effectively with the complexities, and overcoming the barriers of e-health services evaluation.

The paper provides a set of clear and useful e-health evaluation criteria that can be used as part of e-health evaluation framework, and to address areas that require further attention in the development of future e-health initiatives.

The proposed criteria were mainly derived from two sources. The first source was two lines of studies relating to the behaviour of users of new products or services. The second source was a broad examining of the existing evaluations initiatives, specifically those who were based on e-health services case studies. Hence, general evaluation criteria were proposed that cover the technical, economic and social dimensions. The proposed evaluation criteria can also be adapted to a specific e-health service by analysing the criteria that apply in that situation.

The limitation of this paper lies in the absence of empirical validation and examination of the proposed evaluation criteria that has not yet been applied in the fieldwork. Hence, the proposed factors require an empirical validation which will be performed by the authors in the next stage of this research using multiple case study strategy and will form the basis for further research.

ACKNOWLEDGMENT

A previous version of this work appeared in the *Handbook of Research on Advances in Health Informatics and Electronic Healthcare Applications: Global Adoption and Impact of Information Communication Technologies;* edited by: Dr. Khalil Khoumabti, Dr. Yogesh Dwivedi, Dr. Aradhana Srivastava and Dr. Banita Lal

REFERENCES

Adams, J. S. (1965). Inequity in social exchange. In L. Berkowitz (Ed.), *Advances in experimental social psychology*. New York: Academic Press.

Aichholzer, G. (2003). Scenarios of e-Government in 2010 and implications for strategy design. *Electronic Journal of E-government*. Available at http://www.ejeg.com

Al-adawi, Z., Yousafzai, S., & Pallister, J. (2005). Conceptual Model of Citizen Adoption of E-government. *The Second International Conference on Innovations in Information Technology (IIT'05).*

Alvarez, R.C. (2003). The promise of e-health: a Canadian perspective. *e-Health International, 1*(1), 4.

Ballantine, J. A., Galliers, R. D., & Stray, S. J. (1999). Information Systems Technology Evaluation Practices: Evidence from UK Organizations. In L. P. Willcocks & S. Lester (Eds.), *Beyond the IT Productivity Paradox* (pp.123-149). Chichester, England: John Wiley & Sons.

Bevan, N., & Macleod, M. (1993). Usability assessment and measurement. In M. Kelly (Ed.), *The management and measurement of software quality.* Ashgate Technical/Gower Press.

Bevan, N., Petrie, H., & Claridge, N. (2007). Strategies for Providing Guidance on Usability and Accessibility. In *Proceedings HCI International 2007.* Springer.

Beynon-Davies. P. (2005). Constructing Electronic Government: the case of the UK Inland Revenue. *International Journal of Information Management*, *25*(1), 3-20.

Bower, A. (2005). *The diffusion and value of healthcare information technology.* Published by the RAND Corporation, Library of Congress Cataloging-in-Publication Data

Brender, J. (2006). *Handbook of Evaluation Methods for Health Informatics.* Elsevier Academic Press Publications.

Burgess, L (2004, October 13-15). A Conceptual Framework for Understanding and Measuring Perceived Service Quality in Net-based Customer Support Systems. *CollECTeR LatAm Conference*, Santiago, Chile.

Caldwell, B., Cooper, M., Reid, L., & Vanderheiden, G. (2007, December). *Web Content Accessibility Guidelines 2.0.*

Carter, L., & Belanger, F. (2004). Citizen Adoption of Electronic Government Initiatives. In *Proceedings of 37th Annual Hawaii International Conference on System Sciences*, Big Island, Hawaii.

Chau, P., & Hu, P. (2001). Information Technology Acceptance by Individual Professionals: A Model Comparison Approach. *Decision Sciences, 32*(4).

Connell, N., & Young, T. (2007, June). Evaluating healthcare information systems through an "enterprise" perspective. *Information & Management, 44*(4), 433-440.

Creswell, J. W. (2003). Research Design. *Qualitative, Quantitative, and Mixed Methods Approaches*. Thousand Oaks, CA, USA: Sage.

Cronholm, S., & Goldkuhl, G. (2003, September 25-26). Six Generic Types of Information Systems Evaluation. *The 10th European Conference on Information Technology Evaluation (ECITE-2003)*, Madrid.

Davis, F. (1989). Perceived Usefulness, Perceived Ease of Use and User Acceptance of Information Technology. *MIS Quarterly, 13*(3), 319-340.

Davis, L., Domm, J., Konikoff, M., & Miller, R. (1999, Jan–Feb). Attitudes of First-year Medical Students toward the Confidentiality of Computerized Patient Records. *Journal of the American Medical Informatics Association, 6*(1).

Eng, T. R. (2001). *The e-health landscape: A terrain map of emerging information and communication technologies in health and health care*. Princeton, NJ: The Robert Wood Johnson Foundation.

Eng, T. R. (2002). E-health research and evaluation: challenges and opportunities. *J. Health Commun., 7*(4), 267-272.

Farbey, B., Land, F., & Targett, D. (1995). A Taxonomy of information systems applications: the benefits evaluation Ladder. *European Journal of Information Systems, 4*, 41-50.

Farbey, B., Land, F., & Targett, D. (1999). Evaluating Investments in IT: Findings and a Framework. In L.P. Willcocks & S. Lester (Eds.), Beyond the IT Productivity Paradox (pp. 183-215). Chichester, England, UK: John Wiley & Sons.

Freeman, R.E. (1984). *Strategic Management: A stakeholder Approach*. Cambridge: Ballinger Publishing Co.

Friedman, C., & Wyatt, J. (2000). *Evaluation methods in medical informatics.* New York: Springer-Verlag.

Fruhling, A., & Lee, S. (2004, September). Designing Trustworthy e-Health Services for Rural Consumers. *MedInfo. American Medical Informatics Association Proceedings.*

Glasgow, R. E. (2007). E-health evaluation and dissemination research. *Am. J. Prev. Med., 32*(5 Suppl), S119-126.

Grover, V., Jeong, S. R., & Segars, A. H. (1996). Information Systems Effectiveness: The Construct Space and Patterns of Applications. *Information & Management, 31*(4).

Gustafson, D., Hawkins, R., Pingree, S., McTavish, F., Arora, N., Salner, J, et al. (2001). Effect of computer support on younger women with breast cancer. *J. Gen. Intern. Med., 16*, 435-45.

Gustafson, D., & Wyatt, J. (2004). Evaluation of e-health systems and services. *British Medical Journal*, *328*, 1150. doi:10.1136/bmj.328.7449.1150

Hans, O., Rizo, C., Enkin, M., & Jadad, A. (2005, February 24). What is e-health? *A Systematic Review of Published Definitions, Journal of Medical Internet Research*. doi: 10.2196/jmir.7.1.e1.

Holliday, I., & Tam, W. (2004). E-health in the East Asian tigers. *International Journal of Medical Informatics, 73*(11-12), 759-769.

Horan, T., Abhichandani, T., & Rayalu, R. (2006). Assessing User Satisfaction of E-Government Services: Development and Testing of Quality-in-Use Satisfaction with Advanced Traveler Information Systems (ATIS). *Proceedings of the 39th Hawaii International Conference on System Sciences.*

Hufnagel, E. M., & Conca, C. (1994). Use Response Data: The Potential for Errors and Biases. *Information Systems Research*, *5*, 48-73.

Jarvinen, O. (2005). *Privacy Management of E-health, Content Analysis of 39 US Health Providers' Privacy Policies*. Publication of Turku School of Economics and Business Administration, Series A-3:2005.

Jones, S., & Hughes, J. (2001). Understanding IS Evaluation as a Complex Social Process: A Case Study of a United Kingdom Local Authority. *European Journal of Information Systems*, *10*(1).

Lapointe, L., Lamothe, L., & Fortin, J. P. (2002). The dynamics of IT adoption in a major change process in healthcare delivery. *Proceedings of the 35th HICSS conference,* Big Island, Hawaii.

Lauer, T., Joshi, K., & Browdy, T. (2000, Jan–Feb). Use of the Equity Implementation Model to Review Clinical System Implementation Efforts. *Journal of the American Medical Informatics Association, V.7*(1).

Lenhart, A., Horrigan, J., Rainie, L., Allen, K., Boyce, A., Madden, M. et al. (2003). *The ever-shifting Internet population. A new look at Internet access and the digital divide.* Washington, DC: Pew Internet & American Life Project.

Löfstedt, U. (2007). E-Government Services in Local Governments – A study of Development in Swedish Municipalities. *Journal of Organisational Transformation and Social Change*, *4*(2), 157-167.

Loiacono, E. T., Watson, R. T., & Goodhue, D. L. (2002). Webqual: A Web Site Quality Instrument. In *Proceedings of the AMA Winter Marketing Educators' Conference*, Austin, TX, USA.

Lowery, D., & Evans, K. G. (2004). The iron cage of methodology. *Administration & Society, 36*(3), 306–327.

Mayer, R. C., Davis, J. H., & Schoorman, F. D. (1995) An integrative model of organizational trust. *Academy of Management Review, 20*(3), 709-734.

Mantzana, V., & Themistocleous, M. (2006). A Method for the Identification of Actors Involved in the Adoption of Innovations in Healthcare Organizations. In *Proceedings of the 39th Hawaii International Conference on System Sciences.*

Mcconaghy, J. (2006). Evolving Medical Knowledge: Moving Toward Efficiently Answering Questions and Keeping Current. *Primary Care: Clinics in Office Practice, 33*(4), 831-837. Elsevier Inc.

Melander-Wikman, A., Jansson, M., & Gard, G. (2005). The MobiHealth Usability Evaluation Questionnaire. *E-health International Journal*.

Melone, N. P. (1990). A Theoretical Assessment of the User Satisfaction Construct in Information Systems Research. *Management Science*, *36*, 76-91.

Mingers, J., & Stowell, F. (1997). Information Systems: An Emerging Discipline? Information Systems Series (pp. 239-266). London: McGraw-Hill.

Mont, D. (2007). *Measuring Disability Prevalence* (SP Discussion Paper NO. 0706). Available at:

http://siteresources.worldbank.org/DISABILITY/Resources/Data/MontPrevalence.pdf.

Moor, J. H. (1997). Towards a Theory of Privacy in the Information Age. *Computers and Society, 27*(3), 27-32.

Myers, M. D., & Avison, D. (2002). *Qualitative Research in Information Systems.* London: Sage Publications.

Nielsen, J. (1993). *Usability engineering (Interactive Technologies).* New York: Academic Press.

Patton, M. Q. (1990). Qualitative Evaluation and Research Methods (2nd ed.). London: Sage Publications.

Paul, L., John, I., & Pierre, C. (2003, January). Why do people use information technology, A critical review of the technology acceptance model. *Association for Information Systems, 40*(3), 191.

Powell, P. L. (1999). Evaluation of Information Technology Investments: Business as usual. In L. P. Willcocks & S. Lester (Eds.), Beyond the IT Productivity Paradox (pp. 151-182). Chichester, England, UK: John Wiley & Sons.

Presti, S., Butler, M., Leuschel, M., & Booth, C. (2006). Holistic Trust Design of E-Services. In R. Song, L. Korba, & G. Yee, (Eds.), Trust in E-Services: Technologies, Practices and Challenges (pp. 113-139). Idea Group Publishing, USA.

Rahimi, B., & Vimarlund, V. (2007). Methods to Evaluate Health information Systems in Healthcare Settings: A Literature Review. *J. Med. Syst., 31*, 397–432. Springer Science + Business Media, LLC 2007.

Ray, S. (2007). Development of a framework towards successful implementation of e-governance initiatives in health sector in India. *International Journal of Health Care Quality Assurance, 20*(6), 464-483. Emerald Group Publishing Limited.

Rodrigues, R. (2003). Deploying e-Health Solutions in Latin America and the Caribbean: Development and Policy Issues. *Forum PL11: Workshop on Telemedicine,* Geneva.

Rogers, E. M. (1995). *Diffusion of Innovations* (4th ed.). New York: The Free Press.

Serafeimidis, V., & Smithson, S. (2000). Information Systems Evaluation in Practice: a Case Study of Organizational Change. *Journal of Information Technology, 15*(2), 93-105.

Skinner, R. (2003). The value of information technology in healthcare. *Frontiers of Health Services Management, 19*(3).

Slaymaker, M.., Politou, E., Power, D., &Lloyd, S. (2004). E-health security issues: the eDiaMoND perspective. In *Proceedings of the 2004 UK e-Science All Hands Meeting*.

Smaglik, P., Hawkins, R., Pingree, S., & Gustafson, D. (1998). The quality of interactive computer use among HIV infected individuals. *J. Health Communication, 3*, 53-68.

Steinfeld, E., & Danford, G.S. (1999). *Enabling Environments .Measuring the impact of Environment on Disability and Rehabilitation*. New York: Kluwer Academic.

Stroetmann, K., Jones, T., & Dobrev, A. (2006, May 10-12). Evaluating the economic impact of e-health applications approach and method. *E-health conference 2006,* Malaga, Spain.

Symons, V., & Walsham, G. (1988). The evaluation of information systems: a critique. *Journal of Applied Systems Analysis, 15*, 119-132.

Terry Ma, H., & Zaphiris, P. (2003). *The Usability and Content Accessibility of the E-government in the UK.* Centre for Human-Computer Interaction Design, City University, London. Available at: http://www.soi.city.ac.uk/~zaphiri/Papers/HCII2003/HCII2003-Accessibility.pdf.

Tornatzky, L., & Klein, K. (1982, February). Innovation characteristics and innovation adoption-implementation: A meta-analysis of findings. *IEEE Transactions on Engineering Management*, *29*(1), 28-45.

Walsham, G. (1993). *Interpreting Information Systems in Organizations*. Chichester: John Wiley & Sons.

Wang, L., Bretschneider, S., & Gant, J. (2005). Evaluating Web-Based E-Government Services with a Citizen-Centric Approach. In *Proceedings of 38th Annual Hawaii International Conference on Systems Sciences,* Big Island, Hawaii.

West, D. (2000). *Assessing E-Government: The Internet, Democracy and Service Delivery by State and Federal Governments.* Brown University. Available at: www.insidepolitics.org/policyreports.html.

Wickramasinghe, N., & Goldberg, S. (2004). How M=EC2 in healthcare. *International Journal of Mobile Commerce*.

Wickramasinghe, N., & Misra, S. (2004). A wireless trust model for healthcare. *International Journal e-Healt*h.

Willcocks, L. (1992). Evaluating Information Technology Investments: Research Findings and Reappraisal. *Journal of Information Systems*, *2*(3), 243-268.

World Markets Research Centre & Brown University (2001). *Global e-government Survey 2001.* Available at: http://www.worldmarketsanalysis.com/pdf/e-govreport.pdf

Yin, R.K. (2003). Case study research: Design and Methods (3rd ed.). Thousand Oaks, CA: Sage Publications.

Zeithaml, V. A., Parasuraman, A., & Malhotra, A. (2000). A Conceptual Framework for Understanding e-Service Quality: Implications for Future Research and Managerial Practice. *Marketing Sciences Institute: Working Paper Series*, (115).

Zeng, X., & Parmanto, B. (2004). Web content accessibility of consumer health information Web sites for people with disabilities: a cross sectional evaluation. *Journal of Medical Internet Research*, *6*(2), e19.

This work was previously published in International Journal of Healthcare Delivery Reform Initiatives, 1(3), edited by M. Guah, pp. 1-18, copyright 2009 by IGI Publishing (an imprint of IGI Global).

Chapter 1.3

Health Technology Assessment: Development and Future

Lise Lund Håheim
Norwegian Knowledge Centre for the Health Services, Norway

Berit Mørland
Norwegian Knowledge Centre for the Health Services, Norway

ABSTRACT

Scientific publications in medical fields are rapidly increasing and are overwhelming in numbers. This poses a challenge to health authorities, and health professionals who need knowledge to make informed decisions in finding the best evidence for treatment and practice in the health provision to the public. They need an accessible system that handle the information flow using a systematic approach. This applies to developing and industrialized countries alike. The rapid development of health technologies with the introduction of new drugs, devices, and complex treatment modalities to achieve better health outcomes increases the need for evaluation of the treatment effect. This chapter illustrates how the health service handles the information flow utilizing information technology, and the great benefit that is gained by this methodology.

DOI: 10.4018/978-1-60566-356-2.ch046

THEORETICAL FRAMEWORK AND METHODOLOGY OF HEALTH TECHNOLOGY ASSESSMENT

The development of evidence based medicine (EBM) has been one important way of a systematic thinking in medicine (NHS Centre for Reviews and Dissemination, 2001; Egger, Smith, & Altman, 2001; Chalmers & Altman, 1995). But in fact the systematic way of identifying and assessing documentation started in the mid seventies with the establishment of the Health Program of the Office of Technology Assessment (OTA) under the Congress in USA (Banta & Luce, 1993).

EBM has been following several paths. The proceeding of the field of health technology assessment (HTA) is one of them (NHS Centre for Reviews and Dissemination, 2001). It has been defined as a process that systematically assesses the medical, social, ethical, and economic implications of the development, diffusion, and use of health technology.[1] In HTA two approaches are combined by making and using systematic reviews of published literature, and appraising relevant issues linked to the task at hand providing a national/local context. Health economic issues related to these technologies are important in setting priorities in health care. Ethical discussions are important to raise the awareness of moral dilemmas as well as patients' views, rights and other implications in the healthcare decision making. Technologies using groundbreaking biotechnology in particular may pose legal problems. The organization of the service may need to be discussed. Patient safety and patient rights are relevant to take into consideration. The aim of HTA is to inform and provide decision makers at all levels of the healthcare system in broad terms about the current best knowledge of health technologies to assist them in making the best informed decisions on which health technologies will provide the highest quality health service and treatments of the best value for money (prioritization).

HTA is a multidisciplinary field of policy analysis. It combines the systematic review of published scientific literature of particular health issues with appraisals that put the health technology in question in a broader context. In this work there is an extensive use of information technology in the search for scientific literature indexed in databases on scientific literature (NHS Centre for Reviews and Dissemination, 2001; Møreland, 2003a; Health Technology Assessment; Lund Håheim & Mørland, 2003). The identified studies are evaluated for relevance of population, intervention, outcome and study design, before being included in the evidence base of the relevant subject. The overall grade of evidence is then evaluated. There are a great number of databases that are searched for specified literature. It is done in a defined and specific manner and the search strategy is published so that it may be repeated by others or at a later date. HTA is done in a transparent way by publishing all the information on how the work was done. The report is indexed to databases as systematic reviews. External review teams are frequently used in this work (Mørland, 2003a; Health Technology Assessment). The teams are most often multidisciplinary having members of the medical professions, epidemiologist, health economist, statistician, and user/patient representatives, or others as needed. The range of disciplines is founded in the need to make sure the literature assessment is relevant and of highest quality. The members of the teams gain knowledge of the methods used in making systematic reviews, and can therefore bring this knowledge back into their own work place. As they are often chosen on a background of being "opinion leaders" in their field, they are important in the challenging work of implementing the results and increase the impact by having the full knowledge of how the work was undertaken. This individual knowledge assists in the transfusion of knowledge of health technology assessments through the health service.

HTA has developed steadily over the years to be a world wide effort to improve the decision making in the health services by presenting best evidence, but the work stops short of making political decisions or making guidelines. Its products are the applied use of research results and it is founded on research into best ways of performing assessments, and increasingly meeting the challenge of finding most efficient ways to disseminate and implement results. HTA relies heavily on information technology (IT) in all parts of the work. In assessing research the work relies entirely on information technology as it is used both in searching and collecting relevant studies/literature, during the assessment process, until the final report is made and it is disseminated. Different tools have been developed that are being used to streamline the work process by using standard forms and checklists, and data programs for grading the evidence level of the studies included and reporting results. For making the quantitative syntheses of effect estimates the statistical method of meta-analysis has been developed. Without the development of IT, and its efficient use in searching and sorting huge amount of literature, the EBM and HTA would not have been possible. Information technology is the basic tool which the work is based on and the use is continually being validated through research efforts on its own methodology.

HISTORIC DEVELOPMENT AND INTERNATIONAL COLLABORATION

HTA seeking scientific evidence on the best outcomes of medical interventions is a field that, as mentioned above, has developed over the last 35 years to become a useful tool for the health services (Banta & Luce, 1993; Jonsson, 2002). There has always been a need to assess the effects of health technologies. Observational methods, opinions, beliefs, and expert statements have been broadly used, but do not give the best evidence in terms of assessing the best clinical effect of e.g. a specific treatment. Then randomized controlled trials are considered to be the best study design, secondly are the controlled study designs. The studies are ranked according to study design and internal and external validity. The study results are then synthesized and graded. The increased production of scientific studies called for a systematic review of the results they provided, in order to make the best available scientific assessments of effect of interventions. HTA was first formally established as a working method in the mid-seventies with the establishment of the Health Program of the Office of Technology Assessment (OTA), USA. Many basic structures developed at OTA are still relevant. A concurrent development happened in Europe with the establishment of similar organizations. The first European workshop on evaluation of medical technology was held in 1979. Health economists from Switzerland, Sweden, UK, and WHO/Europe organized a conference titled Economic Evaluation in Health Care Technologies. During the first half of the 1980s the HTA activities were gaining momentum in Europe. The first agency was established in Sweden in 1987 and soon other agencies followed. One of the first studies made by the Swedish agency was successful in both documenting scientific evidence for best clinical practice in the use of preoperational laboratory routines, and showing the important economic gain by following this practice. The HTA work became more formalized with time in Europe and also the Canadians and Australians were very active. In 1991 the Cochrane Centre was established and in 1993 the Cochrane Collaboration (www.cochrane.org). Consensus conferences also played an important part in some countries in the development of HTA.

International collaboration is very much appreciated and is an integral work in HTA. The exchange of knowledge was the basis for the initiative of a scientific journal called International Journal of Technology Assessment in Health Care first published in 1985. This year there also was a meeting at the WHO in Copenhagen where the International Society of Technology Assessment in Health Care (ISTAHC) was established. It was reorganized in 2002 into Health Technology Assessment international (HTAi).

The health authorities and policy makers saw the use of establishing HTA centres that could relate health technology assessments to their national specific situation on the macro and meso level rather more than on micro clinical level. They were interested in the quality of the health care provided, equity in treatment across groups, equal access for necessary treatment, and involving more than medical professionals. It has also become increasingly important to include cost-effectiveness analysis. The need for international collaboration has resulted in the establishment of INAHTA (International Network of Agencies for Health Technology Assessment, started in 1993) (http://www.inahta.org/) (Hailey & Menon, 1999). INAHTA, a non-profit organization, has now grown to 46 member agencies from 26 countries including North and Latin America, Europe, Asia, Australia, and New Zealand. All members are non-profit making organizations producing HTA and are linked to regional or national governments. Many organizations throughout the world assess healthcare technology. There is an evident need to cooperate and share information from different cultures. INAHTA serves this purpose. The Secretariat is located at SBU in Sweden.

The EU has for a long time seen HTA as an important tool to improve health care. Several research programs were introduced in the 1990s. Such programs were the EUR-ASSESS (1994-97), HTA-Europe (1997-98) and ECHTA/ECAHI (2000) (Jonsson, Banta, Henshall, & Sampietro-Colom, 2002) that where established in order to stimulate coordinated efforts for collaboration between agencies. The work is now being taken further in the 3-year EU-project for a sustainable network of HTA-agencies called European Network for Health Technology Assessment (EUnetHTA) (2006-9). EUnetHTA will be described in more detail and is expected to form the basic network of the future organization of HTA in Europe (http://www.eunethta.net). EUnetHTA will be supporting the policy makers in making informed decisions on health care, but also decision makers on all levels and the clinical level (micro level). It aims to become the focal point for HTA by establishing a communication and clearinghouse facility making a common direct contact between users, providers, and stakeholders of HTA. A major aim of developing this network is to reduce duplication of HTA reports through the development of methods and material that ease the translation of the products into national/regional conditions. The products are core HTA information, adaptation tools, efforts for monitoring new technologies, and information on how to establish an HTA-agency. New technologies will be registered on a regular basis and a newsletter on early warning of new technology will be provided. It will be a comprehensive system of information on all levels of HTA production and use for the best of the community at large.

THE NORWEGIAN HTA EXPERIENCE

Norway has since 1997 had a national centre for HTA (Mørland, 2003a; Health Technology Assessment). The Norwegian Centre for Health Technology Assessment (SMM) was from the start the first and only HTA agency in Norway and has continued being this. The organization consisted of the main agency (10-12 scientists), its steering committee and a consulting panel of 60 experts representing a range of health institutions, universities, hospitals, central health administration, and professional and patient organizations. SMM was housed purposely outside the central health administration. Review teams led by SMM using international principles of HTA in their work formed the major working method (NHS Centre for Reviews and Dissemination, 2001; Health Technology Assessment). In this way knowledge dissemination of HTA as a working method and of the results of the subject under study was achieved. One may say that SMM was perhaps more pointing at the clinical /micro decision-level, than most other HTA agencies. The reports were published and presented at dedicated seminars and national/international conferences. The web-page was soon established and a newsletter published regularly all using a publication profile that was made early on making the products easily recognizable

Examples of work are the report on Hip replacement prostheses that revealed that more than 50 different types were in use in Norway and that a third of these lacked sufficient scientific evidence on clinical results (Nordsletten, Havelin, Indrekvam, Aamodt, Utvåg, & Hviding, 2002). Another report that made an impact on changes in the service was that on the use of PCI. A meta-analysis of 17 studies showed PCI to reduce mortality, re-infarction, and stroke (Wiseth, Gundersen, Halvorsen, Nordrehaug, Steigen, & Myhre, 2002). But some questions were also raised by the health policy (macro) level, i.e. the documented clinical outcomes from using PET as a diagnostic procedure, and the possible future need for PET in Norway (Mørland, 2003b).

In sum, this multilevel way of organizing and disseminating the work ensured a rapid spread of knowledge of HTA in Norway. What started as a three year trial project proved a sustainable working method.

SMM was reorganized in 2004 with two other related organizations into the Norwegian Knowledge Centre for the Health Services (NOKC) (http://www.kunnskapssenteret.no/). NOKC summarizes and disseminates evidence concerning the effect of treatments, methods, and interventions in the health services, in addition to monitoring health service quality. The aim is to support good decision making in order to provide patients in Norway with the best possible care. The centre serves as the Norwegian HTA agency, and hosts branches of the Cochrane Collaboration and the Campbell Collaboration. One department is dedicated to patient satisfaction surveys, patient safety, quality measurements and quality registers. An internet library with links to publications and databases of literature has been established. The Centre is organized under The Directorate for Health and Social Affairs, but is scientifically and professionally independent. The Centre has no authority to develop health policy or responsibility to implement policies.

RESEARCH IN HTA

HTAi (and formerly ISTAHC) conferences and the Journal of Technology Assessment in Health Care (JTAHC) are major focal points for presentation and publication of research on health technology assessment methods and results. The aspects cover a broad range.

The research areas can be illustrated by the main themes that have been chosen for the HTAi conferences the last years: The History of HTA, Krakow, Poland, 2004; HTA and Clinical practice (Hospitals), Rome, Italy 2005; HTA and Health Policy, Adelaide, Australia, 2006; HTA for Evidence-based Public Health, Barcelona, Spain, 2007; and HTA in Context, Montreal, Canada, 2008.

In the conference held in Barcelona 2007 the range of research areas were impressive. Themes of the panel sessions are presented in Table 1.

HTA as a methodology is the focus of research and development. In the following will be given two research examples from SMM and NOKC that illustrates the way the two subjects are 1) Review Teams Experience and 2) Implementation of Reports.

Review Teams Experience

The review teams at SMM worked after the principles of consensus group work, but in a more systematic way, independently evaluating the identified literature after preset criteria (Christofides et al., 2006). In order to follow up their experience with the work, every participant received a survey after completion of a report. It was of importance to evaluate the use of review teams as a working method and to what degree the experts should be involved in the literature assessments. The composition of the review teams reflected an interdisciplinary approach. SMM should work in close cooperation with the clinical services, research centres and health authorities and select members from these areas. The participants were chosen among opinion leaders in their field. Team members were chosen from different areas of medicine, and health care. As the HTA reports also handle appraisal issues like health economics, ethics, law, and health service organization, additional expertise from these fields was sought if needed and these persons joined the team as needed.

Methods

At the completion of the HTA-report the review team members were given a questionnaire on their

Table 1. Overview of research themes presented at the HTAi conference in Barcelona, Spain, 2007.

Methods for knowledge transfer: What is the impact of Knowledge networks in Public Health and HTA?
HTA, Industry and Health Systems: Are we ready to set up an agenda for effective cooperation?
Patients and Citizens: involving patients and the public in the development of health guidance.
Evaluation of interventions: Evidence or ignorance – Air pollution, Health and Policy.
Evaluation of breast cancer: screening and treatment.
Assessing Telemedicine
Patients: information and involvement.
Evaluation of Mental Health intervention.
Evaluating economic consequences of Human Papilloma Virus: screening and vaccination
HTA for clinical practice.
Ethics and socio-cultural aspects in HTA.
HTA for quality and reimbursements policy decisions
Methods for HTA: Qualitative
Evaluating interventions for substance misuse
Assessment of viral diseases prophylaxis and prevention
Teaching HTA: What knowledge and skills should students of HTA acquire?
HTA, industry and Health Systems: Understanding systems for post-regulatory assessment and decisions on health technologies
Assessing oftalmological interventions
Evaluating interventions for vulnerable groups
Economic Analysis of Public Health Interventions
Evaluation of foetal abnormalities and infant interventions
HTA in context
Evaluating complementary medicine
Evaluation of interventions: from population screening to individual treatment: where is the gap?
Assessing interventions for obesity
Evaluation of colorectal cancer: screening and treatment
Pandemic Flu: Managing the inevitable

experience. The working period lasted from 4 to 33 months. The questionnaires were sent to all 112 participants in the 17 review teams for the period of January 1998 to June 2003. Responses to the questionnaire were given by 58 participants (51.8%). The number of team members ranged from 4 to 14 persons. The questionnaire was concentrating on the theme/mandate of the assessments, the composition of the review team, the organization of the work, the working method, and the interest of participating in the update of the report.

Results

The results showed that a total of 83% thought the theme was well argued for doing an HTA, and 62% thought the mandate for the assessments was sufficiently clear. About 80% were positive to the composition of the review team. In all 22% expressed that the work method was too extensive and 43% wanted more tuition. General comments were that the working method gave added competence in assessing medical literature, relevant professional training and tutoring in a working method that ensured the legitimacy of their work. Participating in a review team gave credit points in the further education in medicine. The review team participants were satisfied with most aspects of the work. Suggestions for improvements in the working process were given. Delays occurred especially as people did not deliver their share of work due to heavy work load. Seventy-six percent were satisfied with the scientific leader at SMM. One person thought it had been a waste of time, but 83 percent were interested in making an update of the report at a later date.

Conclusion

We concluded that nothing in the results indicated the need to discontinue the work process with review teams in doing HTAs, but decided to increase the tutoring of participants.

Implementation of Reports

Making HTA reports is a time consuming effort on behalf of many persons. As most HTA agencies do not have the concrete mandate and responsibility to implement the results themselves as a matter of principle, it is of strong interest to observe if they are disseminated and implemented.

We present results whether the work and the specific conclusions obtained, have had an impact on the problem areas of the health services which they addressed. The reports were published by SMM from 1998-2003 (Lund Håheim & Mørland) and by NOKC from 2004 to 2007.

Methods

All the reports are made in accordance with the HTA principles for systematic reviews. The systematic reviews of the literature were within effects of treatment, prevention, diagnosis, screening, or other. Health technology assessments are expected to include an appraisal of related factors important to the evaluation of the results. The appraisal can be within health economics, ethics, Norwegian practice, organisation, or law. Five HTA-reports were on health economics alone.

We assembled information about our reports regarding who commissioned the reports, field of subject, and the type of appraisal included. Several reports concern more than one medical field, but in this presentation (After Table 2, See Table 3) is chosen the main field. Codes for different conclusions were based on the synthesis of the results. Known lines of impact were recorded. From reviewing the reports it was apparent that results indicated areas where insufficient evidence was available and in the conclusions were often pointed out areas for further actions. We grouped these in three:

1. The reports could conclude with suggestion on the medical practice or technology as such, being discontinued, i.e. stopped being used, change in current practice, no change in current practice, introduced as new method or further survey required before a certain conclusion could be drawn.
2. Secondly, the report could call for other concrete actions, i.e. establishing or extending existing registry, or establishing or changing guidelines.
3. Thirdly, new data or more research was asked for, i.e. on the current use, on studies of higher evidence level, or that the new method was introduced within the framework of a scientific study.

The impact of the conclusions was grouped in nine as affecting national procedures, national guidelines, distribution of duties, clinical guidelines, national drug use, advice of no change, advice not considered. It was also recorded whether there was given advice of no change, advice not followed or that no information was available.

Table 2. Overview of commissioners of HTA-reports by the year of completion of the reports

Year	**Ministry of Health**	**Hospital-service**	**Directorate of Health and Social Affaires**	**SMM / NOKC**	**Others**	**Total**
1998/9	2			1		3
2000	3			3		6
2001	5			1		6
2002	2	1		3		6
2003	4		1	5		10
Total SMM	16	1	1	13	0	31
2004			4	3	1	8
2005	1		4	4	2	11
2006		7	14	1	1	23
2007	2	5	9	1	4	21
Total NOKC	3	12	31	9	8	63
Total	**19**	**13**	**32**	**22**	**8**	**94**

Table 3. Overview of main medical fields by year of completion of the reports*

Year	**Prevention**	**Diagnostics**	**Screening**	**Treatment**	**Other**	**Total**
1998/9			1	2		3
2000	1	2		3		6
2001	1	1		4		6
2002			1	5		6
2003	4	1		5		10
Total SMM	6 (19%)	4	2	19 (61%)		31 (100%)
2004	3		1	4		8
2005	4			3	2	9
2006	6	2		14	1	23
2007	6		3	10	2	21
Total NOKC	19 (32%)	2	4	31 (52%)	5	60(100%)
Total	25	6	6	40	5	94

*Many of the reports are looking into several fields and main field is reported

Results

HTA Reports from SMM

Of the 31 reports included were 18 commissioned from external sources and 13 from SMM itself by the Board of Governors (steering group) or by the panel of advisors (mostly clinical experts) (Table 2). The implementation of the results was not found to be significantly different if the commissioner was external or internal. External sources were primarily the Ministry of Health. During the period others such as the Directorate for Health and Social Affairs and the National Advisory Council on Priorities in the Health service needed SMMs services. Other commissioners could be the Norwegian Board of Health, Norwegian Medi-

Table 4. Appraisal issues included

	SMM **31 reports of total n=31**	**NOKC** **10 reports of total n=41**
	Number*	Number
Norwegian practice	24	4
Health economics	21	8
Medical ethics	13	9
Organisational issues	17	7
Legal implications	6	2

* Numbers may be more than one for each report

cal Control Authority, Regional hospital services, clinicians or the public.

SMM made no preferences as to which medical field would be of interest (Table 3). Six reports have been on prevention, four on diagnostics, two on screening, and the majority of 19 on effects of treatment. A wide range of subjects have been covered, including dental interventions (wisdom tooth extractions). The subjects have often been comparisons of different modes of treatment, e.g. in the report on ovarian cancer treatment where cytostatica and radiation therapy were compared. Another example is the report on palliative cancer surgery which covered treatment of symptoms and function within five surgical specialities.

One or more appraisal themes have been included for each report (Table 4). Twenty-four reports presented information on relevant Norwegian practice such as rate of PSA-tests for prostate cancer evaluation, and distribution among hospitals of specific kinds of surgery. Health economic analyses were included in 21 reports ranging from information on DRG, presenting simulation analyses and QALY-calculations in cost-utility analyses. SMM established a separate small unit for health economics to cover cost-effectiveness analysis. A discussion around ethical considerations was included in 13 reports. SMM had employed a specialist in medical ethics. Organisational issues were of interest for 17 reports such as ventilation and cleaning routines of operating theatres including a survey of current practice in major Norwegian hospitals (Segadal et al., 2001; Segadal et al., 2003). Legal implications were few and discussed in 6 reports only. One example was Gene therapy – status and potential in clinical medicine, where a short overview of how international regulations differ from Norwegian ones (Smeland et al., 2000). Comments and recommendations from the group of experts were presented for a simpler yet adequate legal process for study protocols and safety regulations on gene therapy in Norway.

Recommendations in the report included suggestions and need for further actions if seen necessary from the level of evidence available (Table 5).

The impact of the conclusions of the reports has in some instances been multiple (Table 6). Twelve of the 31 reports made, influenced national policy decisions such as the establishment of PET technology in Norway (Mørland, 2003b). Two national guidelines were altered. Distribution of duties was changed as a result of the reports such as treatment with PCI in myocardial infarctions (Wiseth, Gundersen, Halvorsen, Norderhaug, Steigen, & Myhre, 2002). Clinical guidelines were changed due to four reports. In three reports there was advised no change in practice and of 7 we had no info. One health economic report did not alter the introduction of a new kind of prescription (on physical activity), although the economic consequence did not support it.

Table 5. Distribution of suggested actions based on the conclusions of the literature assessments grouped according to medical practice/technology, actions, or new studies/more data required

	SMM	**NOKC**
	Number* of reports	**Number of reports**
I – Medical practice/technology	16	35
No change in current practice	4	2
New introduction	4	7
Change in current practice	1	0
Stop practice	4	0
Survey of current use		
II – Actions	0	1
New registry	5	1
Extend existing registry	3	10
Develop guidelines		
III – New studies/more data	2	13
New data of current use	14	29
Studies of higher evidence level	4	1
Introduction of new method as a scientific study		

* Numbers may be more than one for each report

Table 6. Areas of impact of conclusions were the results of the reports influenced the further development

	SMM	**NOKC**
	Number of reports	**Number of reports**
National practice	12	14
National guidelines	2	7
Distribution of duties	2	2
Clinical guidelines	4	6
National drug use (new unit at NOKC)	-	3
Report indicated no need for change current practice	3	3
No information of impact available	7	18
Advice in report not followed	1	5
In process	-	10

HTA Reports from NOKC

NOKC increased the number of completed HTA--reports using external reviewers from 8 in 2004 to 21 in 2007 totalling 60 over a four year period as a result of increasing number of staff and the consolidation of the new organisation (Table 2). Systematic reviews on organizational issues in the health service are excluded. The commissions have to a large extent changed from SMM to NOKC and many are now channelled through The Directorate for Health. An increasing number is coming from the regional hospital boards and this is encouraged. Few reports are initiated from other sources. A separate health economic analysis are becoming more important as part of the evidence base for policy decisions. As an example NOKC have made a separate health economic analysis in addition to three HTA-reports, on new technologies or drugs, and as evidence for a policy decisions on a possible start of a HPV-vaccination program in Norway (Neilson & Freiesleben, 2007).

Discussion

The reason behind the commissioning of these reports are multiple and varied. The aims have been to clarify areas of diverse opinions within the health service, establish the best knowledge available on certain issues in a world of a rapidly increasing flow of published medical articles, or make an overview and establish status of complex fields of treatment.

The relevance of the assessments is important for the implementation. The choice of themes was considered carefully. Points of consideration were that the process must not take too long time in order for the report not to be outdated. In some fields the development is fast and a revision of a report is necessary within a few years.

Implementation is also dependant on the professionals, the health authorities or the public finding the reports relevant to answer problem areas that were in need of clarification. The subject of the reports ought to address areas that are in due course for a change and for which it is possible to give a direction for change. When the problem concerns a lot of patients, there is a dispute among health professionals, treatment is costly, resources are scarce, introduction of new technology or facing out old none effective treatment, a systematic review of effect of treatment is called for. This is part of the foundation for getting acceptance for its results among health service employees, central administration and politicians. We have experienced that impact is greater among policy makers at the macro and meso levels rather than the micro level i.e. clinical level. They are also the main commissioners of HTA reports. More effort is needed to make an impact at the clinical level. This experience appears to be shared by the NHS HTA programme in UK. The impact of NHS HTA program in UK was assessed after 10 years (1993-2003) (Hanney, Buxton, Green, Coulson, & Raftery, 2007). They were interested in identifying which factors which were associated with HTA research that made an impact on health care policy and clinical practice. Four approaches were done. First a systematic literature review was made of research programs on impact. Secondly, the work of the National Coordinating Centre for Health Technology Assessment (NCCHTA) was reviewed, lead researchers were surveyed, and 16 detailed case studies were undertaken. They conclude that the HTA program had considerable impact in terms of knowledge generation and perceived impact on policy and to some extent practice. They believe that the programs objective and relevance to NHS and policy customers may partly explain the high impact. The strict scientific methodology and peer review may also be a contributing factor. They suggest health research impact studies in an ongoing manner to be valuable.

One aim of our study was also to look into the consequence of the change in different organizational structures of SMM and NOKC after the reorganization. Combining information from Tables 4, 5, and 6, we see there are differences in including the appraisal issues in the reports. NOKC often get the tasks from commissioners using the assessments and implement them into guidelines. They will, as a consequence, often do the appraisal themselves.

SMM as well as NOKC have, however, put an increasing emphasis on health economic issues as this perspective concerns the importance of the best use of resources in the health service. There is after all a limited amount of economic resources and they ought to be spent in a manner to the best of all. An evaluation of new and established treatment modalities is important in order to achieve the best level of quality in the health service without excessive spending of money on non efficient treatment.

The acceptance and implementation of the results of these HTA-reports into new policies, new guidelines or change in clinical practice are dependent on the receivers of the reports finding them useful. It was not observed a difference in implementation with time. The publication strategy has most likely been adequate throughout this period in order to reach the most relevant persons and groups that are interested in the subject and were in a position to make the necessary alterations. The reports have had a certain news interest when they have been first published and they exerted their impact most likely within the first six month after publication.

Conclusion

The reports have had an impact on the use of medical technologies on national and professional level. The implementation of the results was not found to be dependent on the commissioner being external or internal during the SMM period. The commissioning changed to Directorate of Health and Social Affairs from The Department of Health. The number of appraisal themes and reports including these dropped when NOKC was established. This can be seen as a result of large expectations to the newly formed unit that had to deliver faster to the authorities. SMM also generated ideas for these reports which were often channelled from the hospital area or direct contact with other commissioners. The degree of implementation of the results of the report did not appear to change during the period.

EUROPEAN DEVELOPMENT OF A SUSTAINABLE NETWORK ON HTA

The European Commission (EC) and the Council of Ministers in 2004 recognized the need for establishing a sustainable and effective European network of HTA (Christofides et al., 2006). It is an open network connecting agencies with each other and developing necessary tools and a common information technology communication platform to facilitate cross-border collaboration aimed to inform policy decisions on the use of health technologies at the national or regional level. The expressed aim was to improve the coordination among the HTA organizations further, reduce duplication of work, save time, and resources. In short, the three year project was launched in 2006 called European Network for Health Technology Assessment (EUnetHTA) co-funded by an EU grant which will prepare for establishing a permanent network as from 2009 (http://www.eunethta.net/). The aims of the network are to reduce duplication of work by HTA institutions, for instance by establishing a system for producing and sharing core HTA information, support the establishing of new HTA organizations and other important activities. The project is structured around the eight work packages (WP) that were established to develop the different tasks and functions needed for the future network and for coordinating the project. It has a steering committee, an executive committee, and a secretariat. A total of 63 HTA institutions and organisations are working with evidence based medicine from Europe or overseas have joined EUnetHTA. They are preparing to share scientific evidence and methodological frameworks.

European agencies taking an active part and receive funding are termed associated partners (AP). Other partners are termed collaborative partners (CP). The partners have chosen which work packages they want to take part in. There were no limitations as to the number of partners in any work package. Each WP has one or two lead partners. The eight WPs have distinct tasks. WP 1 is the executive committee (EC) where the eight work package leaders are main members. The lead partner DACEHTA, Denmark, holds the Secretariat and has the administrative responsibility for the project. WP2 has two strands. One strand develops the web-communication and all aspects related to developing the extra- and intranet for the EUnetHTA. The other strand develops a clearinghouse functionality which is a central

Table 7. Overview of some relevant databases that can be used in the systematic search for information. The databases have different contents in addition to journal publications such as books, technical reports, annual reports, conference reports, master theses, PhD dissertations and/or other information. Not all databases can be used free of charge.

Database	Content
African Index Medicus http://indexmedicus.afro.who.int/	Medicine and other health issues.
INFO http://www.cpa.org.uk/ageinfo/ageinfo2.html	*Health and welfare of older people.*
AGELINE http://research.aarp.org/ageline/home.html	Gerontologi
AIDSinfo http://www.aidsinfo.nih.gov/	Treatment and prevention on HIV/AIDS, including vaccination and drugs.
AMED **(Allied & Complimentary Medicine)** http://library.nhs.uk/help/resource/amed	Complementary medicine
ASSIA **(Applied Social Sciences Index and Abstracts)** http://www.csa.com/factsheets/assia-set-c.php	Social science database
BIOMED CENTRAL http://www.biomedcentral.com/home/	Medicine and health related research
The Campbell Library http://www.campbellcollaboration.org/	Social sciences database
CCMed **(Current Contents Medicine)** http://opac.zbmed.de/wocccmed/start.do	Medicine and health related research
CDSR **(Cochrane Database of Systematic Reviews)** www.thecochranelibrary.com	Systematic reviews produced by the international Cochrane Collaboration
CENTRAL **(Cochrane Central Register of Controlled Trials)** www.thecochranelibrary.com	*Cochrane Collaborations register over controlled studies*
CINAHL **(Cumulative Index to Nursing and Allied Health)** http://www.ebscohost.com/cinahl/	Nursing
Clinical Evidence http://www.clinicalevidence.com/ceweb/conditions/index.jsp	Effect and side-effects of treatment controlled
Cochrane Library www.thecochranelibrary.com	Medicine and health related research including research methods for systematic reviews and randomized trials
DARE **(Database of Reviews of Reviews of Effects)** http://www.york.ac.uk/inst/crd/crddatabases.htm	Database of evidence based systematic review and HTAs
EED (Economic Evaluation Database). http://www.york.ac.uk/inst/crd/crddatabases.htm	Health economy
EMBASE **(Excerpta Medica)** http://www.embase.com	Medicine and health related database
HERBMED www.herbmed.org/about.asp	Herbal medicine
HTA (Health Technology Database) http://www.york.ac.uk/inst/crd/crddatabases.htm	Database of health technology assessments
International Bibliography of the Social Sciences http://web5s.silverplatter.com/webspirs/start.ws	Social science database
INDMED http://www.indmed.nic.in/	Indian database on medicine and health related issues
ISI Web of Knowledge **http://isiwebofknowledge.com**	Citation database over a wide range of subjects

Continued on following page

Table 7. Continued

Database	Content
KOREAMED http://www.koreamed.org/SearchBasic.php	Korean medical database
LILACS **(Latin American & Caribbean Health Sciences Literature)** http://bases.bvsalud.org/public/scripts/php/page_show_main.php?home=true&lang=en&form=simple	Scientific journals on medicine and health related issues
MEDLINE http://www.cbi.nlm.nih.gov/numed	The worlds largest database on medicine and health related issues
MIDIRS **(Midwives Information and Resource Service)** http://www.midirs.org/midirs/midmem1.nsf?opendatabase&login=1	Pregnancy and midwifery
NORART **(Norske og nordiske tidsskriftartikler)** http://www.nb.no/baser/norart/	Database of Nordic journal publications
HEED **(Health Economic Evaluations Database)** http://www3.interscience.wiley.com/cgi-bin/mrwhome/114130635/HOME?CRETRY=1&SRETRY=0	Database on health economy
OLD-MEDLINE http://www.ncbi.nlm.nih.gov/pubmed	Database of publications before 1966
PEDRO **(Physiotherapy Evidence Database)** http://www.pedro.fhs.usyd.edu.au/index.html	Physiotherapy and related subjects
PRE-MEDLINE http://www.ncbi.nlm.nih.gov/pubmed	Publications in process of being registered
PSYCINFO http://www.apa.org/psycinfo	Psychology and related subjects
Social Care Online http://www.scie-socialcareonline.org.uk/	Database on social care
Social Services Abstracts http://www.csa1.co.uk/	Database on social services
Sociological Abstracts http://www.csa1.co.uk/	Database on sosiology and related subjects
SPORT Discus http://www.sirc.ca/products/sportdiscus.cfm	Database on sports and related subjects
SWEMED http://micr.kib.ki.se/	Scandinavian database on medicine and health related subjects

information hub in the network of agencies and that will facilitate knowledge transfer and sharing within EUnetHTA. WP3 concerns the continuing internal evaluation of the project which was a prerequisite from the EU. The evaluation collects information through yearly Participant surveys and five monthly WP-leader interviews. The other five WPs each develop essential deliverables making common grounds for the work in HTA agencies in Europe and increase the interchange of knowledge for producing HTA reports. WP4 has developed the HTA core model which is a tool for comprehensive analysis of the elements to be included in an HTA-report that can be adapted to different countries. Core HTA information has been developed and is being piloted on one medical device and one diagnostic technology. WP5 makes the adaptation tool kit to assist HTA agencies to adapt HTA reports from other countries or settings than their own. WP 6 works on the information process towards health authorities and stakeholders by producing a textbook and organizing a stakeholder forum on the EUnetHTA extranet and arranging a stakeholder meeting. WP7 develops the program for searching for new technologies and for making a newsletter on these technologies. WP8 is producing a handbook on the development of an HTA agency and curriculum proposal for training in HTA work to assist in the establishment of new HTA agencies. These WPs have varying numbers of AP and CP members. Altogether there are 27 countries, 24 EU-members and 3 EEA members, and a number of organizations now collaborate in EUnetHTA.

EUnetHTA holds a vision of contributing to the generation of HTA reports to inform policy and health care decision makers in Member States in order to bring about high quality, safe, accessible and efficient health care for citizens across Europe. HTA agencies hold the value of transparency in their work processes and the sharing of information. Their products shall be based on best scientific evidence in a common methodological work process. The collaboration so far has been successful and the project is heading for a transition period towards the established network. (See Table 7)

CONCLUDING REMARKS

Health technology assessments are being in demand by the health authorities, health decision makers, health workers, and the public. Best scientific evidence as basis for decision making is important. The additional evaluation of the consequences for the health service regarding health economics, ethical, legal, professional, and organisational aspects strengthens the foundation for decisions to be taken in our common search for the best use of health resources. The use of information technology management in this work is essential and totally integrated in this work. It is information technology that allows for most importantly the retrieval of the scientific information by literature searches in relevant databases, assembling the information into reports, and communication between collaborating partners.

REFERENCES

Banta, H. B., & Luce, B. R. (1993). *Healthcare technology and its assessment: An international perspective*. Oxford, UK: Oxford University Press.

Chalmers, I., & Altman, D. G. (1995). *Systematic review*. London: BMJ Publishing Group.

Christofides, S., Kristensen, F., Chamova, J., Rehnqvist, N., Allgurin-Neikter, S., Lund Haheim, L., et al. (2006). The European network for health technology assessment–EUnetHTA. In J. Nagel & R. Magjarevic (Eds.), *World Congress on Medical Physics and Biomedical Engineering 2006,* (Vol. 14, pp. 3586-3589). *Incorporating the 21st International Conference on Medical and Biological Engineering and the 15th International Conference on Medical Physics. IFMBE Procedings*.

Egger, M., Smith, G. D., & Altman, D. G. (2001). *Systematic reviews in healthcare: Meta-analysis in context*. London: BMJ Publishing Group.

Hailey, D., & Menon, D. (1999). A short history of INAHTA. *International Journal of Technology Assessment in Health Care*, *15*, 236–242. doi:10.1017/S0266462399015342

Hanney, S., Buxton, M., Green, C., Coulson, D., & Raftery, J. (2007). An assessment of the impact of the NHS health technology assessment programme. *Health Technol Assess, II*(53). Health Technology Assessment. *An introduction*. In Norwegian. Retrieved from www.kunnskapssenteret.no/smm

Jonsson, E. (2002). Development of health technology assessment in Europe. A personal perspective. *International Journal of Technology Assessment in Health Care*, *2*, 171–183.

Jonsson, E., Banta, H. D., Henshall, C., & Sampietro-Colom, L. (2002). Summary report of the ECHTA/ECAHI project. European collaboration for health technology assessment/assessment of health interventions. *International Journal of Technology Assessment in Health Care*, *2*, 218–237.

Lund Håheim, L., & Mørland, B. (2003). Health technology assessment–a systematic approach for evaluation of the scientific documentation of medical technologies. In Norwegian. *Norsk Epidemiologi, 13*, 309-314.

Lund Håheim, L., & Mørland, B. Implementation of recommendations from 31 Norwegian health technology assessment reports. *Poster: 9th Biannual Meeting of the European Society for Medical Decision Meeting (ESMDM)*, Rotterdam, Nederland.

Mørland, B. (2003a). Experiences form 5 years of health technology assessment in Norway. [In Norwegian]. *Tidsskrift for Den Norske Laegeforening*, *123*, 1213–1215.

Mørland, B. (2003b). *Positron emission tomography (PET)-diagnostic and clinical use. SMM report no. 6/2003*. Oslo: The Norwegian Centre for Health Technology Assessment. Retrieved from http://www.kunnskapssenteret.no/filer/Rapport6-03.pdf

Neilson, A. R., & Freiesleben, D. B. (2007). *Cost-effectiveness of human papillomavirus (HPV) vaccination in Norway. In Norwegian. Report no 12–2007. Health economic model*. Oslo, Norway: Norwegian Knowledge Centre for the Health Service. Retrieved from http://www.kunnskapssenteret.no/filer/rapport_0712_HPVdel2.pdf

NHS Centre for Reviews and Dissemination. (2001, March). *Undertaking systematic reviews of research on effectiveness. CRDs guidance for those carrying out or commissioning reviews.* CRD Report Number 4 (2nd Edition). UK: University of York.

Nordsletten, L., Havelin, L. I., Indrekvam, K., Aamodt, A., Utvåg, S. E., & Hviding, K. (2002). *Choice of primary hip replacement prosthesis. SMM report no. 6/2002*. Oslo: The Norwegian Centre for Health Technology Assessment. Retrieved from http://www.kunnskapssenteret.no/filer/Rapport6-02.pdf

Segadal, L., Andersen, B. M., Haugsbø, A., Hotvedt, R., Jacobsen, T., Kristiansen, I. S., et al. (2001). *Ventilation of operating theatres. In Norwegian. SMM report no. 5/2001*. Oslo: The Norwegian Centre for Health Technology Assessment. Retrieved from http://www.kunnskapssenteret.no/filer/Rapport5-01.pdf

Segadal, L., Andersen, B. M., Haugsbø, A., Hotvedt, R., Jacobsen, T., Kristiansen, I. S., et al. (2003). *Cleaning of operating theatres. In Norwegian. SMM report no. 9/2003*. Oslo: The Norwegian Centre for Health Technology Assessment. Retrieved from http://www.kunnskapssenteret.no/filer/Rapport9-03.pdf

Smeland, E., Prydz, H., Ørstavik, K. H., Frøland, J., Aamdal, S., Myklebost, O., et al. (2000). *Gene therapy–current status and possibilities in clinical medicine. SMM report no. 1/2000*. Oslo: The Norwegian Centre for Health Technology Assessment. Retrieved from http://www.kunnskapssenteret.no/filer/Rapport7-00.pdf

Wiseth, R., Gundersen, T., Halvorsen, S., Norderhaug, J. E., Steigen, T., & Myhre, K. I. (2002). *PCI treatment in acute infarction. In Norwegian. SMM report no. 5/2002*. Oslo: The Norwegian Centre for Health Technology Assessment. Retrieved from http://www.kunnskapssenteret.no/filer/Rapport5-02.pdf

ENDNOTE

[1] www.inahta.org

This work was previously published in Handbook of Research on Information Technology Management and Clinical Data Administration in Healthcare, edited by A. Dwivedi, pp. 746-762, copyright 2009 by Medical Information Science Reference (an imprint of IGI Global).

Chapter 1.4

Researching Health Service Information Systems Development

Said Shahtahmasebi
The Good Life Research Centre Trust, New Zealand

ABSTRACT

Information is considered the currency within health systems. Numerous reorganisations and restructuring, coupled with many buzz words (e.g. evidence-based practice) and the various advancements in ICT (information and communication technology) are apparently designed to improve the utilisation of this currency. However, what constitutes information appears to vary between health professionals. For some, only the data derived from RCTs (randomized control trials) is considered evidence, for others it is the conclusions drawn from focus groups, whilst for others, finding information goes well beyond subjectivity and experimental design and comes from understanding human behaviour and other processes. Although advancements in ICT have greatly improved access to information (currency), the data often disguised as information appears only as small change. Restructuring and reorganizing have been used to inflate the value of this currency (information) leading to the replacement of information departments by the Public Health Intelligence Units or Observatories. However, a change in behaviour is difficult to bring about and manage, while it is easier to change the tools with which the tasks are carried out. It is all too easy to fall into the trap of reproducing what has been produced before by information departments only under a different guise, as well as using different configurations, software or updated hardware and ICT (e.g. the Internet). These units hardly concern themselves with exploring the underlying message of the data. A quick trawl of the web pages of these entities can be testimony to this fact. The process so far has been, in effect, one of test-tubing health outcomes and then extracting the data from the test tubes. Although we have been eager to embrace technological advancements and change, we have failed to monitor the impact and consequences of change on our behaviour and thus on health outcomes. This chapter will delve into the current availability of information for public health policy purposes and will argue its ineffectiveness as information/evidence in the context of human behaviour and social processes. Behaviour and processes are by nature dynamic. Specifically, the feedback effect, a feature of dynamic process, can have a profound attenuating effect on data that

DOI: 10.4018/978-1-60566-356-2.ch037

was once important, thereby affecting not only the shelf life of a policy but also its intended outcomes. Examples from published reports by public health intelligence units/observatories in New Zealand and the UK, plus references to teenage smoking and suicide, will be used to illustrate these concepts and issues. A conceptual but pragmatic model of data collection based on current health care data management systems will be argued as a way forward for translating data into information and tangible evidence with a view to informing the process of public health policy formation. This chapter discusses a holistic approach to identifying data needed as evidence to inform the process of policy formation/decision making as a conceptual model.

INTRODUCTION

The central issue in information technology (IT) and its management is information itself, for without it, decision making and policy formation would have had to follow a different process. However, with the advancement in technology and the development of social, health and political models, we may have spent more resources on the relationship between technology and access to information than on how information and technology may be utilised to inform the process of decision making more effectively and efficiently.

In the health service sector, IT management has been focused on using the technology to manage health data primarily to develop information systems that cater for the storage of data without hindering access to it. Within the health service, this line of approach may be limiting by unwittingly reinforcing the assumption that the development of an information system is specific to the task under study. Therefore, by allowing market forces to dictate to the management of the health service sector, there will naturally be competing models of IT management which in turn will lead to different IT models operating different sections of the same organisation, for example, variation in IT models between and within GPs, hospitals, and private health service providers.

In recent decades we have witnessed rapid advancements in technology which may have contributed to improvements in ICT (information and communication technology) such as faster communication and data transfer devices, smaller but faster storage devices with large storage space e.g. hard disks, and database software. However, to some extent the advancement in ICT may have encouraged a move to develop models to improve inter-agency access to data. Certainly, using the latest database package and appropriate hardware, technology data from various sources can be uploaded, stored and retrieved centrally.

Although IT management involves adopting models that utilise various tools including hardware and software to improve the collection, storage and access/retrieval of data, too much emphasis on the technology and access to data may have helped to shift the focus away from the actual data itself. The health service sector generates huge volumes of data, including morbidity and mortality outcomes. However, social and lifestyle information is often collected separately as part of projects with specific aims and objectives. In the UK, hospital records were expanded to include the routine collection of data on social class. In the early 1990s attempts to utilise these pieces of information with other health outcomes proved ineffective as social class had only been collected for a handful of patients' records.

Indeed, in order to include socio-economic data in the analysis of health outcomes, the Analysis Unit in the former Yorkshire Regional Health Authority (UK) using a multi-method approach, utilised a mix of databases from various sources (Bensley et al 1994, also see Shahtahmasebi 1997, 1999, 2001). The process of preparing, analysing and presenting the information involved extracting health and census data from various sources into a readable format and preparing and matching census based socio-economic data with health records for use with statistical, graphics and mapping packages. The project design appeared fairly routine because theoretically all the necessary data was available and the only main issue was to match different data from various sources. Dealing with different types of data from different sources is not always straightforward. By using today's technology, parts of the project may be considered routine as most statistical packages, in addition to statistical analysis, are capable of sophisticated graphics and mapping analysis.

There are two questions that immediately come to mind: fourteen years on, can we expect to see census based socio-economic data along with health outcome data from various sources in one database? And why, in the era of advanced ICT, do we have to rely on creative methodologies to generate proxy data for socio-economic and lifestyle using routinely collected data?

BACKGROUND

Like any other business, the health sector relies heavily on information for its operations; from a government's fund allocation to the distribution of resources, to health care service development and interventional programmes. Morbidity and mortality statistics have been used for these purposes. Given that geographical regions may vary in health care needs, clearly more information about each region than just the numbers in each health outcome are necessary. And if health care planning and resource allocation were to be proportional to the size of the population, then a population-based comparison of health care needs between geographical regions based on mortality and morbidity statistics is also essential.

Population-based standardisation also enables comparison of prevalent trends of given health outcomes between predefined areas within and between regions. Data items such as age, sex, post code, diagnosis, and mortality cause have been routinely collected and are available through patients' records.

However, as health care systems have became more and more complex, in order to respond to all the ill-health needs of its population, a few began to equate resources with rising demand and inequalities in health. The fable of the physician on the river bank may describe the problem more clearly, retold by (McKinlay 1975), though attributed by him to Irving Zola:

> *"You know", he said, "sometimes it feels like this. There I am standing by the shore of a swiftly flowing river and I hear the cry of a drowning man. So I jump into the river, put my arms around him, pull him to the shore and apply artificial respiration. Just when he begins to breathe, there is another cry for help. So I jump into the river, reach him, pull him to shore, apply artificial respiration, and then just as he begins to breathe, another cry for help. So back in the river again, reaching, pulling, applying, breathing and then another yell. Again and again, without end, goes the sequence. You know, I am so busy jumping in, pulling them to shore, applying artificial respiration, that I have no time to see who the hell is upstream pushing them all in."*

Thunhurst (1982) argued that we have spent too long measuring the flow of the river, the size of the fishing nets and the rate at which people are brought to shore. Health statisticians and health professionals need to refocus, Thunhurst argues, to investigate the largely unmapped terrain upstream, particularly in solving the problem of differential class experiences of health.

In an earlier paper, Shahtahmasebi (2006) argued that despite the attempts to research and map upstream, the health services still rely heavily on downstream research, thus building up information systems consisting of data collected after the event i.e. an occurrence of ill-health which necessitated a consultation with a health service professional.

The principle of collecting information on morbidity and mortality as and when they present themselves in order to cater for the health needs of the population will lead to, or has inevitably led to, a reactionary health care system. Assuming that there are no other constraints such as budgetary resources or otherwise, the system would be as good as the fable of the physician on the river bank. In other words, the health care system would be reacting to cries of help from people in need of being saved.

There is no doubt that mortality and morbidity data are essential to help with the planning and distribution of resources to deliver health care. However, without interrogating these data and asking the question "why", the health care system remains ignorant of disease development and in particular how the health care system could have been more effective in preventing an outcome.

Today's health care systems are far too big and complex, and governments around the world spend huge sums of money maintaining a health care system. In the short term, maintaining is often all that can be done. Due to the dynamics of public health, the feedback effect (i.e. the more demand, the more need for maintenance) will lead to a costly future maintenance of the same system as health care systems will continue to be stretched. Thus the fable of the physician on the river bank comes to life. This feedback effect gives rise to additional complexities which will then confound the feedback effect. The need to react to the ever increasing downstream events means that health care systems appear to drain more resources and thus there is a great urgency to maintain at least the current level of care services making it more difficult to justify spending sufficient resources to investigate upstream events. Research and Development (R&D) funding and evidence-based decision making is often restricted to RCTs of specific treatments or to bring about a change in providing care (i.e. method of delivery of care). The urge to continue to react to ill-health is also fuelled by incompatible upstream research, often considered academic and thus separate from the everyday operation and decision making of the health care system.

The problem with relying on separate study design type research to investigate upstream is an inherent inability to generalise the results and relate them back to the population. This inconclusiveness fuels further the urgency to rely on "available" information to plan and maintain a reactive health care system. For example, within the suicide literature, despite the large volume of work, criticisms have been aired that our knowledge of suicide is based on scant scientific evidence (De Leo 2002, Institute of Medicine 2002,Cutcliffe 2003). The study design and the quality of data have been cited as being responsible for the ambiguities in the evidence. One of the consequences of accepting this relationship to explain suicide is to concentrate on building a case that would associate the suicide case with mental illness. And given the public mindset, it would be only too easy to suggest a link to mental illness after the event. For example, in suicide research Beautrais (1994, 2001, 1996) claims that depression and mental illness are the cause of suicide, Khan et al (2000) claim that antidepressants do not reduce suicide and may increase the risk of suicide while Hall et al (2003) claim that antidepressants reduce suicide rates. The latter study compared the first point in the time series with the last point which happened to be lower than the first point and did not make much of the upward trend of suicide rates in between. Suicide data, in particular those based on psychological autopsy type investigations such as Beautrais (1994, 2001, 1996), are often plagued with a high degree of bias and the confounding and compounding of random effects with the structural error such as error-in-variables. Given the current public mindset, helped by the medical model and the media, namely that depression causes suicide, the collection of data on suicide cases after the event from friends and relatives will be highly biased towards mental ill-health as in the Canterbury Suicide Project (Beautrais

1994, 2001, 1996). These studies have failed to address the methodological issues related to design, data collection and analysis thus resulting in misleading conclusions. *Uncritical* use of this type of information as evidence to inform practice will lead to a disparity in service development and delivery. While some practitioners will adapt, only a few may exercise caution. For example, the NZ Medical Journal claims depression is a common, serious and significant illness and links it to suicide and recommends medication [http://www.nzma.org.nz/journal/117-1206/1200/]. It is not surprising to hear that young people have been prescribed antidepressants including preschool children. But more alarming is the prescribing of antidepressants to some children under a year old [http://www.nzherald.co.nz/section/1/story.cfm?c_id=1&objectid=10462684]. It seems arguable, therefore that, if discovered early enough, suicide is commonly treated as depression regardless of the circumstances (also see Shahtahmasebi 2008).

It is this ambiguity in the literature, possibly due to poor study design, inappropriate methodology and inadequate statistical and analytical methods (e.g. see Shahtahmasebi 2006, 2007a), that encourages an elective approach to decision-making where decisions are made subjectively and the evidence to support them is sought after policy implementation (also see Short 1997). There is also ample anecdotal evidence to suggest that such an elective modeling approach encourages policies that artificially tackle an outcome i.e. in effect manipulating outcome(s) rather than attending to the associated parameters.

We must not confuse the advancements in technology with the progress made in understanding health and public health care delivery. All the progress we have made in keeping patients alive longer through past medical and technological research has been uni-directional with only one aim; to intervene. Even the current resources allocated to genetic research have only one aim, namely to intervene. Although on the one hand we appear to be making advances at a faster and faster pace, on the other hand, it feels as though that we have given up; that we are unable to improve ourselves further by understanding health so we attempt to intervene physically by changing our biological code in the hope of affecting change.

THE CONCEPT AND METHODOLOGY BEHIND THIS CHAPTER

If information is indeed the main currency in health service development and delivery, it is only reasonable to study the flow of information and its quality, relevance and appropriateness. In particular, given the resources dedicated to the utilisation of IT within the health industry to improve access to information for the main reason of practicing "evidence based" decision making. To do this, I have adopted a pragmatic approach of briefly exploring how easily a task carried out in the early 1990s could be carried out today. It is assumed that the reader is familiar with the technological progress both in hardware and software, as well as the culture within the health service, in particular towards internet technology and emails since 1990.

In this context, this chapter is a discussion paper on the relationship between technological advancements and evidence-based practice which has led to the creation of "intelligence" units and public health "observatories". In other words, how the technological advancement has been utilised within the health sector to improve information and thus access to data.

A pragmatic approach was adopted to explore the internet for public health data. It soon became clear that new entities purporting as "intelligence" units and "observatories" have become the middle men of 'data' in the health sector. To get some idea as to what "intelligence" refer to, an internet search and scan of selected web pages was carried out. Subsequently, a conceptual model that may help understand the nature of information that may be required as evidence is also discussed.

An important point of this chapter is to ask "how is the advancement in technology being utilized, and whether the utilisation of technology has shifted focus away from the value of data as information?"

The reader may be feeling, quite rightly, bewildered, firstly, that all the progress we have made may appear to be still "downstream" and secondly, how this lack of progress may be related to information and ICT. Let us consider two aspects of information, the flow of information and "information" itself.

FLOW OF INFORMATION

As mentioned in the introduction, the 1994 Public Health Directorate's Annual Report (Bensley et al 1994) was an attempt to explore morbidity and mortality data in the light of social circumstances and geographical area of residence. To achieve this, project data from mortality data sets, hospital records, census, population, digital road maps and geographical boundaries and other additional data had to be extracted from different databases. Furthermore, in addition to the census based deprivation scores, as proxy for social class and lifestyle, individuals were associated with the profile of their area of residence. The idea was that since postcodes were consistently collected for most patients, this data item could be used to link the various data.

In theory, and indeed on paper, the methodology appears easy enough. However, in 1994 it was not merely a case of pressing a few buttons and creating a database of your choice. Each set of data items was received from a different source. One can imagine the number of information departments, officers and data analysts that were necessary to liaise with in order to obtain the data, not to mention the man-hours spent purely on data administration and recovery and the cost of purchasing data. To perform the various tasks involved in the analysis and presentation, a number of software packages were used from the humble spreadsheet to statistical, graphics and mapping packages. Obviously, these computer packages could not directly communicate with each other and the results from one package, e.g. the statistical analysis, output had to be in ASCII and then imported into a spreadsheet to be read by another, e.g. the mapping package.

Although meeting the challenges of utilising different datasets can be exciting and satisfying, the question was raised yet again: why are health data from the same organization in different sources some of which are incompatible with each other? Indeed, this was raised in the meeting of the steering group on the 'Health of the Nation's targets on Mental Health' and was adopted as one of the main guidelines on data collection (Yorkshire Regional Health Authority, May 1993 pp12). The guideline prescribed that the health service commissioners develop a *unified* database by 1994 with particular reference to suicide.

It is fairly obvious that health services operate with a number of professions from medical personnel to managers and PAMs (professions allied to medicine). Although information is important in health care delivery, yet, medical training conditions students in all disciplines about a more important item: a doctor's/consultant's time. In their training, medical students are taught to be concise and brief in their presentation of a patient's case, whereas they should be taught a *critical* assessment of all the information about a patient's case. In training the students to observe facts, the system inadvertently conditions the dynamics of disease development out of the training. Thus, it may lead to a pattern of care that treats the symptoms as opposed to the cause. For example consider the treatment of suicide as mentioned above.

The application of IT within the health industry to improve access to information began with replacing the paper trail. However, while the design and implementation of IT systems were broadly based on the paper trail, computerised systems made access easier and quicker. This means that only some aspects of IT (storage, faster access and retrieval) have been taken advantage of as the same information is simply transferred from paper to disk whether it is a GP service, hospital/Trust, district or area health authority and so on. From an epidemiological view point, this transition may have sped up and overcome some of the obstacles of the past to produce aggregate measures of health outcomes. For example, relevant information departments may have set up databases containing mortality or morbidity (hospital records) and appropriate population files on the main server available to be queried through the organisation's network. There is still no sign or a hint of a unified database.

Even without a unified database, given that most existing records and data in the health sector are available electronically, IT has had a large impact on access time. It all sounds very good, in particular when compared with the experiences of a decade ago in trying to utilise different health outcomes data. Nevertheless, it appears that these achievements have been really a remold of the past into a different medium i.e. faster access to the same data. In other words, the technology has been under-utilised to improve the communication and flow of information between the various sections of the health industry e.g. giving clinicians access to patients' health and health related records, and vice versa.

INFORMATION

Whether or not the flow of information is reasonably satisfactory, our main concern must be the nature and type of information. Currently, routine health/demographic/epidemiological data collection appears to be resource management oriented. It is absolutely essential to investigate trends in mortality and morbidity by cause, age and sex, just as it is also necessary to understand the underlying and causal relationships between the various processes and health outcomes. Therefore, collecting upstream data or information becomes a critical part of the health care service development and delivery. As will be discussed in the next section, this is more easily said than done.

One major aspect is deciding what constitutes appropriate information, while another is what constitutes the appropriate dissemination of information. A common perception of the medical profession is that it operates with knowledge and trust. Therefore, why should the public not listen to, and act on, their advice? For the most part, the flow of information is considered separately and in isolation in developing health care services. What we often choose to ignore is that there are other agents who wish to get the public's attention. With the advancement in information technology, competition has become intense to reach not only more people but those who were previously difficult to reach. Thus what was once an information superhighway has become part of an elaborate industry that includes a whole collection of competing media to provide public access to information e.g. the Internet, television and the entertainment industry, radio, newspapers, popular and tabloid magazines, multi-media, voluntary and government agencies. Therefore there are competing forces seeking more of our attention. For example, the effects, if any, of antismoking campaigns may be counteracted by the covert pro-smoking campaigns through the media and the entertainment industry e.g. see (Gilpin et al. 2007; Shelley et al 2007; Ibrahim & Glantz 2007; Healton et al 2006; Peters et al 2006). Yet, through the information industry, the expectation that "the cure" is only around the corner has become the public norm. The public have become well aware of the advancements in medical science. The idea of the fountain of youth or the magic pill may well relate to man's wish to fulfill his heart's desire without worrying about responsibility and the consequences. In particular, this leads to the presumption that it may not be long before cancers, heart disease and respiratory and other health problems can be treated, thus, making smoking (or other risky behaviour) safe. In the meantime, transplantation has become quite routine and therefore is a viable option. Although superficially "the public's right to information" may be used to disseminate information, the consequences could be adverse, from the expectation of a magic pill, to the Hawthorn effect, to apathy, to the ineffectiveness of science and confusion in setting health care goals. Once again the BBC provides the examples: "Children could get 'diet pills': Children as young as 12 could be given anti-obesity drugs to help them shed excess weight (http://news.bbc.co.uk/go/em/-/1/hi/health/4130992.stm)"; "Many 'imagine' food intolerance: Millions of people in the UK have self-diagnosed a food intolerance and may be cutting out essential foods as a result, a survey suggests (http://news.bbc.co.uk/go/em/-1/hi/health/7000291.stm)"; "Media 'sensationalising science': 'Irresponsible' science reporting undermines public confidence in science and government, a report says (http://news.bbc.co.uk/go/em/-/1/hi/sci/tech/4771154.stm)"; "Sun warnings confuse the majority: Many people are confused by weather warnings designed to help them reduce their risk of developing skin cancer, research shows (http://news.bbc.co.uk/go/em/-/1/hi/health/4566627.stm). There are many other agencies and products using a whole array of information technology to attract the public's attention. The hasty reporting of research results and the media's slant and trivialization of claims and counter claims to the public's amusement could have eroded public sensitivity to the critical receptiveness of information. We do not know how this increased insensitivity affects behaviour. For example, consider the development of organ transplant from its early days to it becoming routine practice. Yet in order for some to live another group must die. And what do we know of the effects of calls by officials such as "everyone should become donors" (BBC 2007) on public expectations and behaviour?

Due to the dynamics of human behaviour, it may not matter how much morbidity and mortality data is made available in a clinical database, for at the end of the day clinicians have to treat the same symptoms over and over again. Individuals are queuing to lie on the operating table. All that clinicians may infer from these activities is a probabilistic association between certain individual characteristics with aspects of ill-health or a disease cross-sectionally or retrospectively. Even threats of refusing care to individuals who knowingly engage in risky behaviour such as smoking has been ineffective.

Thus, temporal dependencies may be understood through exposure, feedback, individual and social behaviour (see Shahtahmasebi 2007a).

DYNAMICS OF INFORMATION SYSTEMS

Information relates to its source and is only good if the dynamics of the source are taken into account. For example, despite advanced statistical techniques and an understanding of the seasonality and cyclic effects, trend analysis will provide some idea of change in the population proportions but we still have to rely on specific epidemiological or other health related studies to gain insight into the disease development process. However, our gained insight is continuously subjected to question due to the conflicting outcomes as discussed earlier (also see Shahtahmasebi 2008). It is not surprising that we may ask the question "how much of our knowledge is actually real insight?" It is therefore of great concern that health and social policies have been developed on our perception of knowledge, without attention to the feedback effect, researchers, policy makers and policies are now part of the problem and not the solution (Shahtahmasebi 2006, 2007a, 2008).

Although, health outcomes are collected at the point of delivery of care, be it a GP consultation or clinical, these are related to the source; individuals whose pattern of behaviour is influenced by processes such as their own characteristic, their social environment and external processes such as the environment. Thus, making human behaviour a dynamic process.

Indeed, the creation of Public Health Intelligence Units (PHIU) and Public Health Observatories (PHO) may be used as a testimony to the recognition of the importance of the above issue. Accordingly, an understanding of the dynamics of the health process is essential if service development to be based on evidence. Furthermore, in recent years, most health sector vacancies in the field of statistics, information, epidemiology or similar jobs appear to promote an understanding between data/information and policy development and can be summarized as follows:

The work is interesting and varied, involving providing statistical advice and analysis for the purpose of developing policies and strategies in support of ... responsible for large-scale data collection and maintain our own and other large datasets, which we use to produce and develop management information, performance indicators and other publications ...

However, it can be noticed from the second part of the above job description that the slant soon changes to a management "culture" of information such as an emphasis on performance indicators and management information which contradicts the first part of developing policies and strategies. To develop policies, information must be able to inform the process of policy development.

The PHIU and PHO boast a multi-disciplinary group of epidemiologists, statisticians, geographers and social scientists to provide intelligence/information which informs health care service planning. For example, the East Midland PHO (UK) is described as one of the nine observatories funded by the Department of Health to strengthen the availability and use of health information at local level (http://www.empho.org.uk/). Similarly, the PHIU in New Zealand boasts a multidisciplinary team of experts in their own fields that make up the PHIU and provide links to a volume of reports and resources such as viewing data in map format.

The question arises as to whether or not these fundamental changes in health information provision to improve health care, have made any difference. Although, evaluation must be an integral part of every policy, every change in organisation or every new strategy and no doubt those authorities responsible for the setting up of the current information systems will have been assessing outcomes, it is not too difficult to get an idea of what the "intelligence" in the PHIU might stand for.

A Google search on "public health intelligence" (using quotes to limit the results to the string rather than each word) resulted in 43,300 hits. A similar search for "public health observatory" resulted in 97,500 hits. Clearly, the majority of the items found are not directly relevant and may merely be related documents. However, a number of key phrases may be observed from those listed on the first few pages and relevant to the PHIU such as to improve access to health data, availability of data, to provide knowledge and information, to improve health, to inform and shape health. All these units appear as initiatives of the health departments of relevant governments.

Obviously it is a huge task, and well beyond the scope of this chapter, to scrutinise each and every single PHIU. From personal experience in the UK, most regional units such as PHIU and PHO perform and produce similar tasks, albeit within their own regions. The slight variation between them may be due to the locality and make up of the staff. For the purpose of illustration some web-links from the first page of the google search results were explored further. The exploration of these websites was based on IT, i.e. applications of (information) technology, and advancement in information. The former refers to access to data, while the latter refers to the nature and quality of information.

There is no doubt that health services information administrators have embraced the technology to make data more accessible to health care organisations and the public. The PHIU's pages visited offer some sort of resources kit for either viewing data or creating tables on chosen parameters such as age, sex, cause and area. Also available for online access are annual reports and other interim bulletins and one-off study results. Perhaps the most advanced feature offered by most is the choice of how data may be viewed. For example, data may be viewed graphically e.g. as a regional map, time series plot, or in tabulated format.

However, for data to be processed, prepared and presented in such a way that can be accessed, queried, tabulised, and graphed on the internet, access to its original source must also be made easy. This will make the work of information/public health specialist much easier. In some of the most recent (UK or NZ) annual reports, it was reported that several different health and social databases had been accessed to produce the reports. So the technology part of IT has, at least, in parts, helped to achieve the philosophical aim of improving access to data by other clients.

A closer examination, however, indicates that these improvements in accessing data have not had a great deal of influence on the information component of IT. Most of the data available is of the aggregate form of proportions, rates and ratios of diseases for each sex and age group. The fact that this type of data can now be graphed and presented in more styles and formats has little bearing on access to information. In essence we are still mapping the current flow and still do not have the means of gaining insight about the flow upstream. Some websites such as the New Zealand's PHI claim that the undertaking and ongoing projects to probabilistically link health records such as hospitals with records from other health care providers. Although record linkage may be carried out with some success using software technology (e.g. see Stott et al. (1994)), record linkage on its own has a limited application and is often utilised alongside other forms of data systems such as surveys or cancer registry e.g. see Tait & Hulse (2005), McGuire et al. (2007), Myint et al. (2006, 2007 & 2008), Hockley et al. (2008). Record linkage may not be as effective as a unified database. The point is that most of the reports produced by the PHIU and PHO on their web pages express public health as a process and there is much talk about other social and economic processes, yet, there is very little evidence of public health being treated as such in their published reports through the data made available.

The current emphasis and guidelines by the Department of Health (UK) on neighbourhood does very little to engage participation by the public at local level and is analogous to the reinvention of the wheel. For example, the annual report posted on the Doncaster PHIU for 2008 provides a method of identifying neighbourhoods as the building blocks for community action. A much more superior work for this purpose has already been published (Openshaw 1983) and applied successfully within the UK National Health Service (e.g. see Thunhurst 1985, Bensley et al 1994). It is very interesting that after some hard work and the use of limited resources to reinvent the wheel, the report recommended the development of an education package of the neighbourhood taxonomy to educate health networks, practitioners (nurses, GPs etc), the academia and that a rollout of successful interventions be targeted, initially within clusters to capitalize on the knowledge of similar environments. This indicates the authors typically prejudging the outcome. Yet again nothing new in this process which is essentially a top-down approach where decisions are made before giving the public a chance to participate. Any public participation has frequently taken the form of a survey. Problematic issues arising from surveys and the consequences of using incomplete information to inform policy formation has been raised and discussed elsewhere (Shahtahmasebi 2008, 2007a&b, 2005a, 2003a).

On the other hand, whilst data can now be easily accessed, the interpretation is often limited to visually observable features. This point is quite clear from studying some of the reports. The documents provided by the New Zealand PHI on their webpage report annual morbidity and mortality statistics. These statistics are often presented graphically with a short description of what the graphs show, see Shahtahmasebi (2008). While some PHIU appear to suggest innovative or new data, most are based on different presentations e.g. using GIS and mapping to present morbidity or mortality data or the neighbourhood building blocks proposed by Doncaster PHIU. All equate to re-inventions of the wheel.

The main point is that despite the application of advanced technology, very little improvement has been made in the availability of new data connecting public health to the dynamics of upstream. Because we are preoccupied with indices and aggregate indicators of health outcomes, we are *still* measuring the current and flow of the river, which does not provide insight into what may be going on upstream.

Both PHIU and PHO claim to improve access to health information as their first goal. It seems, however, that in addition to the duplication, there is yet more work to be done in terms of fully utilising the "T" of IT as both PHO and PHIU appear to be involved in some sort of facilitating role in terms of data collection, collation, processing before it is reported and made available online.

A HOLISTIC APPROACH

Health care services collect individual data at the point of care delivery. Similarly, social care services collect individual data at the point of delivery. Despite the intelligence in the PHIU it is still difficult to get simple data for simple epidemiological feasibility studies. For example, although rates and ratios for suicide and hospitalization due to self-harm are readily available (NZHIS 2001) and have been used to highlight differences in rates between males and females (Shahtahmasebi 2008), from such data it is not possible to answer fairly simple but important questions of proportions and duration, such as:

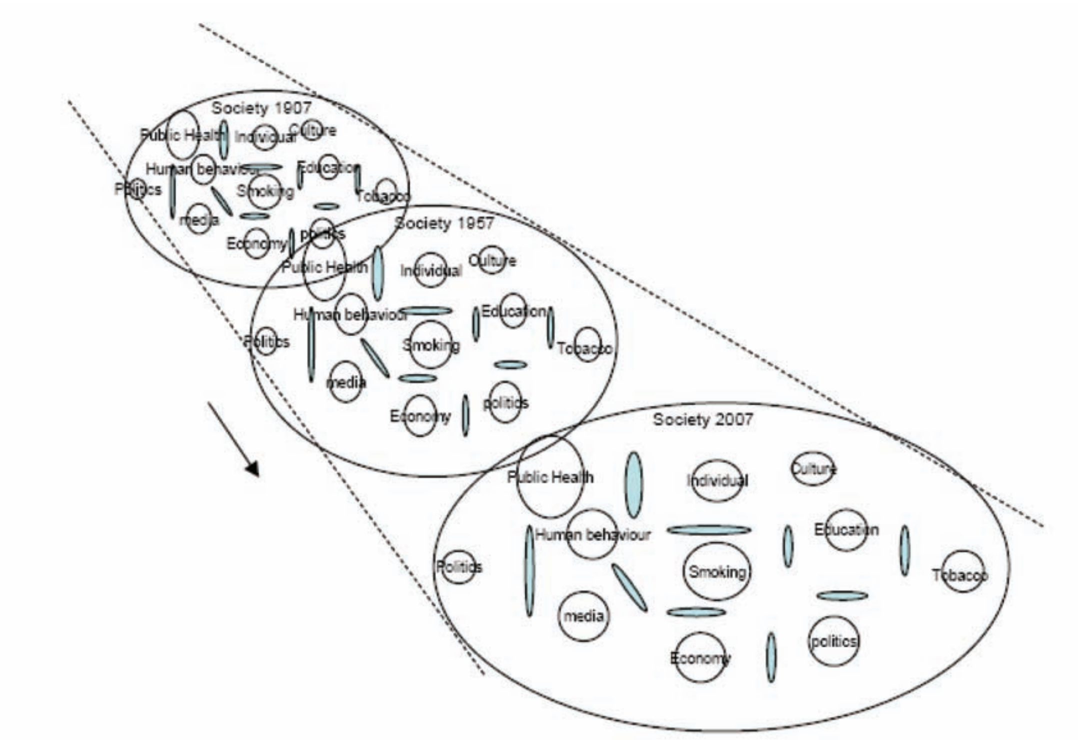
- What proportion of hospitalisations due to self-harm were new cases?
- What proportion were repeat attempters?
- What proportion received psychiatric care and for how long?
- What proportion received any medical care in the community and for how long?
- What proportion completed suicide?
- What proportion have not re-attempted?

And so on. To do so, the above had to be included as part of a major proposal (Shahtahmasebi et al 2001, Shahtahmasebi & Bagshaw 2003b).

These new entities impress upon the public the virtues of evidence-based decisions to improve public health. While they also refer to health and social as processes, it is not clear whether by processes it is meant the administrative aspect of health/social care policy development, or the health/social outcomes, or both. Regardless of what is meant by process, currently accessible data does not lend itself to the understanding of any process. Processes are by nature dynamic.

Most of the above issues were discussed in an earlier paper (Shahtahmasebi 2006) and summarised in Figure 1. The circular line around the process "society" is merely convenience to distinguish time periods and does not indicate that it is a closed process. The solid ellipses symbolize filters, interfaces and unobserved effects which may be process outcomes in their own right. These processes may, for instance, be the outcome of implemented policies that were either withdrawn or were based on incomplete information. The transparent circles symbolize social processes that are directly responsible for social changes and may influence the outcome of interest (in this case smoking) directly or indirectly. It can

Figure 1. An example of a conceptual model of smoking (Shahtahmasebi 2006).



be visualized that this influence will be through relationships and interactions with other processes and unobserved filters/interfaces over time. For example, broadcasting images of smokers, under the banner of art and entertainment or in visual antismoking campaigns, taking a deep puff and then exhaling with an expression of profound satisfaction may be more effective than the old images of cool and confident hero. Most televised anti-smoking advertising in New Zealand show the act of smoking during a televised anti-smoking campaign i.e an anti-smoking message may begin with a smoker lighting up a cigarette and taking a deep puff. The anti-smoking message may be the effect of smoke on internal organs in which case the camera follows and tracks the path of smoke all the way into the lungs and blood stream; or if the message is passive smoking, the smoker is shown to exhale the smoke into the environment and onto other people e.g. in the car or in the house over children etc. What more or better publicity could an industrious cigarette manufacturer wish for?

The main issue here is that, in terms of information, we may have improved access to numbers, rates and ratios of morbidity, mortality and possibly other events such as administration of a treatment e.g. type of medication, surgery, but we do not have any ideas or information on the competing forces in society (as shown in the diagram) on our health-related behaviour. As an example, consider smoking behaviour and suicide. Smoking is considered a major cause of morbidity and mortality yet, despite the restriction placed on the sale (including advertising) of tobacco, taxation regime and smoking in public places, people continue to smoke. It seems that the single message of "smoking kills" on its own is not sufficient, which may be due to advancements in medical technology e.g. the hope that the cure for heart disease and cancers in particular lung cancer are not too far away. Other competing forces may include the tobacco industry and the media's portrayal of smoking and constantly exposing the public to smoking under "art", "entertainment" and public interest or news worthiness (for a discussion of such issues see Shahtahmasebi 2007a). Similarly, as mentioned above, despite the improvements in access to health information in some cases, information on suicide does not go beyond numbers, rates and ratios which makes health care planning a hit and, perhaps more frequently, a miss. Any "hits" may be the temporary feedback effect coinciding with the effects of other competing forces. To illustrate, consider the suicide report issued by Doncaster PHIU on their web page (Doncaster PHIU 2003). Once again the same data (i.e. rates and ratios by sex, age and groups) are presented graphically and a description of the graphs (highs and lows) is given. This report, however, takes an extra step of looking into the claim that a pain killer (co-proxamol) had been a common method of committing suicide and therefore in 1998 attempts were made by the Doncaster Health Authority to reduce access to this drug. The report then presents a graph of superimposing the rate of prescriptions of co-proxomal on the number of suicides using co-proxomal and makes a tantalizing projection that such a policy may have had a significant effect on reducing suicide (Doncaster PHIU 2003, page 8). The report does not appear to take into account the fact that in 1995, 1996 and 1997, when the prescription of co-proxomal was at its highest, there were the same number of suicides as in 1999 and 2001 after the reduction in prescribing co-proxomal. By the same token, such a policy of removing access to a method of suicide may have an effect on suicides using that method but there is evidence to suggest that suicide victims do switch to more violent methods to ensure successful completion (e.g see Shahtahmasebi 2005a&b). It can, therefore, be argued that research and health care development must treat suicide as a process of decision-making which is not too dissimilar from a decision to smoke with the same set of competing forces influencing the decision- making process. In Figure 1 smoking may be replaced by suicide.

If the intention of health/social care services is purely to cater for the population needs they are serving and if there are no resource limitations, trends of outcomes of interests may be used to forecast needs and resource allocation. However, neither health and social outcomes nor resources are static. Clinical successes may be counteracted by the increasing trends previously unnoticed in other outcomes or changes in social outcomes. For example, as a result of clinical successes in making organ transplantation fairly routine, social expectations may have changed accordingly; the public are expected to automatically become donors. On the other hand, those in need of a transplant may be praying for a donor which is ironic as it means someone else must die for a transplant organ to become available.

The feedback effect, a feature of a dynamic process from successes in advancement in technology, has placed the emphasis onto not only maintaining but also increasing the pace of progress e.g. designer organs for transplantation using cloning technology. Thus we have not been able to concentrate on exploring upstream to gain insight into why and how we are in the current position.

Clearly, it is not possible for one service provider to design and collect information on a massive scale as conceptualised in Figure 1. Certainly, I am not proposing that health services around the world to develop complex IT systems. Furthermore, I suggest that adopting a new phrase or a change in title should not be a revolution in name alone! I am proposing that the authorities go beyond their buzzwords invented every now and then to gloss over the reinvention of the wheel such as case-mix, "intelligence" units, observatories, neighbourhood and so on and so forth. In other words, we need to understand that we need information *not* only to calculate budgets and costing of services for intervention, but to develop the sustainable and effective services we need to gain an insight into disease development. We need information from other processes. Theoretically, given the advancement in ICT, this is neither impossible nor difficult to achieve.

In the UK the NHS routinely collects information in various formats e.g. from qualitative and textual reports such as health visitors' records to minimum data sets and hospital records. From these records it should be possible to gain factual and objective information on the population from birth to death. Apart from the quantitative hospital records and mortality data, almost no other NHS records have been utilised (see Shahtahmasebi 1997b). It is plausible that until recently there may have been technical issues with utilising such records. However, the technology is now available, such as powerful palmtops with cell phone technology and networking capability. But it must be first recognized and acknowledged that appropriate information is necessary for any sustainable policy development.

One of the features of the conceptualisation in Figure 1 is an understanding that data from various processes is essential. It can then be conceptualised that in order for the model to work data must be allowed to flow between processes. This means depoliticising and sharing of data. Most countries now have IT systems for the monitoring of health, social, education and economic outcomes. A unified database may take the form of a *virtual* warehouse, perhaps acting as a buffer or filter, providing access to *more* data collected at various stages of life.

Assuming that the technology can be utilised to accommodate privacy and confidentiality requirements, there are two immediate benefits for clinical practice and research. The virtual warehousing can be used to generate aggregate and anonymous multi-level population based data for research, be it a pilot or feasibility study, to explore and assess a broad issue or to test developed hypotheses using appropriate modelling methodologies.

The second advantage is that individuals can be given an access key (such as their own National Insurance Number) to access all information held on them. This facility can be extended to provide further information in the form of responding to online voluntary update forms. Perhaps the greatest gain will be in the clinical and practice where the health care professionals are able to access primary care records (GPs, public health nurses, health visitors, etc) as well as hospitals, and socio-economic and education parameters. However, access to all records may not be appropriate for every health/social consultation, and access to all information may only be provided by the individual who may offer their access key to the health professional. On the other hand, an ability to have an objective life events history complemented by the patient's own recounting will be an important tool in predicting and preventing or modifying health-related behaviour, in particular suicide and self-harm, obesity and smoking.

CONCLUSION

Although it is apparent that routinely collected data such as mortality and hospital records may be readily accessible, it is more difficult to access primary care data such as GPs and nursing and social care records. Nevertheless, data is routinely collected by the various care organisations and their internal departments but the various data or information systems do not communicate with each other in terms of the flow and sharing of data. Whether the blocking issues are political so that each department is viewed as a separate entity to perform a certain task, or incompatible technologies, or a combination of processes, it is, nevertheless, possible using the current information technology to create a multidimensional flow of information. An important implication may be access to additional data/information from publicly funded projects (e.g. medical and health research councils, government departments, research and development). These projects may be linked to the virtual warehouse in a multi-way flow of information, to some extent, to fill the current and future gaps in data and research. The concept of a holistic approach to inform the process of policy formation is the subject of a proposal currently being developed by the author. Therefore, it is difficult to prejudge the outcomes in terms of strength and weaknesses. However, the idea of a holistic approach is to create a flexible policy that can respond to the short-term needs and is sustainable to respond to future needs. The limitation or weaknesses associated with such an ideal 'framework' are the complexities associated with human behaviour (e.g Politics, conflict and politics e.g see Irestig and Timpka 2007), methodology (e.g see Pilemalm and Timpka 2007) and costs. On the other hand, assessments of a flexible policy, at least theoretically, lead to the projection that sustainable policies may be more economical over time as the need for short-term expenditure will be greatly reduced.

The intention of this chapter is to highlight the shift away from evidence given the current emphasis on "evidence" for decision making. It is a good feeling to know that one can find data at a few click of the mouse through fast access to the internet. However, very few question the limitation of the data that can easily be accessed as evidence. On the other hand there are a number of specialty longitudinal databases such as the longitudinal census and FACS (the Department of Work and Pension's Families and Children Study). As discussed in this chapter, analytical methodologies are equally as important as the research methodology to translate data into information (e.g see Emerson et al 2008). Although, the creation of longitudinal databases is a step in the right direction, given the technological advances to date, a unified database is still well out of sight.

REFERENCES

BBC. (2007). *Everyone should donate organs. The chief medical officer says everyone should be viewed as an organ donor when they die unless they have requested not to be*. Retrieved from http://news.bbc.co.uk/go/em/-/1/hi/health/6902519.stm

Beautrais, A. L. (1996). *Serious suicide attempts in young people: A case control study*. Unpublished doctoral dissertation, Christchurch School of Medicine, Christchurch, New Zealand.

Beautrais, A. L. (2001). Suicides and serious suicide attempts: Two populations or one? *Psychological Medicine*, *31*, 837–845.

Beautrais, A. L., Joyce, P. R., & Mulder, R. T. (1994). The Canterbury suicide project: Aims, overview, and progress. *Community Mental Health in New Zealand*, *8*(2), 32–39.

Bensley, D., Shahtahmasebi, S., Fryers, P., & Merrick, M. (1994, March). *A census based view of the population and its health* (Statistical Review). Public Health Annual Report, former Yorkshire Regional Health Authority report. Northern & Yorkshire NHS Executive, John Snow House, Durham University Science Park, Durham DH1 3YG. UK.

Cutcliffe, J. R. (2003). Research endeavours into suicide: A need to shift the emphasis. *British Journal of Nursing (Mark Allen Publishing)*, *12*(2), 92–99.

De Leo, D. (2002). Why are we not getting any closer to preventing suicide? *The British Journal of Psychiatry*, *181*, 372–374. doi:10.1192/bjp.181.5.372

Doncaster, P. H. U. I. (2003). *Suicide*. UK: Doncaster Public Health Intelligence Unit. Retrieved from www.doncasterhealth.co.uk/phiu

Doncaster, P. H. U. I. (2007). *Improving health, narrowing the divide,* a joint annual report of the directors of public health in South Yorkshire. UK: Doncaster Public Health Intelligence Unit. Retrieved from www.doncasterhealth.co.uk/phiu

Emerson, E., Berridge, D. M., & Lancaster, G. (2008). *The association between child disability and poverty dynamics in British families. Funding application, ESRC grant no. RES-000-22-2874*. Lancaster University, UK.

Gilpin, E. A., White, M. M., Messer, K., & Pierce, J. P. (2007). Receptivity to tobacco advertising and promotions among young adolescents as a predictor of established smoking in young adulthood. *American Journal of Public Health*, *97*(8), 1489–1495. doi:10.2105/AJPH.2005.070359

Hall, W. D., Mant, A., Mitchell, P. B., Rendle, V. A., Hickie, I. B., & McManus, P. (2003). Association between antidepressant prescribing and suicide in Australia, 1991-2000: trend analysis. *BMJ (Clinical Research Ed.)*, 326.

Healton, C. G., Watson-Stryker, E. S., & Allen, J. A. (2006). Televised movie trailers: Undermining restrictions on advertising tobacco to youth. *Archives of Pediatrics & Adolescent Medicine*, *160*(9), 885–888. doi:10.1001/archpedi.160.9.885

Hockley, C., Quigley, M. A., Hughes, G., Calderwood, L., Joshi, H., & Davidson, L. L. (2008). Linking millennium cohort data to birth registration and hospital episode records. *Paediatric and Perinatal Epidemiology*, *22*, 99–109.

Ibrahim, J. K., & Glantz, S. A. (2007). The rise and fall of tobacco control media campaigns, 1967-2006. *American Journal of Public Health*, *97*(8), 1383–1396. doi:10.2105/AJPH.2006.097006

Institute of Medicine. (2002). *US Report Calls for Improved Suicide Research*. Washington, MEDLINEplus, http://www.nlm.nih.gov/medlineplus/news/fullstory_9705.html.

Irestig, M., & Timpka, T. (2007). Politics and technology in health information systems development: A discourse analysis of conflicts addressed in a systems design group. *Journal of Biomedical Informatics*, *41*(1), 82–94. doi:10.1016/j.jbi.2007.05.009

Khan, A., Warner, H. A., & Brown, W. A. (2000). Symptom reduction and suicide risk in patients treated with placebo in antidepressant clinical trials: An analysis of the food and drug administration database. *Archives of General Psychiatry*, *57*, 311–317. doi:10.1001/archpsyc.57.4.311

McGuire, A. J., Raikou, M., Whittle, I., & Christensen, M. C. (2007). Long-term mortality, morbidity, and hospital care following intracerebral hemorrhage: An 11-year cohort study. *Cerebrovascular Diseases (Basel, Switzerland)*, *23*, 221–228. doi:10.1159/000097645

McKinlay, J. (1975). A case for refocussing upstream: The political economy of sickness. In A. Enelow (Ed.), *Applying behavioural science to cardiovascular risk*. New York: American Heart Association.

Myint, P. K., Luben, R. N., Wareham, N. J., & Welch, A. A. (2006). Combined work and leisure physical activity and risk of stroke in men and women in the European prospective investigation into cancer-Norfolk prospective population study. *Neuroepidemiology*, *27*, 122–129. doi:10.1159/000095551

Myint, P. K., Luben, R. N., Welch, A. A., & Bingham, S. A. (2008). Plasma vitamin C concentrations predict risk of incident stroke over 10 y in 20 649 participants of the European prospective investigation into cancer Norfolk prospective population study. *Am Soc Nutrition*, *84*, 64.

Myint, P. K., Surtees, P. G., Wainwright, N. W. J., & Luben, R. N. (2007). Physical health-related quality of life predicts stroke in the EPIC-Norfolk. *Neurology*, *69*, 2243. doi:10.1212/01.wnl.0000296010.21252.78

NZHIS. (2001). *Suicide trends in New Zealand 1978-98.* Retrieved from http://www.nzhis.govt.nz/publications/suicide.html

Openshaw, S. (1983). Multivariate analysis of census data: The classification of areas. In D. Rhind (Ed.), *A census user's handbook.* London: Methuen.

Peters, R. J., Kelder, S. H., & Prokhorov, A. (2006). The relationship between perceived exposure to promotional smoking messages and smoking status among high school students. *The American Journal on Addictions*, *15*(5), 387–391. doi:10.1080/10550490600860346

Pilemalm, S., & Timpka, T. (2007). Third generation participatory design in health informatics-making user participation applicable to large-scale information system projects. *Journal of Biomedical Informatics*, *41*(2), 327–339. doi:10.1016/j.jbi.2007.09.004

Shahtahmasebi, S. (1997a). *An epidemiological profile of mental health service users in Leeds* (Internal Report). Leeds Community and Mental Health Services Trust, Meanwood Park Hospital, the Mansion, Tongue Lane, Leeds, UK.

Shahtahmasebi, S. (1997b). *The quality of routinely collected nursing data*. A proposal funded by the R&D Seedcorn Funds. Leeds Community and Mental Health Services Trust, Meanwood Park Hospital, the Mansion, Tongue Lane, Leeds, UK.

Shahtahmasebi, S. (1999). *An epidemiological profile of service uptake in Salford* (Internal Report). On behalf of the PHRRC, University of Salford for the Salford Health Authority, Salford, UK.

Shahtahmasebi, S. (2001, December 2-5). Residential area characteristics and health of the population: A census based analysis. In P. A. Whigham & A. Moore (Eds.), *Sircumnavigation: Where have we been? Where are we going?* In *Proceedings of the 13th Annual Colloquium of the Spatial Information Research Centre*, Otago University, Dunedin, New Zealand.

Shahtahmasebi, S. (2003a). Teenage smoking: Some problems with interpreting the evidence. *International Journal of Adolescent Medicine and Health*, *15*(4), 307–320.

Shahtahmasebi, S. (2005a). Teenage smoking: A longitudinal analysis. *International Journal of Adolescent Medicine and Health*, *17*(2), 135–153.

Shahtahmasebi, S. (2005b). A view of suicides and mental illness in Leeds, UK. In J. Merrick & G. Zalsman (Eds.), *Suicidal behavior in adolescence. An international perspective.* Tel Aviv: Freund Publishing.

Shahtahmasebi, S. (2005c). Suicide in New Zealand. *TheScientificWorldJournal*, *5*, 527–534. doi:10.1100/tsw.2005.74

Shahtahmasebi, S. (2006). The good life: A holistic approach to the health of the population. *TSWJ-Holistic Health and Medicine*, *1*, 153–168. doi:10.1100/tswhhm.2006.90

Shahtahmasebi, S. (2008). Suicide research and adolescent suicide trends in New Zealand. *TheScientificWorldJournal*, *8*, 287–302.

Shahtahmasebi, S. (in press). Teenage smoking: Researching behaviour. *Int. J. of Psychology Research.*

Shahtahmasebi, S. (in press). Teenage smoking: Longitudinal vs. cross-sectional modelling. In R. S. Grenell (Ed), *Adolescent behaviour research studies.* Nova Science Publishers, Inc.

Shahtahmasebi, S., & Bagshaw, S. (2003b). *An epidemiological profile of suicide in New Zealand: South Island.* Funding application to the New Zealand Health Research Council for the 2003/2004 round of funding. The Good Life Research Centre Trust New Zealand.

Shahtahmasebi, S., Holt, A., Wade, M., Bagshaw, S., & Farrow, T. (2001) *A critical review of all completed suicides: Using multidisciplinary and advanced multimethod approach*. Funding application to the New Zealand Health Research Council for the 2001/2002 round of funding.

Shelley, D., Cantrell, M. J., & Moon-Howard, J. (2007). The $5 man: The underground economic response to a large cigarette tax increase in New York City. *American Journal of Public Health*, *97*(8), 1483–1488. doi:10.2105/AJPH.2005.079921

Short, S. (1997). Elective affinities: Research and health policy development. In H. Gardner (Ed.), *Health policy in Australia*. Melbourne: Oxford University Press.

Stott, D., Francis, B., & Wain, R. (1994). Software for routine record linkage in public health. In B. Richards (Ed.), *Proceedings of current perspectives in healthcare computing* (pp. 681-686).

Tait, R. J., & Hulse, G. K. (2005). Adolescent substance use and hospital presentations: A record linkage assessment of 12-month outcomes. *Drug and Alcohol Dependence*, *79*, 365–371. doi:10.1016/j.drugalcdep.2005.03.016

Thunhurst, C. (1982). Measuring the health consequences of social and economic policy. *Bias*, *9*(1), 41–59.

Thunhurst, C. (1985). The analysis of small area statistics and planning for health. *The Statistician*, *34*, 93–106. doi:10.2307/2987507

Yorkshire Regional Health Authority. (1994, March). *Health of the nation: Strategic outcome targets*. Former Yorkshire Regional Health Authority Health of the Nation steering Committee report, Northern & Yorkshire NHS Executive, John Snow House, Durham University Science Park, Durham, UK.

KEY TERMS AND DEFINITIONS

Evidence-Based Practice: Critical evaluation of research results to inform policy development.

Health Information Systems: Any formal utilisation of ICT, IT, databases and Public Health.

Information and Communication Technology (ICT): Any means of storing, retrieving and transferring/communicating information.

Information Technology (IT): Any means of storing and retrieving data/information.

Public Health: Formal study and prevention of diseases.

Smoking: The act of smoking tobacco.

Suicide: Terminating one's own life.

Unified Database: Multi-dimensional multi-layered multi-disciplinary database.

This work was previously published in Handbook of Research on Information Technology Management and Clinical Data Administration in Healthcare, edited by A. Dwivedi, pp. 598-615, copyright 2009 by Medical Information Science Reference (an imprint of IGI Global).

Chapter 1.5

Monitoring and Controlling of Healthcare Information Systems (HIS)

Stefan M. Graeber
Saarland University, Germany

Ansgar Kutscha
Diakonie Hospital Schwaebisch Hall gGmbH, Germany

BACKGROUND

Information management (IM) at a health care institution encompasses the management of information, the management of application systems, and the management of information and communication technology whether computer supported or not, that is, IM provides function, performance, and quality of HIS. Management means, as well, the responsible persons and organizational units as the tasks of planning, directing, and monitoring HIS. IM has to be done systematically to enable an orderly processing of information coherent with the goals of the health care institution.

While planning and directing are supported comprehensively by basic methods of strategic planning and project management (Brigl, Ammenwerth, Dujat et al., 2005; Haux, Winter, Ammenwerth, & Brigl, 2004; Winter, Ammenwerth, Bott et al., 2001), the monitoring is neglected sometimes and thus insufficiently supported (Ammenwerth, Ehlers, Hirsch, & Gratl, 2007). As nevertheless a continuous and careful monitoring is a very important task in interaction with all other management tasks, we will define the relevant terms and describe the most significant concepts and methods.

Monitoring

Generally, *monitoring* of HIS means the continuous observation of whether the directives and objectives defined in the strategic information management plan will be reached, and whether the HIS is able to fulfill the required tasks. Therefore, the IM must be able at any time to assess the state of the HIS using quality criteria which can be derived from the objectives. Its results affect directing and planning again by feedback mechanisms.

The tasks of monitoring may be linked to the strategic level (auditing HIS quality as defined by means of strategic information management plan's directives and goals as well as quality of the strategic management process itself), the tactical level (check whether the initiated projects are running as planned and whether they will produce the expected results), and the operational level

DOI: 10.4018/978-1-59904-889-5.ch116

(verifying the proper working and effectiveness of all HIS components) (Haux et al., 2004, p. 182-184).

Nowadays the management tasks providing an excellent service for all users of HIS are embraced by the term *IT service management* (ITSM). There are several frameworks describing an architecture for installing and maintaining ITSM. The most known framework is the *IT infrastructure library* (ITIL) (www.itil.org). It is a set of best practices enabling organizations to deliver their services more efficiently and thus at last to reach for a maximum of customer (patient) satisfaction. ITIL may be regarded as a guideline for monitoring of HIS.

IT Controlling

Management decisions require information or data. In this context, the part of IM delivering information needed as basis for management decisions is called *IT controlling*. For this purpose, IT controlling applies different approaches and methods, for example, the continuous measuring and interpretation of indicators and characteristic values explaining the current state of HIS, or the realization of evaluation studies. Thus, among other IT controlling, comprises following tasks (the terms reference model, indicator, and evaluation project are outlined below):

- Defining and operationalizing objectives (in cooperation with partners of IM)
- Defining models, selection and application of reference models
- Defining indicators and appropriate values
- Planning, initiating, and continuous measurement of indicators
- Planning and performance of evaluation projects
- Reporting results
- Analyzing results (which may influence all preceding steps by feedback-mechanism) (in cooperation with partners of IM)
- Preparing decisions (in cooperation with partners of IM)

Depending on tasks and questions, different methods of information acquisition are applied. Sometimes one performs ad-hoc-studies (field studies) to find hypotheses, to get some insight in the features of performance measuring, or to detect problems and deficiencies (screening). An example of screening is a survey performed to discover the problems with a new nursing documentation system two weeks after installation. More important are the continuous data collection via indicators and occasional deeper investigations (evaluation).

Indicators and Characteristic Values

Indicators are variables whose values (characteristics values) represent an aspect of HIS. To discern good and bad quality of information processing and to assess the achievement of goals, one has to compare the current value of indicator with one or more predefined reference values. With standardized indicators comparisons between different HIS become possible. Relevant aspects may be all components of HIS, for example, strategy, projects, quality, processes, functionality, or parts of IT infrastructure. The indicators can be qualitative (e.g., user satisfaction), quantitative non-monetary (e.g., failure time), or quantitative monetary (e.g., cost). They should be specified as follows:

- Comprehensive description, including its purpose and correlation with the objectives
- Data source, measurement procedure, and algorithms (when indicators are derived from others)
- Characteristic values and reference values (limits), for example, corresponding to quality goals
- Time interval for measurement (e.g., daily, weekly)

- Time of availability
- Responsible organizational unit and person(s)
- Procedure to check adequateness, completeness, and correctness of results afterwards (evaluation of indicators)

To describe complex aspects of HIS, several indicators have to be considered. The combination of logically associated indicators is called an *indicator system*. The Balanced Scorecard (see next paragraph) is an example for an indicator system.

Balanced Scorecard

A suitable tool for management and controlling is the *Balanced Scorecard* (BSC) (Kaplan & Norton, 1992, 2000). At first developed for strategic management of an organization, the BSC can be applied for purposes of monitoring too. It provides feedback around both the internal business processes and external outcomes in order to continuously improve strategic performance and results. When fully deployed, the balanced scorecard transforms strategic planning into the "nerve center" of an enterprise. Using BSC the manager may establish a "balanced" situation between the traditional financial measures and other success factors of an organization. The BSC combines the continuous measurement of performance with a reviewing and refinement strategy as well an ongoing evaluation process.

The basic terms are so-called *perspectives*, for example, potentials (learning and growth), internal processes, customers, and financial perspective. Depending on the view, the term customer can vary: customers from the view of health care organization are mostly patients, customers from the view of IM are users of IT applications. For each perspective, strategic objectives, indicators, and measures to achieve these objectives must be defined.

Models and Reference Models

A *model* is a simplified representation of a section of the real world (subject area). Models are developed for understanding, analysis, or improvement of subject area. Depending on purposes of modeling the relevant aspects of subject area are selected and built in only. Models become an important tool for the IM, because they help overwhelm the complexity of HIS.

A metamodel can be considered as a toolbox for building models. With general metamodels like ARIS (www.ids-scheer.com/international/english/products/53961), one can describe processes independent of the business field. The three-layer graph-based metamodel (3LGM²) is a specialized tool for static HIS modeling. The domain layer consists of functions and entity types. The logical tool layer focuses on application components, and the physical tool layer describes physical data processing components. Additionally several inter-layer-relationships are defined (Winter, Brigl, & Wendt, 2003). The 3LGM² allows building of models of HIS presenting their current state with adequate levels of granularity. So one can find out, for example, which functions are supported by which application systems, or the kind and scope of communication processes between different applications. In this manner, deficiencies may be detected, too, for example, gaps in information transfer. Additionally the 3LGM² allows to integrate indicator systems and to compute indicators along the relations between the model objects (Kutscha, Brigl, & Winter, 2006).

A *reference model* is a template for a well-defined class of models, that is, from a reference model concrete models are derived by modification, restraints, or additions (Haux et al., 2004, p. 73). Furthermore one can check by comparison, whether concrete models have the same features as the reference model, for example, completeness of functions. Therefore the use of a reference model can deliver relevant indicators. Depending on subject area, there are reference models for organizations, information systems, software, or procedures.

Reference models support the quality assessment better than models. They function like standards, that is, if the quality of reference model is proved, the quality of a concrete model may be made evident by comparison using quality indicators. The reference model itself should be evaluated also to provide that the model is a sufficient map of reality.

For the monitoring of HIS, one needs reference models for information systems to find out whether the business processes are supported by efficient tools, or the necessary information flows are established (Winter et al., 1999). But also reference models for procedures are useful (see examples provided).

Evaluation

Evaluation is the act of measuring or exploring properties of a health care information system (in planning, development, implementation, or operation), the result of which informs a decision to be made concerning that system in a specific context (Ammenwerth, Brender, Nykanen, Prokosch, Rigby, & Talmon, 2004). With the information acquired by evaluation, one can learn something, answer relevant questions, or make decisions. In this manner the screening mentioned above can be regarded as a "simple" evaluation. Evaluation of health care systems is a main topic of research in medical informatics (Brender, 2006; Friedman & Wyatt, 1997). Therefore, here some methodical principles are outlined only.

There is a wide spectrum of evaluation methods. It reaches from simple surveys to exactly planned longitudinal investigations. Some studies are performed like clinical trials. It means that one should try to apply principles of Good Clinical Practice (http://www.ich.org/LOB/media/MEDIA482.pdf). But often some techniques are not applicable (e.g., randomizing or blinding). Nevertheless reliable studies can be performed, if some recommendations are taken into account (Ammenwerth, Graeber, Herrmann, Buerkle, & Koenig, 2003). All decisions and steps should be documented in a detailed study protocol. An adequate study design and appropriate methods to answer the study questions have to be selected. The combination of quantitative and qualitative methods may be helpful. Wherever possible, validated evaluation instruments should be used. Often a multi-methodic and/or multidisciplinary approach is necessary (Ammenwerth et al., 2003).

Evaluation studies can be formative or summative. Formative evaluation strives to improve the HIS component under evaluation by providing the developers (and implementers) with feedback. Summative evaluation tries to demonstrate the outcome of a "mature" HIS component in routine (Friedman & Wyatt, 1997, p. 304).

Organization of IM

Organizational structures for IM differ considerably among health care institutions. In general, each institution should have an adequate organization for strategic, tactical, and operational IM, depending on its size, internal structure, and needs. Reference models for the organization of IM in hospitals are given in Haux et al. (2004, p. 187ff).

The relation between IM and IT controlling may be formed very differently. Between the two "poles" (IT controlling totally embedded without own directives vs. IT controlling as specific organizational unit beside IM) several structures are possible.

Next to organization the performance of IM plays an important role. For example, the performance level of IM can be assessed by the Capability Maturity Model (www.sei.cmu.edu/cmmi/). The IM should have a high maturity level, that is, it should function as *business enabler* for the hospital.

Table 1. Perspectives and corresponding objectives for a BSC (examples)

Perspective	Objectives
Potentials Employees Infrastructure Organization *Information management* …	*Efficient support of processes by IT* Establishing interdisciplinary functional units …
Processes Medicine Research Teaching Administration …	Establishing structured and transparent workflows for patient care (e.g., clinical pathways) Better and faster implementation of current medical evidence …
Customers Patients and relatives Cooperating practitioners Cooperating hospitals Students Consultants …	Increasing the integration of in- and out-patient care Enhancement of user satisfaction …

EXAMPLES

Table 1 shows perspectives (without financial perspective) and corresponding objectives from a BSC established at a German university hospital. The main perspectives of BSC were modified slightly. A part of the indicator tree for the subperspective *information management* and the appropriate objective *efficient support of processes by IT* is presented in Table 2. The indicator tree defines the indicators and their dependencies, which have to be measured for a perspective. Overall this BSC contains 11 composite performance indicators reflecting particular strategic objectives. These measures are expressed in terms of actual performance as percentage of expected performance. For further examples of BSC application, see Kaplan and Norton (2000).

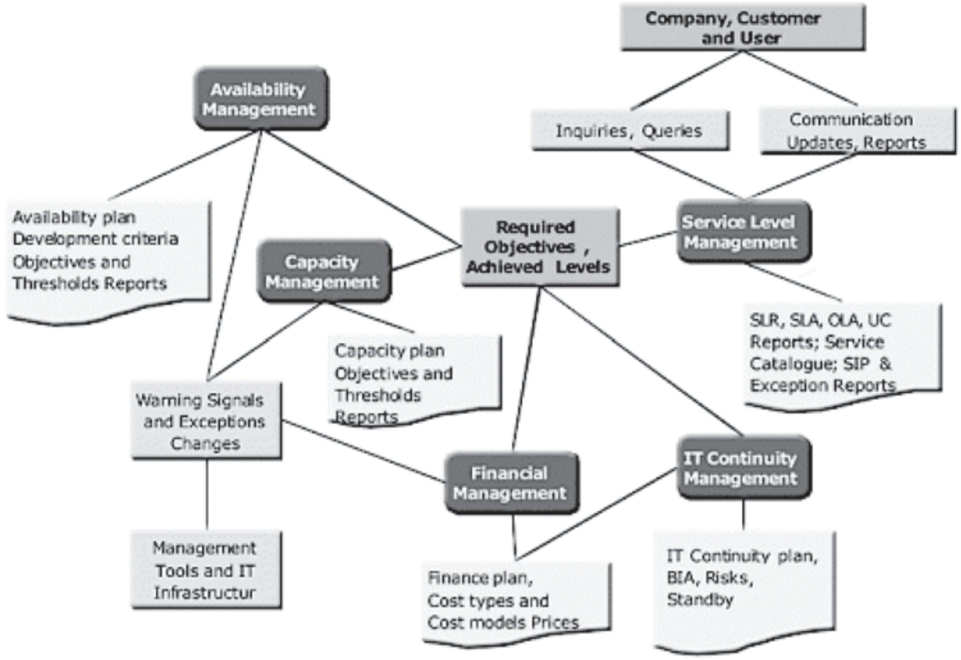
Ammenwerth et al. (2007) developed a so-called HIS-monitor to describe the strengths and weaknesses of information processing at hospitals. This monitor is a matrix whose rows represent several quality indicators while the columns define the necessary processes and subprocesses of patient care. The matrix is filled out during standardized interviews with hospital staff. Thus, one can reveal the processes that are not sufficiently supported by IT.

Table 2. Part of the indicator tree

Function level Availability of application infrastructure Failure time Applications Basic services Hardware Network Reaction time/problem-solving time Number of problems Number of problems solved within one day Completeness of medical record Ratio of digital images Ratio of released documents User satisfaction Functionality Availability Support …
Dissemination level …
…

ITIL is an example for a reference model for procedures. It defines the necessary management tasks at tactical level (service delivery, Figure 1) and operational level (service support, Figure 2).

Figure 1. Tasks and objects of service delivery (from Ammenwerth et al., 2007)



The advantage of ITIL for the alignment of IT with business objectives is reported (Kashanchi & Toland, 2006).

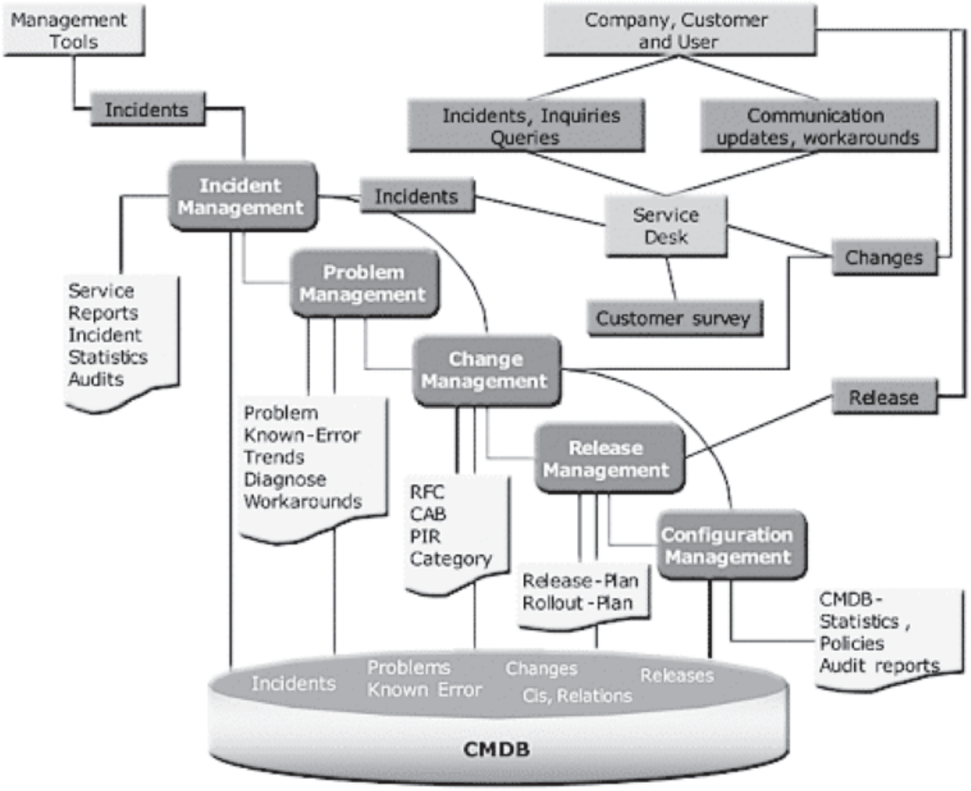
An example of a reference model for a hospital information system is the requirements index for information processing in hospitals (Ammenwerth, Buchauer, & Haux, 2002). German experts established the index in a consensus-based, top-down, and cyclic manner. Each functional requirement was derived from information processing functions and subfunctions of a hospital. It contains 233 functional requirements and 102 function-independent requirements. The functional requirements are structured according to the primary care process from admission to discharge, handling of patient records, work organization and resource planning, hospital management, research, and education. For example, with the index, one can find out the ratio of implemented functions.

Only three examples of evaluation studies are mentioned here, two of those were conducted and published by the first author. A method for the selection of software for a subsystem of HIS is described in Graeber (2001). An investigation of user satisfaction with clinical workstations was published in Graeber (1997). Machan, Ammenwerth, and Schabetsberger (2006) published the rather comprehensive and understandable description of an evaluation project to assess the electronic transmission of medical findings. Evaluation projects of the last 20 years can be found in the Web-based inventory of evaluation studies in medical informatics (evaldb.umit.at). The database can be searched with keywords. Many entries may be used as patterns for successful evaluation studies in fields of HIS.

Problems and Challenges

Often an insufficient organization of IM is the main obstacle for an effective HIS monitoring. This problem includes the lack of highly qualified staff for ambitious management tasks. Sometimes the objectives of IM are not adequate defined or they

Figure 2. Tasks and objects of service support (from Ammenwerth et al., 2007)



are not consequently derived from the enterprise goals (Brigl et al., 2005). Also a general deficiency of awareness of the importance of monitoring and controlling as well as insufficient consideration of the needs of customers and users can inhibit the establishment of an IM resp. ITSM structure at health care institutions.

A further problem is the development from *hospital* information system to *health care* information system. A modern HIS encompasses many different health care organizations and institutions with different IT infrastructures. This complexity makes a comprehensive and effective IM very difficult.

Although the successful use of BSC in health care sector is described (Stewart & Bestor, 2000; Protti, 2002), its application for HIS monitoring yields some new aspects. Especially the following success factors have to be considered:

- The method must be strongly supported by the enterprise management
- The application of BSC requires a lean management. Otherwise a schism may occur between the management and the need to get detailed understanding of work processes and motivation from staff (Brender, 2006, p. 86)
- An early and continuous communication with employees about the purpose and results of BSC is needed
- All involved people must have an open mind for definition of perspectives, objec-

tives, indicators, and measures as well for the interpretation of results
- One should prefer less but significant indicators
- IT-support of BSC is not compulsory, but helpful. One should strive for the integration of BSC in a data warehouse system
- The BSC has to be evaluated periodically

Although the effort for the development of BSC can be considerable, its use for monitoring is very functional. It helps to translate the vision of a health care institution and to gain consensus, to communicate the objectives, to link goals with strategy, to allocate resources, and to provide feedback and ensure learning. It is an efficient way to link day-to-day operating activities to the strategic objectives.

A suitable model of HIS is an important prerequisite for an efficient IM. With the 3LGM² not only technical and semantic aspects but also computer-based and paper-based information processing are integrated in the model. Deficiencies in the current state of HIS can be detected and hence the quality of information processing can be assessed. Such a model can be the basis of the strategic information management plan (Brigl et al., 2005) as well as of economic analyzes (Kutscha et al., 2006). A disadvantage of 3LGM² is the static view. For modeling of dynamic aspects a business process metamodel (e.g., ARIS at www.ids-scheer.com/international/english/products/53961) has to be used.

Contrarily to other branches, reference models for the information management in health care are seldom. A cause may be that most models are too specific and not suited as reference. These restrictions concern the BSC too. Therefore the development of valid reference models for HIS is a major challenge.

Rapid changes in technology (e.g., telehealth) and increasing complexity of HIS cause also new conditions for evaluation projects, for example.

- Studies must be carried out in different types and size sites, with different HIS components and different groups of users
- People, organizational, social, and ethical issues must be taken into account
- Evaluation aspects must be incorporated into all phases of a project
- Importance and effect of formative evaluations are increasing

Problems and challenges of evaluation projects in medical informatics are discussed detailed in Kaplan and Shaw (2004).

REFERENCES

Ammenwerth, E., Brender, J., Nykänen, P., Prokosch, H. U., Rigby, M., & Talmon, J. (2004). Visions and strategies to improve evaluation of health information systems—Reflections and lessons based on the HIS-EVAL workshop in Innsbruck. *International Journal of Medical Informatics*, *73*, 479–491. doi:10.1016/j.ijmedinf.2004.04.004

Ammenwerth, E., Buchauer, A., & Haux, R. (2002). A requirements index for information processing in hospitals. *Methods of Information in Medicine*, *41*(4), 282–288.

Ammenwerth, E., & de Keizer, N. (2006). *A Web-based inventory of evaluation studies in medical informatics.* Retrieved February 12, 2008, from evaldb.umit.at

Ammenwerth, E., Ehlers, F., Hirsch, B., & Gratl, G. (2007). HIS-monitor: An approach to assess the quality of information processing in hospitals. *International Journal of Medical Informatics*, *76*, 216–225. doi:10.1016/j.ijmedinf.2006.05.004

Ammenwerth, E., Graeber, S., Herrmann, G., Buerkle, T., & Koenig, J. (2003). Evaluation of health information systems – Problems and challenges. *International Journal of Medical Informatics*, *71*(2-3), 125–135. doi:10.1016/S1386-5056(03)00131-X

Brender, J. (2006). *Handbook of evaluation methods for health informatics*. Burlington: Elsevier Academic Press.

Brigl, B., Ammenwerth, E., & Dujat, C. (2005). Preparing strategic information management plans for hospitals: A practical guideline. *International Journal of Medical Informatics*, *74*, 51–65. doi:10.1016/j.ijmedinf.2004.09.002

Friedman, C. P., & Wyatt, J. C. (1997). *Evaluation methods in medical informatics*. New York: Springer.

Graeber, S. (1997). Application of clinical workstations: Functionality and usability. *Clinical Performance and Quality Health Care*, *5*(2), 71–75.

Graeber, S. M. (2001). How to select a clinical information system. In *Proc AMIA Symp*. (pp. 219-223).

Haux, R., Winter, A., Ammenwerth, E., & Brigl, B. (2004). *Strategic information management in hospitals.* New York: Springer.

ICH Harmonised Tripartite Guideline—Guideline for good clinical practice E6. (2006). Retrieved February 12, 2008, from http://www.ich.org/LOB/media/MEDIA482.pdf

Kaplan, B., & Shaw, N. T. (2004). Future directions in evaluation research: People, organizational, and social issues. *Methods of Information in Medicine*, *43*(3), 215–231.

Kaplan, N., & Norton, D. (1992). The balanced scorecard – measures that drive performance. *Harvard Business Review*, *70*(1), 71–79.

Kaplan, N., & Norton, D. (2000). *The strategy-focused organization: How balanced scorecard companies thrive in the new business environment*. New York: McGraw-Hill.

Kashanchi, R., & Toland, J. (2006). Can ITIL contribute to IT/business alignment? *Wirtschaftsinformatik*, *48*(5), 340–348. doi:10.1007/s11576-006-0079-x

Kutscha, A., Brigl, B., & Winter, A. (2006). Modeling economic aspects of hospital information systems to give decision support for strategic information management. *Studies in Health Technology and Informatics*, *124*, 672–678.

Machan, C., Ammenwerth, E., & Schabetsberger, T. (2006). Evaluation of the electronic transmission of medical findings from hospitals to practitioners by triangulation. *Methods of Information in Medicine*, *45*(2), 225–233.

Protti, D. (2002). A proposal to use a balanced scorecard to evaluate information for health: An information strategy for the modern NHS (1998-2005). *Computers in Biology and Medicine*, *32*(3), 221–236. doi:10.1016/S0010-4825(02)00017-3

Stewart, L. J., & Bestor, W. E. (2000). Applying a balanced scorecard to health care organizations. *Journal of Corporate Accounting & Finance*, *11*(3), 75–82. doi:10.1002/1097-0053(200003/04)11:3<75::AID-JCAF12>3.0.CO;2-Y

Winter, A., Ammenwerth, E., & Bott, O. J. (2001). Strategic information management plan: The basis for systematic information management in ospitals. *International Journal of Medical Informatics*, *64*, 99–109. doi:10.1016/S1386-5056(01)00219-2

Winter, A., Brigl, B., & Wendt, T. (2003). Modeling hospital information systems. Part 1: The revised three-layer graph-based meta bodel 3LGM2. *Methods of Information in Medicine*, *42*(5), 544–551.

Winter, A. F., Winter, A., Becker, K., Bott, O., Brigl, B., & Gräber, S. (1999). Referenzmodelle für die Unterstützung des Managements von Krankenhausinformationssystemen. *Informatik . Biometrie und Epidemiologie*, *30*(4), 173–189.

KEY TERMS AND DEFINITIONS

Balanced Scorecard: The balanced scorecard (BSC) is a *management* tool that enables organizations to clarify their vision and strategy and translate them into action. Using BSC, the manager may establish a "balanced" situation between the traditional financial measures and other success factors of an organization. The BSC combines the continuous measurement of performance with a reviewing and refinement strategy as well an ongoing evaluation process. The basic terms are so-called perspectives, for example, potentials (learning and growth), internal processes, customers, and financial perspective. For each perspective, strategic objectives, indicators, and measures to achieve these objectives must be defined.

Evaluation: Evaluation is the act of measuring or exploring properties of HIS (in planning, development, implementation, or operation), the result of which informs a decision to be made concerning that system in a specific context. Contrarily to continuous data collection, evaluation studies are carried out to answer special questions, usually in form of a project with a clear time limit. When possible, for such studies the same criteria and methods as for clinical trials should be applied.

Indicators and Characteristic Values: Indicators are variables whose values (characteristics values) represent an aspect of HIS. To discern good and bad quality of information processing and to assess the achievement of goals, one has to compare the current value of indicator with one or more predefined reference values.

IT Controlling: In this context, the term controlling (or more precisely IT controlling) is restricted to the tasks of information acquisition and data collection as basis for decisions of IM. For this purpose IT controlling applies different approaches and methods, for example, the continuous measuring and interpretation of indicators and characteristic values explaining the current state of HIS, or the realization of evaluation studies.

IT Service Management: Beside the internal business processes, the focus of monitoring should be the external outcome, as well. To provide an excellent service for all users of HIS and at last to reach a maximum of customer (patient) satisfaction, nowadays the appropriate management tasks are embraced by the term IT service management (ITSM). There are several frameworks describing an architecture for installing and maintaining ITSM. The most known framework is the IT infrastructure library (ITIL), which defines the necessary management processes at tactical level (service delivery) and operational level (service support).

Monitoring: Monitoring of HIS means the observation as to whether the directives and objectives defined in the strategic information management plan will be achieved, and whether the HIS is able to fulfill the required tasks. Therefore the IM must be able at any time to assess the state of the HIS using quality criteria which can be derived from the objectives. The tasks of monitoring may be linked to strategic level (monitoring of the achievement of strategic information management plan), tactical level (monitoring of projects), and operational level (operational monitoring, that is, verifying proper working and effectiveness of all HIS components).

Reference Model: A reference model presents a kind of model patterns for a certain class of aspects. It can be used to derive a specific model or for purpose of comparison. Comparing a specific model of HIS (or subsystem) with a reference model congruencies and differences may be stated and used for planning and direction of HIS.

This work was previously published in Encyclopedia of Healthcare Information Systems, edited by N. Wickramasinghe & E. Geisler, pp. 941-949, copyright 2008 by Medical Information Science Reference (an imprint of IGI Global).

Chapter 1.6

IT Benefits in Healthcare Performance and Safety

Stephen Bolsin
Melbourne University, and The Geelong Hospital, Australia

Mark Colson
The Geelong Hospital, Australia

ABSTRACT

There is no doubt that carefully designed IT solutions enhance the capture of performance and critical incident reporting data in clinical environments. This chapter will examine the effectiveness of recent initiatives in this area and the value of the information that can be generated. While outlining the proposed savings to healthcare systems that can be anticipated by improved performance monitoring and incident reporting, the authors will also explore the additional value that the IT solutions can offer to clinicians in terms of improved learning experiences and ethical behaviour. Extensions of these applications will be discussed, with the necessary prerequisites (e.g. ease of data entry, single data entry/multiple data use, speed of data collection, rapid and accessible feedback of results, etc.) that underpin these advances. The potential barriers (e.g. technophobia, fear of performance monitoring, poor ethical standards) to successful uptake and implementation in healthcare are also considered.

DOI: 10.4018/978-1-60566-356-2.ch049

INTRODUCTION

The earliest work on accurately monitoring the success and failure of healthcare systems is attributed to Florence Nightingale and Lord Moynighan in the UK and Ernest Codman in the US. The pioneering of the professional role of nurses by Florence Nightingale in the 19th Century is well known, but her extension of healthcare analysis into the audit of hospitals is less well publicised. She worked with the British Home Secretary Lord Moynighan in producing these early audits, which, in the absence of computing power, were time consuming and extraordinary for their time (Chambler & Emery, 1997; Nuttall, 1983). Later, in the early 20th Century, a New England physician, Ernest Avery Codman, attempted a similar analysis by defining the "outputs" of a hospital and attempting to relate these to different practices. Again all of Codman's analyses were undertaken without the assistance of computers and represent a large number of calculations that can currently be undertaken by modern computers in fractions of a second. However his work was uniformly unpopular with his colleagues and he was ostracised by the local medical community

(Codman, 1914; Kaska & Weinstein, 1998). The importance of these early pioneers of audit and performance monitoring was that they assumed that individual and system performance could be measured and then optimized (Spiegelhalter, 1999). The tacit assumption that ensured their lasting unpopularity with the medical profession was that healthcare performance was not already perfect; or that system or individual error was occurring in the hospitals and health systems that they examined. Largely due to the work of these pioneers and the application of sophisticated computing programs and devices we now know much more about the frequency and cost of these adverse events in healthcare.

Errors in medicine are expensive, not only in terms of human life and the suffering they impose on patients, relatives and carers but also the financial burden that they impose on healthcare systems in the developed world (Kohn, Corrigan, & Donaldson, 1999; Lesar, Lomaestro, & Pohl, 1997; Michel, Quenon, de Sarasqueta, & Scemama, 2004; Vincent, Neale, & Woloshynowych, 2001; Wilson et al., 1995; Woods, 2000). Information about these episodes in complex healthcare delivery has only become widely available through the use of large computing and IT systems designed to collect clinical information. The most recent estimates indicate that this cost was $17-29 billion, in the US alone, in 2000 and may have contributed to between 48,000-98,000 deaths in the same period (Fenn, 2002; Kohn et al., 1999). Despite this human and financial cost, rates of adverse events do not appear to be falling, certainly in Australia and the US there is little evidence that adverse event rates are decreasing (Ehsani, Jackson, & Duckett, 2006; Wilson & Van Der Weyden, 2005).

Studies of adverse events have defined generic failings that have contributed to these identified errors (Thomas et al., 2000; Thomas et al., 2000; Wilson, Harrison, Gibberd, & Hamilton, 1999). Incident reporting in clinical medicine improves patient safety by reducing future errors. This occurs as incident reports lead to the identification of underlying generic and systemic errors and measures are put in place to prevent their recurrence (Barach & Small, 2000; Bolsin, Faunce, & Colson, 2005; Kraman & Hamm, 1999; Wolff, 1996; Wolff, Bourke, Campbell, & Leembruggen, 2001).

PERFORMANCE MONITORING

Monitoring the Performance of Healthcare Systems

The feedback of performance data to medical practitioners in healthcare has been demonstrated to improve the quality of measurable patient outcomes in several situations. Mark Chassin, as Head of Public Health in New York State, developed a comprehensive, compulsory IT-based programme for the collection and dissemination of risk-adjusted outcomes from cardiac surgery to all cardiac surgeons and hospitals undertaking cardiac surgery in New York State (Chassin, Hannan, & De Buono, 1996; Hannan, Kumar, Racz, Siu, & Chassin, 1994). Remarkably the use of the IT-enabled data collection and outcome feedback programme led to a 40% reduction in risk-adjusted mortality over a 3-year period (Hannan, Kilburn, Racz, Shields, & Chassin, 1994). Another voluntary cardiac surgery programme set up with similar goals also in the Northeast of the USA, and also employing sophisticated computing programs and enormous computing power, achieved almost identical results (O'Connor et al., 1996). This confirmed the value of measuring outcomes from complex interventions, adjusting for the patient's risk in the intervention and feeding back risk-adjusted outcomes in a sustained and systematic fashion. The importance of this work relates, in part, to the uniformity of the findings in a complex speciality of medicine (cardiac surgery), and the use of risk-adjustment to validate the process of data collection and feedback to the clinicians. However the timing of the studies also shows that the profession has known about this method of achieving quality improvement for patients for well over 10 years but made little progress to concrete implementation across many specialities.

An early concern about this type of database collection related to the anonymity of the data collected and whether the highly sensitive performance data could be accessed by anyone other than those professionals closely involved in the data collection (Green & Wintfeld, 1995). In fact these concerns proved completely unfounded. Publicity about the data collection led a North American television programme, *Newsday*, to attempt to obtain access to the information contained in the database. The television journalists mounted a legal case, in the New York courts, to obtain disclosure of the performance data. The data that they requested to be disclosed was not only of individual cardiac surgeons, or cardiologists but also of each particular hospital contributing to the data collection. Mark Chassin and the New York State Health Department vigorously defended the challenge to the secrecy of the database claiming clinicians would shun the data collection in the future if the detailed information about individual and institutional risk-adjusted performance was revealed. This persuasive argument carried some weight with the Judge, who saw the need for privacy for the profession and the survival of the database. He was able to relate the database survival to future good that the data collection and feedback would contribute to patient outcomes in the State of New York. The counter argument put forward by the journalist's legal representatives was that the information that the Department of Health had collected was so important to future patients who might be considering, or at risk of, cardiac surgery, or cardiac procedures, that the information should be made public.

This argument carried more weight with the judge and he ordered the release of all the information in the database. The response of the journalists and the press was not to publish only the risk-adjusted outcome data from the database but to publish the crude mortality rates for named individual surgeons and physicians as well as the crude mortality rates for named hospitals. Apart from the uproar within the profession in the US and across the world there was remarkably little response from the clinicians who contributed to the database. The hard work of Mark Chassin and the New York Health Department ensured that the data collection survived and has continued.

The importance of this sequence of events is that it demonstrated that anonymity and institutional clinical privacy in data collections is not a prerequisite for their success or for the clinicians contributing data to trust such data collections. This is an important conclusion and can be applied to all databases of this nature. The outcome of the court case in New York was to demonstrate that future performance monitoring projects involving sophisticated, IT systems and computer calculations as part of database analysis do not need to be set up as privileged data collections. The computer reliant, electronic performance monitoring data collections and analyses of the future do not need to be set up as secret, private or legally privileged. However when they are set up they can expect to significantly reduce morbidity and mortality rates in that medical speciality and geographical region.

Work in San Francisco also demonstrated that the feedback of outcome data in other specialities such as urological surgery also improved patient outcomes (Shortell, Bennet, & Byck, 1998). A similar data collection for cardiac surgery has been set up in the State of Victoria, Australia with regular, risk-adjusted mortality and morbidity results which are fed back to voluntarily participating cardiac surgeons (Reid et al., 2004). These data collections require a considerable amount of data input and in the case of the Victorian State programme a dedicated data input clerk is employed at each centre. However there is no reason to propose that these programmes, designed with such data entry requirements, need to be sustained with such a costly workforce. There is ample evidence that using well-designed data entry screens individual practitioners can and will correctly and continuously enter performance data into hand held computing devices (Bent, Creati, Bolsin, Colson, & Patrick, 2002; Bolsin, Faunce, & Colson, 2005).

The value of the crude or risk-adjusted outcome data from such data collections has recently been given much more emphasis by two Australian bioethicists. Stephen Clarke and Justin Oakley have proposed, in the American journal *Philosophy & Medicine*, that clinicians who do not know their own crude or risk-adjusted outcome data cannot gain *full* or *proper* informed consent from their patients (Clarke & Oakley, 2004). This ethical assertion has potential wide-reaching ramifications for clinicians and healthcare organisations. If it is not possible to obtain true informed consent from patients without a clinician knowing their mortality and complication rates it is necessary for clinicians, on their own or in specialist groups, to try to collect the necessary performance information. This assertion, if either the profession, or the healthcare industry, or most importantly the public, accepts it, has enormous implications for information technology and the future of performance monitoring data collection in health care. The logical consequence of requiring doctors and their healthcare organisations to provide prospective patients with their performance data is enormous (Bolsin, Faunce, & Oakley, 2005; Bolsin, Patrick, Colson, Creati, & Freestone, 2005; Bolsin et al., 2005). There will be an urgent requirement for detailed, reliable data collections utilising large amounts of computing power and also requiring the development of sophisticated computer programs to link doctors in particular, but health care professionals in general, to detailed data collections, housed in possibly remote databases and linked to mobile computing devices (Bolsin et al., 2005). Such devices, similar to the recently released iPhone, will be the data entry point for clinical information to be entered into the database and then disseminated with appropriate flags and restrictions (e.g. privacy, confidentiality, end-user status, security) to be used in a series of computer analyses to produce performance and outcome measures irrespective of site, location, professional speciality or grade (Bolsin et al., 2005a; Bolsin et al., 2005b; Bolsin & Freestone, 2007). This exciting vision of optimised patient care in a modern health service is not as remote as it may sound with foundational work already achieved in the Geelong Hospital in Australia and successful "proof of concept" studies published (Bent et al., 2002; Bolsin & Colson, 2003; Bolsin et al., 2005; Bolsin & Colson, 2000; Bolsin & Colson, 2003; Bolsin & Day, 1998; Bolsin et al., 2005; Bolsin & Freestone, 2007).

IT improvements, since this pioneering work was undertaken more than 10 years ago in North America, have made the processes of data entry, data collection, data collation and data analysis much quicker and easier (Bent et al., 2002; Bolsin et al., 2005; Bolsin & Freestone, 2007). There is no reason why these advances should not be incorporated into current health care programmes in order to accommodate the principles of quality improvement and quality assurance in modern healthcare systems (Garg et al., 2005).

The major challenge for IT specialists employed in the healthcare arena is to design data entry and access screens for the busy clinician, that accommodate their requirements for personal access, ease and speed of data entry. Another important consideration surrounds the addition of value or "value adding" that such portable computing devices can achieve through providing laboratory or imaging results, educational links or decision support applications (Bolsin et al., 2005a; Bolsin et al., 2005b; Bolsin & Freestone, 2007). The easily achievable goal must be simple, rapid, reliable data entry at each point of care by multiple health care professionals using mobile computing platforms; each professional obtaining extra value from the data input by simultaneously accessing their own performance data (individually analysed with personalised feedback), and the units outcome data, risk-adjusted by accepted specialist risk-adjustment algorithms. The evidence clearly demonstrates that the design, adoption and widespread use of such performance monitoring programs in clinical care would significantly reduce the occurrence of complications and death in routine and highly specialised healthcare interventions (Hannan, Kilburn et al., 1994; O'Connor et al., 1996; Reid et al., 2004; Shortell et al., 1998). Furthermore the savings attributable to such improved practice would more than pay for the introduction of the IT system proposed and would also lead to year on year savings to the health care providers involved (Bolsin, Solly, & Patrick, 2003).

Although it would appear on the face of it to be an axiom of modern healthcare, as well as a common sense conclusion, the evidence that compliance with the guidelines of Specialist Colleges or Societies in Medicine improves outcomes has been relatively hard to find. The demonstration of the value of adhering to accepted clinical guidelines from specialist societies has only recently been published (Peterson et al., 2006). In a landmark article in the New England Journal of Medicine Peterson and co-workers analysed data from a clinical trial designed to examine outcomes from patients presenting with acute myocardial infarction and acute coronary syndromes. The study examined data collected for a large multicentre, randomized, controlled trial and therefore represented the highest quality of data available in clinical medicine (Barton, 2000; Benson & Hartz, 2000; Concato, Shah, & Horwitz, 2000). Furthermore the study was able to breakdown the contributing centres into 4 groups, or quartiles, with differing compliance with the AHA & ACC guidelines for the management of Acute Coronary Syndromes (ACS) and Non-ST Elevation Myocardial Infarction (Non-STEMI). These conditions are known to the layperson as cardiac ischaemia and acute myocardial infarction or angina and heart attack respectively.

They showed that not all centres, collecting data for a multicentre trial, had the same level of adherence to specialist society guidelines (Peterson et al., 2006). Failure to comply with Specialist Guidelines in this analysis was not blindly interpreted on a simple "Yes" or "No" basis but involved examination of documentation for reasons for failure to comply. For example if a patient had a history of asthma, (when β-blockers can be contraindicated) and therefore was not prescribed β-blockers, the centre was deemed to have complied with the Guidelines. The study did not examine cutting edge or 'time critical' components of the American Heart Association (AHA) & American College of Cardiologists (ACC) guidelines, but concentrated on nine relatively simple actions in the guidelines. For example "Did the patient receive aspirin, a β-blocker, heparin or an intravenous glycoprotein IIb/IIIa inhibitor in the first 24 hours after diagnosis?". Or "Did the patient receive aspirin, a β-blocker, clopidogrel, an ACE inhibitor and a statin prior to discharge?". The detailed analysis of the large computer database of institutional performance and outcome, demonstrated that those centres that had greater compliance with American Heart Association and American College of Cardiologists (AHA & ACC) Guidelines had a lower mortality than those centres that had much lower compliance with the guidelines (Peterson et al., 2006).

When the mortality for each group of centres was examined there was a statistically significant and graded *increase* in mortality associated with the *decrease* in compliance with the AHA & ACC guidelines. The quantative expression of this effect was that there was a 10% reduction in mortality, for each condition (ACS or Non-STEMI) for every 10% increase in process compliance. Given that the maximum compliance of any centre was 90% and the worst compliance was <40% there is obviously significant room for improvement and reduction in mortality.

We know many of the components of optimal care that are currently not being delivered are routine items in an ideal clinical pathway (Forkner, 1996; Hindle & Yazbeck, 2005; Spur, Flammini, & Goulart, 1996). The clinical pathway is an ideal composite amalgam of items of care delivered by many different health care professionals and includes multi-professional features such as drug delivery, coordination of care (e.g. arranging appointments prior to hospital discharge), communication (e.g. discharge summary) and checking (e.g. Laboratory or imaging results) (Choong, Langford, Dowsey, & Santamaria, 2000; Forkner, 1996; Swanson, Yellend, & Day, 2000). We know that often in complex care situations important steps are missed because of "human error" but we also know that the memory of an appropriately programmed computer can supplement and improve on the fallibility of human behaviour (Garg et al., 2005; Kohn et al., 1999; Wilson et al., 1995; Wilson & Van Der Weyden, 2005) (See incident Reporting below). Consequently if the mobile computing platform can be designed to provide this extra connectivity between different members of the health care team such as doctors, nurses, pharmacists, primary care physicians, community nurses, dietitians, etc, it is possible to create a connected network of health care workers informed about each patient's clinical pathway, knowledgeable about relevant immediate, medium and long-term future care plans and goals and connected to all relevant secure information sources, with automated reminders on critical components of care about the patients for whom they have been, are and will be caring (Bolsin et al., 2005; Bolsin & Freestone, 2007; Garg et al., 2005).

The value that computing and Information Technology are contributing to the ability to analyse outcomes from complex medical processes is currently enormous but widely underutilized (Garg et al., 2005). IT-based analyses similar to the one quoted are capable of identifying patterns of practice and assigning causes of both good and bad performance, linked to patient outcomes. This incredibly constructive and valuable application of computing, power, Information Technology and programming must be applied to all aspects of health system activity. Even if healthcare managers or clinicians are reluctant to improve process compliance surely their patients would be urging optimal compliance at almost any cost.

Individual Performance Monitoring

The errors identified in the Quality in Australian Healthcare study have been attributed to different generic causes (Wilson et al., 1999).

These include:

- 35% complication/failure of technical performance
- 15.8% decision action failure
- 11.8% failure to arrange procedure/investigation/consultation
- 10.9% lack of care/attention

Many of the errors in the first category (complication/failure of technical performance) could be reduced by the adoption of simple IT solutions that are currently available (Bent et al., 2002; Bolsin, 2000; Bolsin & Colson, 2003a; Bolsin et al., 2005; Bolsin & Colson, 2003b; Freestone, Bolsin, Colson, Patrick, & Creati, 2006; Garg et al., 2005). Work in the Geelong hospital, Victoria, Australia demonstrated that accredited anaesthetic trainees provided with a simple and 'easy to use' program on a portable, handheld computing device would log their success or failure (i.e. performance) of practical clinical procedures for subsequent analysis and monitoring (Bent et al., 2002).

One of the important components of the data analysis and feedback was the employment of a relatively 'simple to comprehend' technique for the analysis and display of performance data. The technique used was the 'Cumulative Summation' analysis or Cusum (Page, 1954). This industrial statistical methodology had been developed in the 2^{nd} World War, but had been transferred to the surgical arena by MRC Research Statistician, David Spiegelhalter, in a seminal paper examining outcomes from paediatric cardiac surgery (de Leval, Francois, Bull, Brawn, & Spiegelhalter, 1994). We decided, in Geelong, to employ this sensitive analysis of the performance data logged by the anaesthetic trainees because it provided reliable early warning of a performance deviation from normal. The measurable change in performance could be in a deleterious direction that required remedial management, as patients and healthcare managers would want, to successfully ensure the quality of the healthcare delivered in their organization. However the analysis is also able to statistically identify meritorious performance indicating that skills had been acquired, competence achieved and training in this area could be completed (Bolsin, 2000; Bolsin & Colson, 2000; Bolsin et al., 2003). This ability of the analysis to routinely identify the acquisition and maintenance of competence is an important requirement in healthcare delivery.

Assessment of competence has been one of the major challenges encountered by healthcare regulators in recent years (GMC, 2006; Irvine, 2004, 2006a; Irvine, 2006b; Irvine, 2004). Lack of competence led to many of the publicized medical scandals in several countries (Kennedy, 2001; Sibbald, 1998; Van Der Weyden, 2005). The manifest inability of healthcare professionals and regulators to agree measures of competence has been surprising despite recommendations in journals of healthcare quality (Bolsin, 2000; Bolsin & Colson, 2003a; Bolsin et al., 2005; Bolsin & Colson, 2000; Bolsin & Colson, 2003b; Bolsin et al., 2005; Bolsin et al., 2003). The Cusum test provides a simple and effective method for making this assessment and is explained in more detail below. While some clinicians are already using the Cusum analysis to assess competence in training and routine practice the test is by no means routinely applied (Lim, Soraya, Ding, & Morad, 2002). While I do not consider that the Cusum test is a final goal in the measurement of competence and assessment of practical tasks in healthcare I believe that it is a good starting point for the objective assessments that healthcare professionals, regulators and patients will require.

The 'Cusum' Statistical Test

Cusum (an invented word derived from Cumulative Summation) is a statistical method first described during World War 2, when it was used to ensure the quality of bullets in a production line (Page, 1954). Cusum extends the concept of plotting cumulative failure using boundary lines, such that instead of reaching an endpoint (crossing a boundary line) after which the process must be re-started, the process is continuous, and can continue indefinitely. The beauty of Cusum is that to create a Cusum plot, one need only define four parameters. These are:

1. The acceptable failure rate
2. The unacceptable failure rate
3. Alpha – or the risk of making a type 1 statistical error.
4. Beta – or the risk of making a type 2 statistical error.

In the biological literature, by convention, alpha and beta are normally set at 0.05 and 0.20. However, when performing Cusum analysis, setting both alpha and beta to 0.10 dramatically simplifies the graphical representation such that acceptable and unacceptable boundary lines are superimposed. This enables the plot to be quickly interpreted since a plot spanning two boundary lines in the positive direction confirms unacceptable performance, while a plot spanning two lines in the negative direction confirms acceptable performance. (See Figures 1 and 2)

At a higher level, the greatest power of Cusum analysis is that performance data can be analysed in a rigorously scientific fashion, which is therefore detached from the often emotive

Figure 1. A cumulative failure graph showing acceptable performance (Bolsin 2000; Bolsin and Colson 2000)

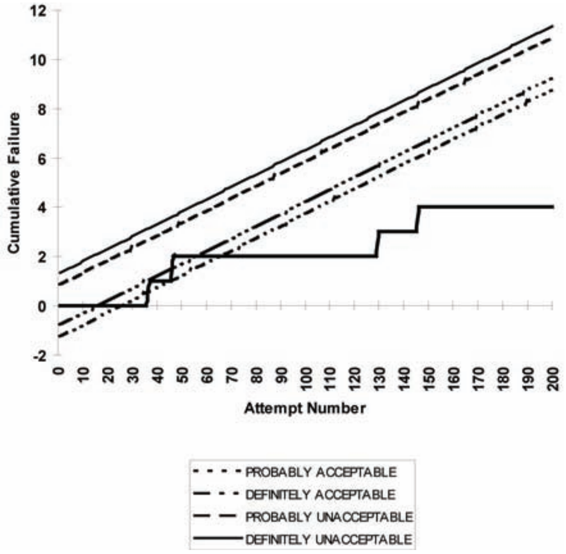
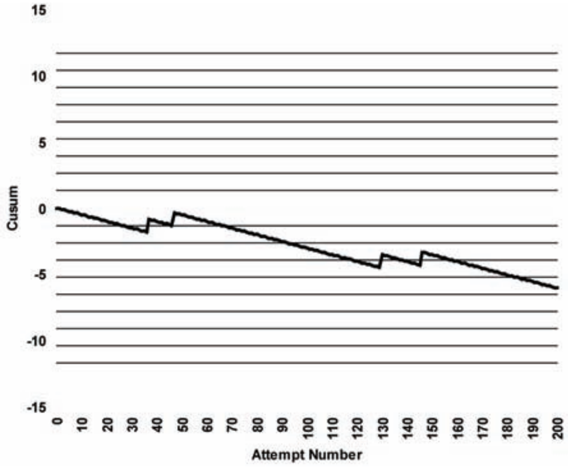


Figure 2. A Cusum graph showing the same data as used in Figure 1 and showing acceptable performance and acquisition of competence (Bolsin 2000; Bolsin and Colson 2000)



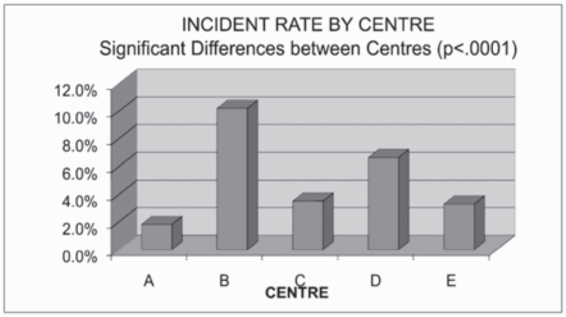
nature of the findings. Without Cusum, a group of doctors would often have great difficulty analyzing raw performance data and reaching a conclusion of unacceptable performance. With Cusum, they don't actually need to agree with any such conclusion, but simply with the four Cusum parameters. The Cusum process itself does the rest!

These records also proved invaluable in demonstrating competence when complications attributable to the procedures logged were encountered (Bolsin et al., 2003; Lim, Soraya, Ding, & Morad, 2002). It must be emphasised that the most important factors contributing to the reliable collection of this data were the ease and speed of data entry by the individuals performing the procedure at the point of care (Bent, personal communication). The financial savings, attributable to the collection of such performance records in the single specialty of anaesthetics, and relating to anaesthetic trainees alone, have been calculated (Bolsin et al., 2003). These have shown that the collection of the performance data alone justifies the expenditure on the devices and data collection system without consideration of their added contribution to incident reporting, improved ethical behaviour and educational and learning capacity (Bolsin et al., 2005a; Bolsin et al., 2005b; Bolsin et al., 2005c). Subsequent programs were developed for specialist practice in Obstetrics and Gyneacology but have not been taken up widely by the profession. The reasons may include lack of support from the Specialist Associations and Royal Colleges; fear of formal performance monitoring in the aftermath of several well-publicised medical scandals including the Manitoba paediatric cardiac surgery scandal in North America (Sibbald, 1998), the Bristol Royal Infirmary paediatric cardiac surgery scandal in the UK (Kennedy, 2001) and the Bundaberg surgery scandal in Australia (Van Der Weyden, 2005); a poor business model that made individual subscription to the program too expensive for individuals; an Institutional (Hospital level) lack of desire to support clinical performance monitoring; an Organizational (State level) lack of vision to perceive the widespread benefits of clinical performance monitoring; a professional fear of technology, particularly Information Technology (IT) in clinical settings (Bolsin et al., 2005b; Bolsin et al., 2005c).

In the context of individual performance monitoring it is well worth noting that the application of complex risk-adjustment is not necessary to detect abnormally bad patterns of medical care. In the infamous case of Dr Harold Shipman, a UK GP, who is thought to have murdered over 200 of his patients, routine analysis of crude data from his practice would have detected a statistically significant elevation of the mortality rate in his practice. The problem would have been flagged by the comparison of crude mortality rates from Dr Shipman's practice and comparing them with the average from other practices in the UK (Spiegelhalter et al., 2003). The retrospective analysis undertaken by Treasure and Co-workers demonstrated that had a routine data collection with routine analysis of crude mortality data been in place it is likely that Dr Shipman's murderous behaviour could have been detected at a much earlier stage (after about 20 excess deaths) and that as more than 180 unnecessary deaths attributable to Dr Shipman's psychopathic behaviour could have been prevented (Spiegelhalter et al., 2003). In this case all that was required was an IT supported data collection that recorded the number of deaths in each General Practice in the UK. Such simple data could have prevented the greatest serial killer in the UK from murdering scores of patients under the innocent cover of his routine General Practice.

However, I believe that the quality assurance benefits of integrated performance monitoring should not be confined to medical professionals (Bolsin et al., 2005b; Bolsin & Colson, 2003; Bolsin et al., 2005c; Bolsin et al., 2003). The quality improvement and financial benefits of all health care professionals entering individual and unit performance data into personalized mobile computing devices to achieve standardized uniform data collections with educational and decision support are achievable now. Unfortunately the vision of the health care professions and associated bureaucracy has not kept pace with the evolution of both medical ethicists and computing and IT. Consequently the solutions presented by the use of novel new IT devices and user-friendly programs are not harnessed or engaged in the drive for sustainable improvements in quality of care and patient safety.

Figure 3. A bar chart of incident reporting rates from different hospitals (Bent, Creati et al. 2002; Freestone, Bolsin et al. 2006)



INCIDENT REPORTING

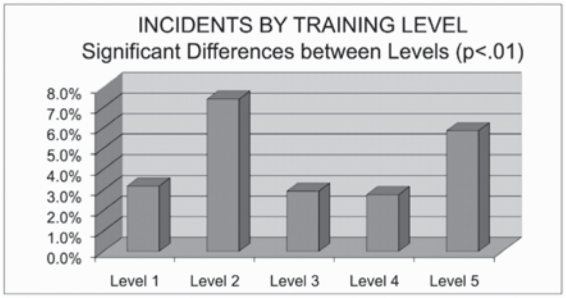
Considering again the causes of 'medical error' identified in the Quality in Australian Healthcare study there are 3 causes (highlighted below) that can be grouped together as 'system error' (Wilson et al., 1999). The key to reducing such errors in healthcare rely on the accurate detection of adverse events, detailed analysis of the causes and introduction of 'forcing functions' to prevent the causes from occurring again:

- 35% complication/failure of technical performance
- 15.8% decision action failure
- 11.8% failure to arrange procedure/investigation/consultation
- 10.9% lack of care/attention

Such work has been undertaken by Alan Woolf in a small hospital in Victoria, Australia where he has demonstrated a reduction in adverse events by such activity (Woolf, Bourke, Campbell, & Leembruggen, 2001). However Dr Woolf and his co-workers required review of the patient's case notes by clerical staff to identify adverse events before they were analysed by a medical group to implement safety strategies. This Limited Adverse Occurrence Screening (LAOS) is used because incident reporting rates in the hospital at that time were not high. In fact poor incident reporting has been a feature of all modern healthcare systems (White, 2004; Kohn, Corrigan, & Donaldson, 1999; Bolsin, 2005c). Work in the Geelong hospital has identified that the application of cutting edge IT solutions to incident reporting in clinical practice can favourably impact incident reporting rates achieving 99.5% (Bent et al., 2002; Freestone et al., 2006). Moreover the analysis of such incident reporting databases provides additional interesting information about the distribution and occurrence of critical incidents in the clinical setting. Unfortunately the preliminary analysis of the data from selected hospitals in Australia underscores the lack of information currently available in this area. For example is hospital A (Figure 3) safer than hospital B or vice versa? Hospital A with a high incident reporting rate may be the safest hospital with a high level of incident reporting attributable to an active safety culture. Conversely hospital A may be a hospital in which many errors occur because of a poor safety culture, lack of incident reporting, and poor safety record. Only analysis of accumulated data over several years showing declining standardised incident reporting rates would confirm improving patient safety.

Another recent debate in healthcare relates to the safety of hospitals at night. The IT data collection provided a robust solution. We were able to use the same data to demonstrate that incident reporting rates did not rise in the evenings or at night. This confirmed that the hospital was as safe,

Figure 4. A bar chart of incident reporting rates from grades of registrar trainee (Bent, Creati et al. 2002; Freestone, Bolsin et al. 2006)



for anaesthetic trainees, during the night and evening as it was during the day. This data was used to inform and reassure the Clinical Governance structures within the hospital. (See Figure 4.)

Incident Reporting, Ethical Behaviour and Cultural Change

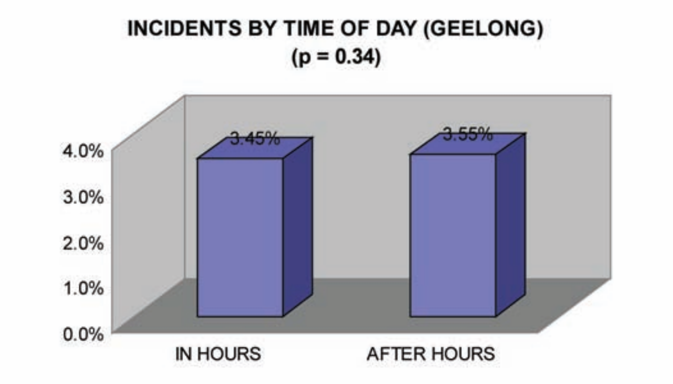
One of the most fascinating linkages demonstrated by the introduction of modern IT devices and programs in the field of patient safety has been that between IT adoption and improved ethical behaviour (Bent et al., 2002; Bolsin et al., 2005a; Bolsin et al., 2005b; Bolsin et al., 2005c; Freestone et al., 2006). The work undertaken at Geelong Hospital, Victoria, shows that incident reporting programs, employing mobile computing devices with programs designed to facilitate incident reporting in the clinical setting can achieve very high levels of incident reporting (Freestone et al., 2006). Contrasted with the reluctance of many clinical staff to report poor care or critical incidents in clinical medicine the 99.5% incident reporting rate identified in this study is an indication of improved ethical behaviour (Bolsin et al., 2005c; Evans et al., 2006; Firth-Cozens, 2002; Firth-Cozens, Firth, & Booth, 2003; Kingston, Evans, Smith, & Berry, 2004; White, 2004).

The important link between IT and medical ethics represents a conceptual advance in thinking in this complex area of medical behaviour. It also seems to demonstrate that all aspects of medical practice and thinking can be positively impacted by the adoption of well-designed IT programs. (See Figure 5)

PATIENT SAFETY

The evolution of personal computer technological has been almost exponential since IBM released the first Personal Computer in 1981. Hardware speed and capacity has increased roughly accordingly to Moore's Law, which states that the number of components on a computer chip doubles every 18 months or so. As computing hardware improved, the software has had to evolve to accommodate and exploit the dramatic increase in prevailing processor power and speed. For many years, the sole axis of computer evolution revolved around faster and more powerful desktop devices. More recently, pioneers such as Stanford University began networking multiple personal computers together to create a network. The benefits of networking were immediately apparent – initially they were limited to sharing of data and messaging. However, vastly more sophisticated applications began to emerge which ultimately resulted in the development of the World Wide Web or Internet, as we know it today. While the Internet initially utilized a hard-wired connection between all computers, this slowly gave way

Figure 5. A bar chart of incident reporting rates according to "Time of Day" in the Geelong Hospital (Bent, Creati et al. 2002; Freestone, Bolsin et al. 2006). ["In Hours": 8.00am-18.00pm; "Out of Hours": 18.00pm-08.00am]



to wireless connections. Simultaneously, ever smaller computing devices were being created. The marriage of the two technologies – wireless and truly portable small devices resulted in the highly functional Personal Digital Assistants or PDA's that are commonly used today.

Nowadays, we have available very powerful yet small PDA's utilizing long-range wireless networking connections. The combination of functions that can now be incorporated into a device the size of a mobile phone is now enormous and epitomised by the 'iPhone', which has access to the internet, e-mail, telephone network and all the commonly available computing programmes (Mac Corporation, 2008). The arrangement is ideally suited to a highly portable and personal error performance reporting system and yet sadly, the use of such applications is limited and patchy, owing to a dearth of suitable software systems. This is likely to change in the near future, and the responsibility for effecting this change must inevitably fall upon the medical profession and healthcare managers and bureaucrats. One of the intriguing explanations for the failure of healthcare managers, professionals and bureaucrats to take up these obviously beneficial advances in computing and IT in the healthcare arena has been proposed by Avril Henry, who describes some of the differences between the younger Generations X & Y and their older Baby Boomer and Veteran counterparts. Baby Boomers and Veterans are "technophobe" mistrusting or misunderstanding technical and electronic devices and lacking spontaneous innovation to learn in this area. By contrast the Generations X & Y are "technophile" and spontaneously search for and adopt innovations in the areas of computing and IT (Henry, 2006). Furthermore, as Avril Henry has pointed out, these surveys reveal that Generation X, and Generation Y want learning opportunities in the work environment and value such opportunities (Henry, 2006). The learning that these junior members of the workforce do value is internet and web-based education that can be easily provided by mobile computing platforms (Bolsin & Fraser, 2006; Bolsin et al., 2005c). An interesting comment in Ms Henry's analysis is that Gen X and Gen Y members of an organisation's workforce will value an employer that provides such learning opportunities and leave organisations that do not provide them (Henry, 2006). At times of workforce shortage in medical and nursing ranks linking learning to cutting edge technological devices in an improved ethical environment are highly likely to improve recruitment and retention in modern healthcare organisations.

Table 1.

Generation	Birth year	Characteristic Features (85% conform)
Veterans	1935-50	Technophobe; poor ethics; prefer classroom learning
Baby Boomers	1951-65	Technophobe; poor ethics; prefer classroom learning
Generation X	1966-80	Technophile; want ethical leaders; IT/internet learning
Generation Y	1981-95	Technophile; more ethical; prefer IT/internet learning

As Avril quite rightly puts it "These are the generations (X & Y) that the baby boomers and veterans hand the television remote to when they want something more than just a channel change". Unfortunately these technophobe generations, who hold the positions of influence and authority in healthcare are also holding back the exciting innovation and development, that must be adopted, to enable the professions, and more importantly the patients, to gain from the opportunities of improved health care that exist through IT and computing advances.

While many feel threatened by such a scenario, a more enlightened view would be that this narrative has much to offer the modern health care professional. Portability is crucial to the adoption of such solutions. Physicians have shown a reluctance to embrace IT solutions, which require queuing to use a fixed desktop PC. The device needs to be portable and personal not just for the convenience of the user, but also for the extra functionality that this mobility will confer. (See Table 1)

CONCLUSION

Current health care delivery can be improved in areas of individual performance, unit performance monitoring, incident reporting and adherence to approved clinical pathways (Bent et al., 2002; Bolsin, 2000; Bolsin & Colson, 2003; Bolsin et al., 2005b; Bolsin et al., 2005c; Bolsin & Freestone, 2007; Bolsin et al., 2003a; Freestone et al., 2006; Garg et al., 2005; Hannan, Kilburn et al., 1994; Peterson et al., 2006). The use of mobile computing platforms with imaginative and sophisticated programming has allowed and will allow many of these desirable objectives to be achieved relatively easily (Bent et al., 2002; Bolsin et al., 2005c; Bolsin & Freestone, 2007; Freestone et al., 2006). The unanticipated benefits of improved ethical behaviour derived from such well-programmed, mobile computing devices confirms the value of such interventions and the use of modern technology (Bolsin et al., 2005a; Bolsin et al., 2005c; Bolsin et al., 2005b). The technical ability and technophile characteristics of the next 2 generations of healthcare employees should encourage the extension of existing, and development of further, similar imaginative programs and devices. The linkage of these programmed devices to educational and learning opportunities via educational websites and programmes, which can improve recruitment and retention of junior staff, represents another exciting, but underdeveloped, facet of computing and information technology in the healthcare arena.

REFERENCES

Barach, P., & Small, S. D. (2000). Reporting and preventing medical mishaps: Lessons from nonmedical near miss reporting sytems. *BMJ (Clinical Research Ed.)*, *320*(7237), 759–763. doi:10.1136/bmj.320.7237.759

Barton, S. (2000). Which clinical studies provide the best evidence? *BMJ (Clinical Research Ed.)*, *321*(7256), 255–256. doi:10.1136/bmj.321.7256.255

Benson, K., & Hartz, A. J. (2000). A comparison of observational studies and randomised controlled trials. *The New England Journal of Medicine*, *342*(25), 1878–1886. doi:10.1056/NEJM200006223422506

Bent, P., Creati, B., Bolsin, S. N., Colson, M., & Patrick, A. (2002). Professional monitoring and critical incident reporting using personal digital assistants. *The Medical Journal of Australia*, *177*(9), 496–499.

Bolsin, S. (2000). Routes to quality assurance: Risk adjusted outcomes & personal professional monitoring. *International Journal for Quality in Health Care*, *12*(5), 367–369. doi:10.1093/intqhc/12.5.367

Bolsin, S., & Colson, M. (2003). The use of statistical process control methods in monitoring clinical performance. *International Journal for Quality in Health Care*, *15*(5), 445. doi:10.1093/intqhc/mzg070

Bolsin, S., Faunce, T., & Oakley, J. (2005a). Practical virtue ethics: Healthcare whistleblowing and portable digital technology. *Journal of Medical Ethics*, *31*(10), 612–618. doi:10.1136/jme.2004.010603

Bolsin, S., & Fraser, B. (2006). The use of a PDA programme to improve patient safety. *Health Care Risk Report*, *12*(4), 18–19.

Bolsin, S., Patrick, A., Colson, M., Creati, B., & Freestone, L. (2005b). New technology to enable personal monitoring and incident reporting can transform professional culture: The potential to favourably impact the future of healthcare. *Journal of Evaluation in Clinical Practice*, *11*(5), 499–506. doi:10.1111/j.1365-2753.2005.00567.x

Bolsin, S. N., & Colson, M. (2000). Use of Cusum techniques in performance monitoring. *International Journal for Quality in Health Care*, *12*(5), 433–438. doi:10.1093/intqhc/12.5.433

Bolsin, S. N., & Colson, M. (2003). Making the case for personal professional monitoring in healthcare. *International Journal for Quality in Health Care*, *15*(1), 1–2. doi:10.1093/intqhc/15.1.1

Bolsin, S. N., & Day, C. J. (1998). Risk evaluation, quality of practice, and audit. In G. Hall & M. Morgan (Eds.), *Short practice of anaesthesia* (First ed., pp. 111-122). London: Chapman Hall.

Bolsin, S. N., Faunce, T., & Colson, M. (2005c). Using portable digital technology for clinical care and critical incidents: A new model. *Australian Health Review*, *29*(3), 297–305.

Bolsin, S. N., & Freestone, L. (2007). Report cards and performance monitoring. In S. Clarke & J. Oakley (Eds.), *Informed consent and clinician accountability* (First ed., vol. 1, pp. 91-105). Cambridge: Cambridge University Press.

Bolsin, S. N., Solly, R., & Patrick, A. (2003). The value of personal professional monitoring performance data and open disclosure policies in anaesthetic practice: A case report. *International Journal for Quality in Health Care*, *12*(4), 295–297. doi:10.1136/qhc.12.4.295

Chambler, A. F., & Emery, R. J. (1997). Lord Moynihan cuts Codman into audit. *Annals of the Royal College of Surgeons of England*, *79*(4Suppl), 174–176.

Chassin, M. R., Hannan, E. L., & De Buono, B. A. (1996). Benefits and hazards of reporting medical outcomes publicly. *The New England Journal of Medicine*, *334*(6), 394–398. doi:10.1056/NEJM199602083340611

Choong, P. F. M., Langford, A. K., Dowsey, M. M., & Santamaria, N. M. (2000). Clinical pathway for fractured neck of femur: A prospective, controlled study. *The Medical Journal of Australia*, *172*(9), 423–426.

Codman, E. A. (1914). The product of a hospital. *Surgery, Gynecology & Obstetrics*, *18*, 491–496.

Concato, J., Shah, N., & Horwitz, R. I. (2000). Randomised, controlled trials, observational studies, and the hierarchy of research design. *The New England Journal of Medicine*, *342*(25), 1887–1892. doi:10.1056/NEJM200006223422507

de Leval, M. R., Francois, K., Bull, C., Brawn, W., & Spiegelhalter, D. (1994). Analysis of a cluster of surgical failures: Application to a series of neonatal arterial switch operations. *The Journal of Thoracic and Cardiovascular Surgery*, *107*(3), 914–923.

Ehsani, J. P., Jackson, T., & Duckett, S. J. (2006). The incidence and cost of adverse events in Victorian hospitals 2003-4. *The Medical Journal of Australia*, *184*(11), 551–555.

Evans, S. M., Berry, J. G., Smith, B. J., Esterman, A., Selim, P., & O'Shaughnessy, J. (2006). Attitudes and barriers to incident reporting: A collaborative hospital study. *Quality & Safety in Health Care*, *15*(1), 39–43. doi:10.1136/qshc.2004.012559

Fenn, P. (2002). Counting the cost of medical negligence. *BMJ (Clinical Research Ed.)*, *325*(7358), 233–234. doi:10.1136/bmj.325.7358.233

Firth-Cozens, J. (2002). Barriers to incident reporting. *Quality & Safety in Health Care*, *11*(1), 7. doi:10.1136/qhc.11.1.7

Firth-Cozens, J., Firth, R. A., & Booth, S. (2003). Attitudes to and experiences of reporting poor care. *Clinical Governance*, *8*(4), 331–336. doi:10.1108/14777270310499423

Forkner, J. (1996). Clinical pathways-benefits & liabilities. *Nursing Management*, *27*(11), 35–38. doi:10.1097/00006247-199611000-00009

Freestone, L., Bolsin, S., Colson, M., Patrick, A., & Creati, B. (2006). Voluntary incident reporting by anaesthetic trainees in an Australian hospital. *International Journal for Quality in Health Care*, *18*(6), 452–457. doi:10.1093/intqhc/mzl054

Garg, A. X., Adhikari, N. K., McDonald, H., Rosas-Arellano, M. P., Devereaux, P. J., & Beyene, J. (2005). Effects of computerized clinical decision support systems on practitioner performance and patient outcomes: A systematic review. *Journal of the American Medical Association*, *293*(10), 1223–1238. doi:10.1001/jama.293.10.1223

GMC. (2006). *Good medical practice*. London: General Medical Council.

Green, J., & Wintfeld, N. (1995). Report cards on surgeons. Assessing New York State's approach. *The New England Journal of Medicine*, *332*(18), 1229–1232. doi:10.1056/NEJM199505043321812

Hannan, E. L., Kilburn, H., Racz, M., Shields, E., & Chassin, M. R. (1994). Improving the outcomes of coronary artery bypass surgery in New York State. *Journal of the American Medical Association*, *271*(10), 761–766. doi:10.1001/jama.271.10.761

Hannan, E. L., Kumar, D., Racz, M., Siu, A. L., & Chassin, M. R. (1994). New York State's cardiac surgery reporting system: 4 years later. *The Annals of Thoracic Surgery*, *58*(6), 1852–1857.

Henry, A. (2006). *The changing face of the workforce and intergenerational impacts*. Retrieved on August 21, 2008, from http://www.icvet.tafensw.edu.au/ezine/year_2006/may_jun/documents/henry_icvet.pdf

Hindle, D., & Yazbeck, A. (2005). Clinical pathways in 17 European Union countries: A purposive study. *Australian Health Review*, *29*(1), 94–104.

Irvine, D. (2004). Health service reforms in the United Kingdom after Bristol. *The Medical Journal of Australia*, *181*(1), 27–28.

Irvine, D. (2006a). New ideas about medical professionalism. *The Medical Journal of Australia*, *184*(5), 204–205.

Irvine, D. (2006b). A short history of the General Medical Council. *Medical Education*, *40*(3), 202–211. doi:10.1111/j.1365-2929.2006.02397.x

Irvine, D. H. (2004). Time for hard decisions on patient-centred professionalism. *The Medical Journal of Australia*, *181*(5), 271–274.

Kaska, S. C., & Weinstein, J. N. (1998). Historical perspective. Ernest Amory Codman, 1869-1940. A pioneer of evidence-based medicine: The end result idea. *Spine*, *23*(5), 629–633. doi:10.1097/00007632-199803010-00019

Kennedy, P. I. (2001). *Learning from Bristol* (website): www.bristol-inquiry.org.uk.

Kingston, M. J., Evans, S. M., Smith, B. J., & Berry, J. G. (2004). Attitudes of doctors and nurses towards incident reporting: A qualitative analysis. *The Medical Journal of Australia*, *181*(1), 36–39.

Kohn, C. T., Corrigan, J. M., & Donaldson, M. S. (1999). *To err is human. Building a safer health system.* Washington: Institute of Medicine.

Kraman, S., & Hamm, G. (1999). Risk management: Extreme honesty may be the best policy. *Annals of Internal Medicine*, *131*(12), 963–967.

Lesar, T. S., Lomaestro, B. M., & Pohl, H. (1997). Medication-prescribing errors in a teaching hospital. *Archives of Internal Medicine*, *157*(14), 1569–1576. doi:10.1001/archinte.157.14.1569

Lim, T. O., Soraya, A., Ding, L. M., & Morad, Z. (2002). Assessing doctor's competence: Application of CUSUM technique in monitoring doctor's performance. *International Journal for Quality in Health Care*, *14*(3), 251–258.

Mac Corportation. (2008). *iPhone official site*. Retrieved on August 21, 2008, 2008, from www.apple.com/au/iphone

Michel, P., Quenon, J. L., de Sarasqueta, A. M., & Scemama, O. (2004). Comparison of three methods for estimating rates of adverse events and rates of preventable adverse events in acute care hospitals. *BMJ (Clinical Research Ed.)*, *328*(7433), 199–204. doi:10.1136/bmj.328.7433.199

Nuttall, P. (1983). The passionate statistician... Florence Nightingale. *Nursing Times*, *79*(39), 25–27.

O'Connor, G. T., Plume, S. K., Olmstead, E. M., Morton, J. R., Maloney, C. T., & Nugent, W. C. (1996). A regional intervention to improve hospital mortality associated with coronary artery bypass graft surgery. *Journal of the American Medical Association*, *275*(11), 841–846. doi:10.1001/jama.275.11.841

Page, E. S. (1954). Continuous inspection schemes. *Biometrika*, *41*, 100–115.

Peterson, E. D., Roe, M. T., Mulgund, J., DeLong, E. R., Lytle, B. L., & Brindis, R. G. (2006). Association between hospital process performance and outcomes among patients with acute coronary syndromes. *Journal of the American Medical Association*, *295*(16), 1912–1920. doi:10.1001/jama.295.16.1912

Reid, C. M., Rockell, M., Skillington, P. D., Shardey, G. C., & Smith, J. A., M.S., M. Y., et al. (2004). Initial twelve months experience and analysis for 2001-2002 from the Australasian Society of Cardiac and Thoracic Surgeons--Victorian database project. *Heart Lung and Circulation*, *13*(3), 291–297. doi:10.1016/j.hlc.2004.05.006

Shortell, S. M., Bennet, C. L., & Byck, G. R. (1998). Assessing the impact of continuous quality improvement on clinical practice: What it will take to accelerate progress. *The Milbank Quarterly*, *76*(4), 593–624. doi:10.1111/1468-0009.00107

Sibbald, B. (1998). Twelve deaths in Winnipeg: Judge must ponder 48,000 pages of testimony. *Canadian Medical Association Journal*, *159*(10), 1285–1287.

Spiegelhalter, D., Grigg, O., Kinsman, R., & Treasure, T. (2003). Risk-adjusted sequential probability ratio tests: Applications to Bristol, Shipman, and adult cardiac surgery. *International Journal for Quality in Health Care*, *15*(1), 7–13. doi:10.1093/intqhc/15.1.7

Spiegelhalter, D. J. (1999). Surgical audit: Statistical lessons from Nightingale and Codman. *Journal of the Royal Statistical Society. Series A, (Statistics in Society)*, *162*(1), 45–48. doi:10.1111/1467-985X.00120

Spur, C. D., Flammini, S., & Goulart, F. D. (1996). Automating clinical pathways: One hospital's initial experience. *Healthcare Information Management*, *10*(4), 87–104.

Swanson, C. E., Yellend, C. E., & Day, G. A. (2000). Clinical pathways and fractured neck of femur. *The Medical Journal of Australia*, *172*(9), 415–416.

Thomas, E. J., Studdert, D. M., Burstin, H. R., Orav, E. J., Zeena, T., & Williams, E. J. (2000). Incidence and types of adverse events and negligent care in Utah and Colorado. *Medical Care*, *38*(3), 261–271. doi:10.1097/00005650-200003000-00003

Thomas, E. J., Studdert, D. M., Runciman, W. B., Webb, R. K., Sexton, E. J., & Wilson, R. M. (2000). A comparison of iatrogenic injury studies in Australia and the USA. I: Context, methods, casemix, population, patient, and hospital characteristics. *International Journal for Quality in Health Care*, *12*(5), 371–378. doi:10.1093/intqhc/12.5.371

Van Der Weyden, M. B. (2005). The Bundaberg hospital scandal: The need for reform in Queensland and beyond. *The Medical Journal of Australia*, *183*(6), 284–285.

Vincent, C., Neale, G., & Woloshynowych, M. (2001). Adverse events in British hospitals: Preliminary retrospective record review. *BMJ (Clinical Research Ed.)*, *322*(7285), 517–519. doi:10.1136/bmj.322.7285.517

White, C. (2004). Doctors mistrust systems for reporting medical mistakes. *BMJ (Clinical Research Ed.)*, *329*(7456), 12. doi:10.1136/bmj.329.7456.12-d

Wilson, R. M., Harrison, B. T., Gibberd, R. W., & Hamilton, J. D. (1999). An analysis of the causes of adverse events from the quality in Australian healthcare study. *The Medical Journal of Australia*, *170*(9), 411–415.

Wilson, R. M., Runciman, W. B., Gibberd, R. W., Harrison, B. T., Newby, L., & Hamilton, J. D. (1995). The quality in Australian healthcare study. *The Medical Journal of Australia*, *163*(9), 458–471.

Wilson, R. M., & Van Der Weyden, M. B. (2005). The safety of Australian healthcare: 10 years after QAHCS. *The Medical Journal of Australia*, *182*(6), 260–261.

Wolff, A. M. (1996). Limited adverse occurrence screening: Using medical record review to reduce hospital adverse patient events. *The Medical Journal of Australia*, *164*(8), 458–461.

Wolff, A. M., Bourke, J., Campbell, I. A., & Leembruggen, D. W. (2001). Detecting and reducing hospital adverse events: Outcomes of the Wimmera clinical risk management program. *The Medical Journal of Australia*, *174*(12), 621–625.

Woods, D. (2000). Estimate of 98,000 deaths from medical errors is too low, says specialist. *BMJ (Clinical Research Ed.)*, *320*, 1269. doi:10.1136/bmj.320.7237.809

This work was previously published in Handbook of Research on Information Technology Management and Clinical Data Administration in Healthcare, edited by A. Dwivedi, pp. 798-813, copyright 2009 by Medical Information Science Reference (an imprint of IGI Global).

Chapter 1.7

IT Adoption and Evaluation in Healthcare:

Evolutions and Insights in Theory, Methodology, and Practice

Ton AM Spil
University of Twente, The Netherlands

Cynthia LeRouge
St. Louis University, USA

Ken Trimmer
Idaho State University, USA

Carla Wiggins
Idaho State University, USA

ABSTRACT

This article focuses on the evolution of theory, methodology, and practice regarding the role of adoption, implementation, diffusion, and evaluation factors, and the interaction of these factors at various levels, to healthcare system success. These topics continue to present challenges to organizations, the research community, and to society in general. The first place that new waves of thought are often aired is at conferences. This article explores the evolution taking place in this domain by looking back through the years over work presented at the longest standing conference track focused on adoption, implementation, diffusion, and evaluation factors in e-health and the interaction of these factors at various levels to healthcare system success. [Article copies are available for purchase from InfoSci-on-Demand.com]

INTRODUCTION

Although Information Technology (IT) is seen as an enabler of change for healthcare organizations both nationally and locally, adoption decisions are complex given a multitude of technologies, stakeholders, and potential levels of analysis. The research presented in this article conveys the complexity and breadth of issues explored by information systems researchers in addressing adoption, implementation, diffusion, and evaluation via a multidimensional review of articles accepted over the past six years at arguably the most noted minitrack conference focused on IT adoption, implementation, diffusion, and evaluation in healthcare information systems. This review shows that there are many disruptions in the innovations of healthcare information systems. Continuous learning, evaluation, and understanding in both practice and research can help to avoid these disruptions and help to smooth IT implementation in the future.

The following sections move back in time to grasp the evolution of e-health adoption and evaluation. We begin by introducing that background and the methods used to conduct this literature review. We then present an analysis of trends, and insight from this body of past work by exploring evolution in theory, methodology, and practice. We close by addressing the future of e-health diffusion and some major lines of thinking.

BACKGROUND AND LITERATURE REVIEW METHOD

The entry for “**academic conference**” on Wikipedia© notes, “together with academic or scientific journals, conferences provide an important channel for exchange of information between researchers.” For purposes of reviewing the evolution and developments in a new and emerging area of interest, such as e-health as explored by IT researchers, it is important to consider conference papers and their associated presentations. While we acknowledge the value and necessity of reviewing work published in refereed journals to understand the school of thought in a domain or sub-specialty, we focus this work on conference papers to emphasize three issues. First, conferences often serve as the first airings of studies and ideas that later make their way into journals. Given the extended turnaround times between first submission and publication in some journals, fresh directions in research may not make their way into press until years after having been presented at a conference. Thus, in work such as the current study, that seeks to look at the evolution of thought, method, and practice, tracing representation in conference proceedings may more closely follow the timeline of the completed studies and present a broader picture. Second, in an interdisciplinary field such as health information systems, the ultimate journal destination of work presented at conferences may scatter and fragment into various journal domains making it difficult to reconnect the threads of thought, method, and practice in the work going on in the domain. Thus, we hope to encourage researchers doing work in this domain to follow our example and visit the work from targeted conferences in their canvas of the literature, even if only to trace the destination of subsequent journal articles that might otherwise be missed in a multi-disciplinary field. Third, topically targeted conferences and tracks/minitracks at general conferences tend to attract “birds of a feather” and thus, promote multi-way dialog on presented research. This dialog may, in turn, influence the direction of colleagues working in the area of interest.

We focus our study on the Hawaii International Conference on System Sciences (HICSS) - IT Adoption, Implementation, Use and Evaluation in Healthcare minitrack within the Information Technology in Health Care (ITHC) track. HICSS is the oldest international system science conference, and the Health Care track is the oldest of the information system conference healthcare tracks. The IT Adoption, Implementation, Use and Evaluation in Healthcare minitrack has been one of the focal tracks in the ITHC. Per online search and review of the agendas and programs from major IT general conferences and targeted meetings since 2000, the IT Adoption, Implementation, Use and Evaluation[1] minitrack appears to be the longest running consistent track dedicated to this focused topic in the field of information systems. This minitrack started in 2002 and has been on-going to date. The average acceptance rate for papers in this track is approximately 50%. One or more of this article's authors participated in the presentations and ensuing discussions of all the papers reviewed as part of the current study. Thus, the authors of this article have not only individually or collectively read each paper, but have dialoged with authors and seen the various reactions and spontaneous thought generated by these works. Therefore, this review is a reflection and interpretation of not only what was written, but also of what was said and discussed among participants. We readily admit there are some limitations in exclusion with the approach chosen for this study. However, this novel lens of using the continuity of the forum from a long standing, respected conference forum for full papers dedicated to this targeted topic may yield insight into early trends that other methods may not. Specifically, we hope to garner insight through the advantage of longitudinal continuity, the screening process, and the ability to reflect on the papers along with the associated presentations and dialog.

Looking at this long-running track also provides the vantage for perceiving evolution in growth and interest in this topic. Between 2002 and 2009, 43 manuscripts have been published in what is in HICSS 42, the IT Adoption and Evaluation in Health Care (AEHC) minitrack within the ITHC Track at HICSS. Although the number of research publications within the minitrack equates to 5.6 per year, since 2005, which is the second official year for the current minitrack, the average between 2005 and 2009 has increased by 2 manuscripts to 7.6 accepted papers per year. More recent years have yielded up to nine papers suitable for presentation and publication, with growing audience attendance. Elaborated versions of the research presented in AEHC have been published in established journals as CAIS, MISQ and more specific healthcare IS journals as IJHIS, IJMI, IJHTM and others.

We summarize papers accepted into this track in Appendix A. To delve into the collection of papers, we begin by discussing their evolution and insights in thought and theory. We follow with a discussion of evolution and insights in methodology and then move to evolutions and insights in practice as evidenced by the research. It is our hope that this review will assist researchers interested in this area leverage past efforts in advancing theory, designing the methodology of their study, and providing relevance and connection to healthcare practice.

EVOLUTION AND INSIGHT IN THOUGHT AND THEORY ON LEVELS OF E-HEALTH IMPACT

In this section, we analyze the collection of studies from the perspectives of levels of interest. Table 1 summarizes the representation of papers in the collection at each level of e-health impact.

IT Adoption: Individual Level

Hu, Liu Sheng, and Tam (1999) and Lapointe, Lamothe, and Fortin (2002), with their application of the TAM model on telecare and level of analysis on clinical care, inspired us to create the research track. Both research teams have a totally different research approach but come to the same conclusions that usefulness or benefits are the main drivers for IT success in healthcare. Relevance can be used to explain usefulness (Schuring and Spil, 2002). Dhillon and Forducey

Table 1. Level of study

Level	Number	Per cent
Policy/Governmental	2	4.651%
Organizational	13	30.233%
Project	5	11.628%
Individual – Providers (Physicians, nurses, etc)	14	32.558%
Individual – Health Care Consumer	3	6.977%
Total	43	100.00%

(2006) draw our attention to the topic of adoption relevance in their telemedicine case study. The authors report that by involving all stakeholders in the project at various stages, without causing perturbation of the basic rehabilitation services delivery process, providers were able to increase their revenue and profitability; the patients realized savings by avoiding travel to a healthcare facility, saved valuable time, and in many cases, avoided serious medical complications resulting from delays in the delivery of services.

Topacan, Basoglu, and Daim (2009) bring together the emerging field of information services with e-health by explaining why telecare applications are adopted by healthcare professionals. Padmanabhan, Burstein, Churilov, Wassertheil, Hornblower, and Parker (2006), also acknowledge the individual level and point out the need for both objective and subjective measures in an evaluation of a handheld support triage prototype called iTriage*,* speaking to its impact on the quality of the triage decision making process.

The Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh, Morris, Davis, and Davis, 2003) was referenced in multiple papers including work by Trimmer, Wiggins, Beachboard, and Woodhouse (2008). In this study, “Electronic Medical Records Use – An Examination of Resident Physician Intentions,” physicians who were experienced with an EMR provided their perspectives on future use and adoption of EMRs. The UTAUT is also applied to e-health by Goh and Agarwal (2008) in “Taking Charge of Your Health: The Drivers of Enrolment and Continued Participation in Online Health Intervention Programs.” In this study, the authors analyzed responses from an online health portal to assess adoption and post-adoption of an online program. Their analysis provides a discussion of direct and interaction effects of a theoretical model. Schaper and Pervan (2007) show us a large quantitative UTAUT study in Australia with over 2000 responses which found that a positive attitude has significant influence on the use behavior.

Other authors go back to one of the sources of the UTAUT model and use the psychological models of Ajzen and Madden (1986) to describe the impact on the individual level. Ilie, Courtney, and Van Slyke (2007) use the Theory of Planned Behavior in a qualitative way. They end in saying that while the use of an Electronic Medical Record may be mandatory for the physician-residents in their study, if they had a choice, the majority of physicians would use the paper chart. A new dimension for technology adoption is discussed based on personality traits and the way in which they influence computer anxiety in a study by Brown, Deng, Poole, and Forducey, (2005). Computer anxiety, of course, is an inhibiting factor in the adoption of, in this case, telemedicine applications. Horan, Tulu, Hilton, and Burton

(2004) also root their work in UTAUT sources to develop a conceptual model for physician acceptance and test this socio-work structure via a survey. The model is a micro approach as it focuses on work-practice considerations of physicians, factors affecting physicians' acceptance and use of decision support system in the clinical setting and task-technology fit .

Relevance and perceived usefulness can be studied from a psychological point of view or from an individual cost/benefit point of view. LeRouge and Hevner (2005) propose *Use Quality* as a refined construct to the DeLone and McLean (2002) model in response to the underlying IT research assumption that there seems to be an appropriate manner and flow for system use. Within the telemedicine context, they define use quality as the practice of applying appropriate processes and protocols in the use of high-end telemedicine encounters to fulfill the desired purpose of patient care.

Bhattacherjee and Hikmet (2007) provide a dual-factor (perceived usefulness and perceived threat) model for assessing the implications of IT threats on an individual's IT usage. This empirical study supports their hypothesis that threats will negatively influence IT use. Cho, Mathiassen, and Gallivan (2008) focus on a telehealth innovation that enables physicians at a teaching hospital to access and diagnose strokes in rural environments. The perspectives of various stakeholders regarding the innovation and its adoption are presented in this longitudinal research. Another longitudinal study, also addressing issues at a teaching hospital, is presented by Ryan, Doster, Daily, and Heslin (2008). They discuss the eventual process improvements that came about after the implementation of a new information system for the hospital's preoperative services.

Finally, many individual adoption studies apply the Technology Acceptance Model (TAM) (Davis, 1989) model in its original form . Raitoharju (2005) derives from a general study that IT stress is a major inhibitor of acceptance in healthcare. The development of IT scores that assess IT capacities in healthcare is a critical step forward toward addressing important research questions involving the relationship between IT capacities and outcome measures. "IT Capacities Assessment Tool: A Survey of Hospitals in Canada" by Jaana, Pare', and Sicotte (2009) presents the development of an instrument for scoring IT capacities in Canadian hospitals. "The Importance of Being Useful and Fun: Factors Influencing Intention to Use a Mobile System Motivating for Physical Activity" by Svendsen, Søholt, Munch-Ellingsen, Gammon, and Schurmann (2009) studies the impact of a mobile phone based motivation system on modifying health behaviors, focusing on health interventions as "fun."

All of the studies in this section have one important thing in common. They focus on the individual level and they find that the value proposition is probably the most important dimension of successful adoption of e-health systems. The value proposition has many disguises, Rogers (1995) called it relative advantage, Davis (1989) called it perceived usefulness and Delone and Mclean (2002) called it net benefits. The individual level studies present a range of examples addressing the nature of value to individuals in the healthcare environment.

IT Adoption: Organization and Project Level

On an organization level, previous strategic choices, strategic priorities, size and location of the organization, information assurance, and many other factors may play a role. Maass and Eriksson (2006) highlight managerial challenges encountered during the adoption of a Picture Archiving and Communication System (PACS) at Turku University Central Hospital (TUCH). The results are based on a five-year survey consisting of statistical data, cost analysis, modeling, customer satisfaction inquiries, time and motion studies, observation and staff interviews.

On a project level, resources, and project management play a role. Kiura (2006) focuses on the need to explore the project level by reporting on a project establishment undertaking as proposed by the STEPS (Software Technology for Evolutionary Participatory System Design) Methodology. Project establishment in STEPS is aimed at getting an inner understanding of a project's environment. This article focuses on evolving a 'participatory culture' to assist in better understanding the project environment.

The contribution by Gagnon, Lamothe, Fortin, Cloutier, Godin, Gagné, and Reinharz, (2004) "The Impact of Organizational Characteristics on Telehealth Adoption by Hospitals," analyses adoption on organizational level. It is structured around hypotheses that are based on previous research and that are tested on the basis of research in 32 healthcare centres involved as telehealth services. The contribution by Maass and Suomi (2004), "Adoption-Related Aspects of an IS System in a Health Care Setting" focuses on adoption of a digital image (PACS) system. It particularly considers financial aspects of this implementation.

Reardon and Davidson (2007) discuss that there is not enough organizational vision to overcome physicians' hesitance to adopt Electronic Medical Records systems (EMR). Questions about interpretability, plausibility, and discontinuity of this innovation and organizational vision remain.

More evidence of the troublesome implementation problems on group and organizational level can be found in section 4 and in reviewing the papers listed in appendix A. Even if, as suggested in the previous section, the relevance of the e-health system is clear, the complex structure and culture of healthcare organization can disturb the successful introduction of IT systems.

IT Adoption: National Level

On a national system-level, reimbursement structures, regulations, inter-organizational concerns, and the existence of standards may have an explanatory role in the slow adoption and acceptance of healthcare IT. To this end, Sherlock and Chismar (2006) argue that the airlines' evolution of computerized reservation systems (CRSs) provide lessons learned to analyze problems and issues in the development of electronic health records. CRSs' turbulent evolution was driven by environmental, technological, and structural factors within the airline industry, which these authors assert is analogous to current trends in the healthcare industry and they predict that similar patterns of adoption will occur in electronic health records.

A second paper with a national focus is "A Telemedicine Transfer Model for Sub-Saharan Africa" (Kifle, Mbarika, Tsuma, Wilkerson, and Tan, 2008). Focusing on Information Communications Technology (ICT) and infrastructure, the authors report the analysis of survey data provided by physicians in twenty-one different African Nations. The results of their analysis provide policy makers in Sub-Saharan Africa with a perspective on ICT projects. In addition, research from Sood, Nwabueze, Mbarika, Prakash, Chatterjee, Ray, and Mishra (2008), "Electronic Medical Records: A Review Comparing the Challenges in Developed and Developing Countries," provides a perspective on barriers to adaptation and implementation between different countries. "The Effects of Culture of Adoption of Telemedicine in Medically Underserved Sub-Saharan Africa", by Meso, Mbarika, Kifle, Okoli, and Nwabueze (2009) reveals that ICT infrastructure and national health services facilitate improved telemedicine capabilities. However, in countries underserved by ICT and national health policies, telemedicine, while highly valued, remains scarce.

Burley, Scheepers, and Owen (2008), present a case study focusing on stakeholders, effectiveness, and efficiency issues regarding mobile systems in Australia. They present the advantages and the balance between the internal system requirements and external systems.

Although the international and national studies are not yet numerous enough to draw valid conclusions, it seems that telecare is being embraced by undeveloped countries as one of the answers to their knowledge and information management problems. To solve these problems, good theory and methodology, as demonstrated in the next section, will provide a solid basis for the learning process.

METHODOLOGICAL EVOLUTION AND INSIGHTS

We canvassed the papers to provide insight to future researchers regarding methodology in healthcare IT research. We address multiple methodological considerations below to highlight methodological considerations that may intrigue and perhaps, inspire readers of the current paper through what has been done, or perhaps, through what is absent.

Epistemological Perspectives

The collection of papers includes interpretivist, positivist, and interventionist studies demonstrating that health IT can be studied from multiple epistemological perspectives. In their study on resident physicians' intentions to use EMR, Trimmer, et al. (2008), illustrate that IT research in healthcare can be done using an interpretive paradigm. In contrast, that same year, Ryan, et al. (2008), demonstrated that a positivist method of case research may also be used, in their investigation of the impact of soft innovation within a hospital environment, from empowered and integrated individuals driven by integrated information.

Fruhling, Tyser, and de Vreede (2005), followed the interventionist perspective using the action research model to evaluate the use of extreme programming for developing and implementing a biosecurity healthcare application. "Action research has the dual intention of improving the practice and contributing to theory and knowledge" (Fruhling, et al., 2005, p. 5). This approach may have merit in healthcare IT studies where the research question is "how" oriented; a depth of understanding is needed of the complex environment, and aligns itself well with the general call for continuous learning in the healthcare environment.

Kiura (2006) also uses action research to gain an inner understanding of a project's

environment in the early stages of a systems development project for a hospital in a developing country. Kiura's intervention was to introduce participatory design concepts through Joint Application Design (Wood and Silver, 1995) and the Software Technology for Evolutionary Participatory System Design (STEPS) methodology..

Method Type

IT in healthcare research calls to qualitative, quantitative, design science, and conceptual studies as can be seen by the distribution of methods in Table 2.

We elaborate below on the details of Table 2 to provide further insight.

Quantitative Methods

Survey research was by far the most prevalent method used for collecting data in the healthcare IT studies presented in this HICSS minitrack. Many of the studies scrutinized technology acceptance and used previously validated items from the UTAUT (Venkatesh, et al., 2003) and related predecessor models to compose some or all of the survey questions.

Table 2. Distribution of methods of study

Method Type of Study	**Number**	**Percent**
Qualitative	14	32.56%
Quantitative	11	25.58%
Quantitative and Qualitative	7	16.28%
Design Research	5	11.63%
Conceptual Paper	6	13.95%
Total	**43**	**100.00%**

In most studies the survey instruments were distributed to survey participants in only one form. Kifle, et al (2008) remind us of the importance of checking for method bias in their study which used both a web and a paper based version of a survey instrument. This may be of particular concern in the healthcare environment where users may be more infrequent computer users and prefer to use paper-based methods for response.

Regression, partial least squares, basic statistics, and structural equation modeling were the most frequent statistical analyses performed. Factor analysis, Chi-Square tests, analysis of variance, and principal component analysis were each used in one study. A rather unique form of analysis was performed by Brown, et al., (2005) . They use the survey method to gather data on various traits proposed as exogenous determinants of computer anxiety for physical therapists using telemedicine systems. The traits were measured using LaForge's Interpersonal Checklist (ICL) (LaForge, 1977) and computer anxiety was measured using a scale inspired by Thatcher and Perrewe (2002). The research is distinguished in method from others in our pool of papers regarding the method of analysis. The researchers measured respondent trait position along the quadrants in the Interpersonal Circumplex Model and used multiple contrast tests to test the proposed hypotheses.

Qualitative and Mixed Designs

Many of the papers using qualitative methods indicate their choice was made due to the need to gain a rich understanding of the healthcare IT context and of the stakeholders in order to address the research question. Qualitative studies may be conducted in a number of ways including case studies, interviews, direct observations, and focus groups. The collection of papers in this review clearly demonstrates that healthcare IT can be researched using many qualitative methods.

Interviewing as a stand- alone method or as part of a case study, was the most frequently used method of collecting data. Qualitative data from interviewing is often analyzed by coding key words and phrases into themes and categories. However, Wiggins, Pumphrey, Beachboard, and Trimmer (2006) used a method of analyzing qualitative interview data that consisted primarily of the creation of a case narratives to develop an accurate and rich description of a phenomenon as seen through the eyes of the interviewees.

The majority of the qualitative studies used a case method and collected data from many sources to facilitate both understanding and breadth, as well as for triangulation. Qualitative methods of data collection represented, in addition to interviews, include workflow modeling, focus groups, review of archival data, direct observation, and usability testing. Though the general characterization of many of these studies is qualitative, data collection frequently included quantitative elements, such as survey data, quantitative analysis of operational data, and time and motion studies. The study by Shaper and Pervan (2007) serves as an interesting example of triangulation using qualitative and quantitative methods. Schaper and Pervan (2007) tested their proposed model quantitatively in a national survey sent to 6453 Australian occupational therapists to provide cross-sectional data on behavioral intention and acceptance of ICT and other issues surrounding utilization of ICT. Interviews, direct observation and other case study field methods were used to qualitatively support the proposed model and the national survey was used to qualitatively support the proposed model. Paré, Mirou, and Girouard (2008) chose to employ another form of mixed qualitative and quantitative design, namely a ranking-type Delphi survey . In this study, the opinions of a panel of experts (i.e., clinical information systems project managers) were elicited through iterative, controlled feedback to build an authoritative list of clinical information systems implementation risk factors and determine the relative importance of these risk factors. A three-phase process was used: phase 1: risk brainstorming; phase 2: the combined list was circulated to all panelists for corrections, additions, and, eventually, validation; and phase 3: ranking of the risk factors in order of priority to the project.

There is a range of how long one should spend in the field to perform a case study. Some studies report a time frame as short as three months. Others, such as Maass and Eriksson (2006), advocate a much longer time frame for an implementation study, perhaps extending into years. They argue that infrastructures grow and develop over a long period of time in healthcare contexts and an information infrastructure is built through extensions and improvements to what already exists – rather than from scratch. What is implemented has to be hooked into the existing infrastructure, which supports the extended longitudinal approach if the goal is to really understand not only the initial implementation and training, but also what happens as users gradually integrate the system in their work practices and learn the possibilities and the limitations of the system. Maass and Eriksson (2006) illustrate this through their case study which analyzes data consisting of statistical information, cost analysis, modeling, customer satisfaction inquiries, time and motion studies, observation and staff interviews.

Schaper and Pervan (2007) provide another example of a longitudinal case study that exemplifies using an extended time period for comparative data collection points. This seven-month longitudinal multi-method field study was designed to test a proposed ICT acceptance and use model and the associated individual and organizational impacts of use or non-use within a small non-profit, community-based healthcare organization. The questionnaire was administered at three points in time: one week post-training, three months post-implementation and seven months post- implementation.

Design Research

In reviewing Table 2, one might be surprised to see Design Research as a category in a healthcare IT literature review. To validate the propriety of this category, we reviewed seminal design research pieces (particularly focused on defining design research) such as those by March and Smith (1995) and Hevner, March, Park, and Ram (2004). We also consulted the Association of Information Systems, which provides a compendium of Design Research thought and references (http://www.isworld.org/Researchdesign/drisISworld.htm) and provides an appropriate summary for the purposes of the current paper. This compendium indicates:

Design research involves the analysis of the use and performance of designed artifacts to understand, explain and very frequently to improve on the behavior of aspects of Information Systems. Such artifacts include - but certainly are not limited *to - algorithms (e.g. for information retrieval), human/computer interfaces and system design methodologies or languages.* (Association of Information Systems, 2008)

The intent of including this category in this paper is not so much to debate the semantics of design research, but to properly identify and showcase a particular group of papers in our collection that stood out from the more classic methodological definitions. The primary purpose of the papers in our "design science" category is to leave the healthcare IT research community with an artifact for future work. Thus, we reviewed the methods of the papers included in this study for those with a primary focus of identifying a problem, providing a suggestion, and developing an artifact for addressing the problem for practitioners and/or researchers to use. Some authors extended this to include evaluation and results of using their artifact in practice, thereby addressing additional steps in the design research process.

To illustrate, the artifact in Fitch's (2004) work, the Ilities Application Method, has the intended purpose of aiding communication, closing the knowledge gap, correctly establishing system requirements, and putting a system into place that is fit for its purpose. The Ilities Application Method and its associated templates are stated to be tools for practice and research. In another design science study, Mantzana and Themistocleous (2006) design and evaluate (via case study) a methodological artifact designed to help (a) address the uncertainties related to the actors in a healthcare setting during adoption, (b) enhance existing adoption models, (c) facilitate healthcare organizations in making robust decisions and (d) provide guidance to increase adoption of innovations. Their study focused on identifying actors involved in the innovation process within healthcare organizations.

It is not surprising that many of the papers that we classify as design research relate to tools and algorithms used for assessment, as artifacts which are needed for evaluating pre-existing tools and processes may not work with emerging technologies. The first of these types of papers appeared in 2006. Randomized control trials (RCT) are often referred to as the gold standard of evaluation for interventions in the healthcare sector. However, RCT's may not always be possible or provide the complete picture when it comes to healthcare IT evaluation. As part of their contribution, Dhillon and Forducey (2006) develop and illustrate the execution and benefit of a methodology for evaluation that considers Access to Health Care, Quality of Care outcomes and satisfaction, and Cost of Care for evaluating telemedicine systems.

The collection of 2009 papers includes two design research papers related to evaluation artifacts. Jaana, Pare', and Sicotte (2009) introduce an IT assessment scoring tool that aims at capturing the level of IT sophistication in hospitals on eight IT dimensions related to the implementation of computerized processes and emerging technologies with the level of internal and external systems integration. The instrument was validated through a survey of hospitals in two provinces in Canada (Québec and Ontario). The study by Roberts, Ward, Brokel, Wakefield, Crandall, and Conlon (2009) assesses the methods researchers use to evaluate health information systems and scrutinizes the recommended metrics and algorithms in the context of a case study that describes the introduction of a technically and systematically complex implementation of a healthcare IT system. They advocate that the analytical approach used should integrate: "(1) key engineering-derived tools such as statistical process control run charts designed to allow a visual examination of fluctuations in process over time and to help identify if those fluctuations are due to random events or a systematic change; (2) a human factors approach that considers the effect of an innovation's implementation upon the human interactions within the system; (3) the capture of robust data that enables stronger analyses of system performance; and (4) appropriate quantitative statistical tools designed to analyze and interpret system models" (Roberts et. al, 2009, p. 2). The researchers report on the benefits of using their linear piecewise spline mixed effects algorithmic model with a jump that the knot to address these concerns.

Conceptual Work

The conceptual papers in this collection provide an in-depth discussion of topics on which the authors have taken a position and want to point out issues which may be often overlooked in research efforts and in practice. Regarding the overlooked or missed, Raitoharju (2005) indicates that IT stress is an issue in the healthcare sector and should be taken into account in evaluating adoption and acceptance. Sood, et al., (2008) illuminate the unique challenges faced by developing countries toward the development, progression and sustainability of electronic medical records. Sherlock and Chismar (2006) use a compare and contrast approach to highlight lessons from the airline reservation system that may be applied to the future of electronic health records, but not readily recognized. Khoumbati, Themistocleous, and Irani (2005) illustrate both the advantages and disadvantages of various integration technologies (e.g. web services, enterprise application integration) that healthcare organizations are exploring and implementing that may be missed by practice and research. McCleod and Clark (2007) put the spotlight on issues of incorrectly identifying the user of health information systems. Yusof, Paul, Lampros, and Stergioulas (2006) review health information system evaluation studies and take the position that the current models are deficient. They then present a research framework that extends the then current models of health information system evaluation.

Experimental Design

Padmanabhan, et al., (2006) conduct a 'two group post-test only' laboratory experiment to evaluate the extent to which a triage prototype used as a decision support tool, impacts the quality of the triage decision-making processes and outcomes. The twenty-nine participants in the experimental groups attempted ten test case scenarios in random groups of five using the triage system. The control group attempted the same randomized case scenarios using paper and pencil. The "effectiveness" of the decision making process (degree of problem understanding, perceived clarity of choice strategy, perceived clarity of the problem solving process, user satisfaction, user confidence and perceived usefulness) and the "efficiency" of the process (accuracy, consistency and actual implementation) were compared for each group via the post-test.

The papers for the 2009 conference indicated in increasing interest in experimental design. Roberts, et al., (2009) use a longitudinal experimental design and analysis to study the trends in adverse drug events (ADEs) and the potential detection of them through HIT implementation. Another 2009 paper introduces the first field experiment by Paré, Sicotte, Chekli, Jaana, and De Blois (2009). The research team used a pre-post research design to evaluate the effects associated with the deployment of a telehome care system.

Sources of Data

One of the issues in designing a healthcare information systems research study is deciding what data to collect from whom. There are multiple resources in this complex environment and deciding on the best sources of data may be challenging.

The system user is the desired source of data in many of the studies on adoption, diffusion, use, and evaluation. However, identifying the user or knowing from which user to solicit data may not be as obvious as it seems in a healthcare setting. Regarding user identification, recent work by McLeod and Clark (2007) highlights the vulnerabilities of making incorrect assumptions regarding who is the health technology user and the impact user misconception can have on the results of the research. They indicate that multiple past studies in adoption and diffusion have focused on the physician as the primary user of health information systems technologies. However, by grounding our definition of use and performing closer inspection, the actual primary user that should be the subject of study in many cases may be another medical professional, such as a nurse or even support staff. Similar misconceptions may occur in designing studies when assumptions are made that a patient is the user of a consumer health web site or other technology. On closer examination, the system under study may actually is used more often by a caregiver in the home.

Multiple studies have also underscored the importance of soliciting data from multiple stakeholders, as there may be a variety of perspectives and pockets of complementary system knowledge when it comes to healthcare IT. Fitch (2004) contributed "Information Systems in Healthcare: Mind the Gap." It considers the knowledge gap and communication ambiguities between healthcare professionals and information technology planners that can result in incorrect translation of user requirements into system requirements. LeRouge and Hevner's (2005) work highlights the importance of data collection from all direct participants for health technology process design and evaluation. This team illustrated that the perspectives of multiple participants (patient, provider, presenter/medical personnel in the room with the patient) were needed to landscape a comprehensive picture of key attributes to assess quality in telemedicine encounters. Though the groups identified often share common attributes, each participant group possesses unique attributes, given their perspective and role in the process.

The research studies in our collection vary in their treatment of the various types of medical professionals (e.g., physicians, nurses, technicians) as one subject pool or distinct subgroups. Wu, Wang, and Lin (2005) do not distinguish these user groups in assessing what determines medical professionals' acceptance of mobile healthcare systems. Mantzana and Themistocleous (2006) take the position that the factors affecting adoption may vary by stakeholder. This team illustrates a method that researchers and practice can use to identify and detail the complex network of stakeholders in a healthcare information system to illuminate different adopter categories and different perspectives on the role of an IT system in various parts of the healthcare delivery process.

Goh, and Agarwal's (2008) work reminds us that primary data collection from human stakeholders is not the only source of data for healthcare IT. Their study used data analysis based on de-identified archival data from a health-program provider company that hosts its programs on a popular online health portal site. This data source was provided as a snapshot from the company's database. The information that serves as the input for the analysis was drawn from the users' responses to health risk appraisal (HRA), users' activity logs, and users' enrollment and participation in the health intervention programs.

Having reviewed the various levels of study and the methodologies employed, we turn now to evolutions and insights regarding the actual applications and uses of healthcare IT investigated in our collection of papers.

EVOLUTIONS AND INSIGHT IN THE USE OF TECHNOLOGY IN HEALTH PRACTICE

Electronic Medical Record Systems

There are at least three different, yet very closely related applications in this area. An Electronic

Medical Record (EMR) is an active tool that provides access to decision support, resources, and alerts. Electronic Patient Records (EPR) goes one step further than EMR: it contains healthcare related information gathered across at least two health organizations. Finally, Electronic Health Records (EHR) is still broader in that it includes wellness information and information that is not routinely collected or kept by health facilities. These three terms, EMR, EPR, and EHR are often used interchangeably by health professionals to describe the same thing; however we would like to start this section with the acknowledgement that, at least technically, there is a slight ascending order among them.

We start with what might be an unusual parallel between the airline and healthcare industries. Sherlock and Chismar's 2006 work points out a somewhat surprising number of analogies and similarities between these two very large and complex industries and predicts that, just as the airlines' computerized reservations systems evolved into vertically integrated, interoperable systems, so with healthcare's EMRs. Until that day, however, researchers continue to investigate the adoption, acceptance, and implementation of EMR throughout the world.

Of concern to many, is the attitude of physicians in regard to EMR. A 2007 study by Ilie, et al., investigated factors that most contribute to physicians' attitudes about, and usage of, EMR. Using Theory of Planned Behavior and a case study approach, this research posited that physicians' EMR behavior would be primarily determined by their attitude and perceptions about EMR use. They found that a majority of the residents and attending physicians identified the complexities of using EMR as a major negative influence on their perceptions and that the EMR system that they were using was not compatible with the workflow of the physicians.

In a similar vein, Trimmer, et al., (2008) found that while overarching attitudes regarding the EMR were positive, a consistent concern voiced by residents was ease of use. Residents unanimously commented on the importance of the accuracy of patient documentation and the ability to easily locate data. Performance expectations related to either gender or age were not observed. In the next iteration of their inquiry, "Prior Experience and Physicians' Intentions to Adopt EMR," Wiggins, et al., (2009) investigate one specific mediating factor of the UTAUT theory: the impact of prior experience with EMR. This preliminary work demonstrates that at least among this group of residents and physicians, there is not necessarily a positive relationship between experience with EMR and a physicians' intent or desire to adopt it.

Finally, with private physician practices as the unit of investigation, Reardon and Davidson (2007) posed the question of how physicians perceive the organizing vision for EMR and found that stakeholders need to do a better job of communicating the plausibility of EMR and at presenting representations of the EMR before an independent physician practice will find the organizing vision as clear, consistent, rich, and as balanced as it needs to be to be approved for adoption.

Moving away from questions about physicians and their reasons for or against adopting and using EMR, MacKinnon and Wasserman (2009) ask "What are the critical success factors for EMR systems implementation?" and propose that an understanding of Enterprise Resource Planning (ERP) systems will contribute to the successful implementation of EMR systems. They yielded strong support for the proposition that treating EMR systems as a type of ERP was a success factor for implementation. Other insights include the necessity of choosing a CCHIT certified and a KLAS evaluated EMR system.

Demonstrating that EMR adoption and implementation is a concern worldwide, "Electronic Medical Records: A Review Comparing the Challenges in Developed and Developing Countries," by Sood, et al., (2008), indicates challenges faced in developing countries hinder the development and progression of EMR and the authors suggest that developing countries may need to build on current structures of healthcare data bases and with technologies which have already be shown to work and add only relevant and disease specific modules unique to each country's needs over time.

In concluding this discussion of EMR, it is vital to point out that EMR has been, and continues to be, touted as the answer to any number of problems plaguing the healthcare industry. The studies above are a strong indication that this area of research is rich, with much yet to be investigated. EMR is a worldwide topic that can be viewed and investigated through a narrow user/organization lens or through a wide-angle national/global lens. As one of the primary impetuses for the use of EMR is to enhance and enable access to, and communication of, health information among caregivers, patients, health organizations, regional systems, and perhaps nations, many questions remain and much work remains to be done.

Clinical Systems

We move now from EMR to the investigation of IT systems used to support specific activities in clinical settings. The findings in this area are somewhat mixed. For example, the 2005 work done by Padmanabhan, et al., described an evaluation methodology for assessing a mobile triage support system on a handheld PDA. The researchers found few opportunities for improving the level of patient care by triage nurses using the decision support technology. More recent research by Burley, et al., (2008) on a similar topic asked in what way do mobile systems deliver internal value in emergency healthcare organizations? Their work indicates that the introduction of mobile services can support ambulance services by providing more efficient and effective information. Yet the authors caution that there is a delicate balance between internal data capture requirements versus external requirements of readability of the final electronic patient care record.

Indeed there is a well-established mythology in healthcare that describes failures in the implementation, use, and adoption of clinical IT. In their 2008 paper, Paré, et al., investigate the typical risk factors associated with clinical information systems, electronic patient record systems, picture archiving and communication systems (PACS), and computerized physician order entry system projects. The researchers then go on to ask "What is the relative importance of these risk factors?" Hypothesizing that the success of any given clinical information system project lies in the ability to identify the risk factors in order to reduce them and thus to improve chances of success, this work finds that failure rates due to unidentified and unanticipated risk factors still prevent clinical information system projects from being beneficial. Managers need to recognize what typical project risks are and their impact of these risks on project success.

Perry (2007) considers the options for process-based systems as "assistants" to professional mental health staff, and considers the extent to which such systems can complement or manage types of tacit knowledge, such as 'know-how' or emotion. The central problems identified in this study are that mental health staff find that person-to person knowledge transfer is reassuring, and trustworthy, while electronic methods are seen as untrustworthy. These findings underscore the idea that there is no evidence that IT-mediated knowledge transfer conveys social reassurance.

Still, all is not doom and gloom. The 2009 research, "On The Economic Role of RIS/PACS in Healthcare: An Empirical Study" from Ayal and Seidmann presents a case study measuring process times and revenues, as well as survey results from staff and customers about perceived operational benefits of integrating RIS/ PACS into a health system. It was hypothesized that RIS/ PACS would improve billing, significantly reduce diagnostic exam times, and improve customers' level of satisfaction of the diagnostic imaging service. Patterns in the surveys were identified using the Principal Components Analysis (PCA) methodology. Results show that physicians were satisfied with their level of interaction with departmental personnel, though customers were indifferent with the quality of the services.

What becomes abundantly clear when considering the clinical applications of healthcare IT is that this is an emerging area that will continue to grow and evolve. Indeed, it is an area that is at the very crux of multidisciplinary research. The places where disciplines intersect, such as nursing and quality, or clinical laboratory and patient satisfaction, are fertile and important areas for future research.

Administrative Applications of Health Information Technology

One could easily argue that EMR and telemedicine applications are excellent examples of administrative uses of HIT as they are seen as avenues to increased efficiency, access, and quality. These applications have been discussed above. The use of information technology in healthcare began with business applications such as accounting and billing and potential administrative applications of HIT continue to be investigated. A case in point is Fruhling, et al., (2005) work that examines the development and implementation of a biosecurity healthcare application. This paper focuses on programming and software engineering, but still makes the point that as terrorism, infectious agents, dirty bombs, and other chemical threats become more likely, healthcare as the largest information business in the US, needs to turn to technology applications such as telehealth to develop and implement biosecurity applications for healthcare.

Another example of research that addresses the administrative uses of IT is Khoumbati, et al.'s 2005 paper on Enterprise Application Integration (EAI). The integration of healthcare information systems with EAI is described with respect to the way they can be integrated at both an internal hospital level and externally with other hospitals, primary healthcare providers and with other stakeholders. The author identified technical, cost, medical errors, decision support system, security, and confidentiality of patients' data as factors that motivate the adoption of EAI in healthcare organizations. The authors conclude that, from a business perspective, EAI reduces the overall integration cost due to the reduction in integration time and maintenance costs.

Telemedicine

A broad number of applications under the umbrella of telemedicine have been increasingly investigated over the years. Telemedicine is the use of telecommunications for the care of patients and can involve a number of various electronic delivery mechanisms. The overarching research questions about telemedicine investigate its acceptance and effectiveness. For example, Wu et al., (2005) studied mobile applications asking what determines health professionals' acceptance of mobile healthcare technology, they conclude that compatibility and self efficacy have significant influence on intentional behavior. Management support, as they had hypothesized, did not influence behavior in this study. Dhillon and Forducey's (2006) "Implementation and Evaluation of Information Technology in Telemedicine" reviewed effectiveness evaluation techniques of telemedicine systems. They report on the successful utilization of HIT in regard to access, quality, and cost in a rural telehealth system. LeRouge and Hevner (2005) indicate that the way technology is used may affect effectiveness in defining quality for medical video conferencing.

In 2008 three research teams investigated three very different and very specific applications of telehealth. Goh and Agarwal (2008) asked these research questions: 1) what factors affect an individual's initial enrollment in an online health intervention program, 2) what factors affect continued participation in the program, and 3) how do the drivers of initial participation differ from those of continued involvement? They found that individuals who are less satisfied with their life and their work are more likely to enroll in a program, social ties are not significant in predicting enrollment, and perception of individual risk of contracting the illness has a positive and significant effect on enrollment. In addition, they found a strong moderating effect of gender, which suggests that gender plays a central role in sustaining participation; site owners need to consider increasing their efforts in sustaining the participation for females more than for males.

Cho, et al.'s (2008) work investigated how a telehealth innovation evolved from its initial adoption by a small network of hub hospitals to wider diffusion into a larger population of rural organizations. Their study resulted in six specific recommendations for success: 1) Develop a long-term plan for post-pilot stages. 2) Position innovation as a win-win proposition. 3) Align with rural hospital processes. 4) Accommodate rural area technology infrastructure issues. 5) Consider institutional arrangements and legal issues and, 6) Build and manage the knowledge base from initial adoption.

Then, in a completely different vein, Kifle, et al., (2008) examined Information and Communication Technology Transfer (ICTT) as it applied to telemedicine in Sub-Saharan Africa. Positing that telemedicine capabilities are positively related to social outcomes of telemedicine, this research found that social outcomes of telemedicine are positively related to value outcomes of telemedicine. Specifically, policies that favor the development of ICTs in general are positively related to telemedicine capabilities, policies specifically tailored to ensure data security and standards are positively related to telemedicine capabilities and to the level of ICT infrastructure, policies specifically tailored to promote the application of ICTs in healthcare are positively related to the level of ICT infrastructure, and that more reliable and readily accessible ICT infrastructure is positively related to telemedicine capabilities.

The investigation of telehealth and factors that impact its acceptance is an overarching theme for the 2009 conference. Are there specific characteristics that are related one's willingness to accept and use telehealth applications? For example, does culture play a role in the adoption of new telemedicine technology? Meso, et al., (2009) find that, among underserved communities, culture significantly influences individuals' intentions to use new technology prior to the implementation of the technology. However, once the telemedicine technology is in place and individuals become more familiar with using it, culture no longer plays a significant role in usage behavior. In a similar line of inquiry, Topacan, et al., (2009) interviewed potential users of telemedicine and asked semi-structured, open-ended questions to study and analyze their perceptions of a prototype service developed for the study. These researchers found that characteristics of the potential users (such as age, education level), cost of services, security, time use, and social factors would influence the adoption of a health information service such as telemedicine among the study group participants.

Taking a slightly different approach, a 2009 study by Svendsen, et al., (2009) of mobile phone based, tailored motivational systems investigated whether they would help to combat growing health problems associated with a lack of physical exercise. Study questions were related to motivation, self-efficacy in regard to exercise, and TAM related issues. Behavioral intention and acceptance of the mobile system was driven by an individual's intrinsic motivation and by the perceived usefulness of the application. The researchers suggest that mobile phone based motivation systems will work best if presented to the public as fun and game-like, and only secondarily if offered as a health enhancing tools.

One study asked, "What are the impacts of the implementation of software aimed at optimizing clinical services delivered at patients' homes?" Paré, et al., (2008) concluded that the implementation of the telehome care software had positive effects on staff productivity and upon accessibility to care services. Specifically, the software allowed the allocation of an additional hour that was used on patient care. Nurses were able to increase the number of home visits as well as devote more time to patient care rather than on paperwork.

Overall, it appears that the use of telecommunications is increasing in healthcare. The important question remains, what is the overall impact of traditional telemedicine media and emerging devices such as mobile phones and hand-held instruments on quality, access and cost?

FUTURE OF E-HEALTH ADOPTION AND EVALUATION

This analysis roughly follows the diagonal of table 3 that highlights the results. For nearly more than two decades researchers on e-health have explicitly shown that value, benefits, perceived usefulness or relevance are the most important determinants for successfully implementing e-health systems in the clinical domain. For almost two decades, practice seems to ignore these scientific findings and continues to introduce standard software in a complex individual medical setting with many disappointments as a result. How can we break through this deadlock situation? Many researchers think that Business Process Management (BPM in table 3) will help to diffuse information systems in healthcare. We think that this will only be the case when e-health provides value driven from an individual perspective of the healthcare professional. Many e-health applications only deliver efficiency as net benefit (see Table 3) and often this efficiency is delivered on the wrong side of the organization. It is therefore important to identify the individual stakeholders (Table 3) and know who the end user is (in Telemedicine often the patient) and who will exert the effort to implement the system.

On the group and organizational level, the main challenge is to integrate the back office and front office (see Table 3) of healthcare. Instead of EMR, here we are talking about ERP (enterprise resource planning) in healthcare or about enterprise wide systems combined with information services in the front office. Enterprise Application Integration is already widely used in business, but healthcare is just in its first steps toward integration. Another challenge on the organizational level is to manage the clinical systems and avoid unanticipated risks (see Table 3). In the future, integration in general, by using standards and building interoperable architectures, will have to stabilize the turbulence in e-health implementations. Because Electronic Medical Records have a value beyond the individual end user, the organization must create vision on how to communicate this to the whole healthcare chain and back again to the end user. On even larger scale, an ICT infrastructure is needed to be able to bridge the digital divide.

Interorganizational systems and mass customization are buzzwords that have strong influence on the globalization of e-health. Telemedicine is

Table 3. Overview analysis

LEVEL/ APPLICATION	*EMR*	*Clinical systems*	*Administrative Applications*	*Telemedicine*
Individual	**(Net) Benefits**	Process/BPM	Efficiency	Stakeholder
Group/organizational	Organize vision	**Unanticipated Risk**	**Back/ Front Office**	ICT infrastructure
(Inter)national	Healthcare Databases	Knowledge	Standardization	**Big Leap Forward**

seen as a weapon to break down the digital divide in healthcare and promises a big leap forward (see Table 3). Global systems like Google Health © l seem to break open the market, but still the dangers at the individual professional level might inhibit the diffusion of these systems. In the end, these systems have to evolve into knowledge management systems that can leverage healthcare at the global level. On the international level, standardization and knowledge dissemination should go hand in hand to solve global healthcare problems.

CONCLUSION AND DISCUSSION

This comprehensive review of HICSS papers underscores our understanding that adoption decisions are complex given a multitude of technologies, stakeholders, and potential levels of analysis when technology is introduced into healthcare settings. The research reviewed spans different technologies such as telemedicine, telehomecare, enterprise wide systems including RIS/PACS and EMR, infrastructure, and capacity assessment. Research in this area addresses implementation, intention to adopt and use, culture, performance, interventions, and methodology. Individual, organizational, and (inter)national levels of analysis are represented.

Many studies focus on the individual level and concentrate on adoption rather than on implementation. Although perceived usefulness and performance expectancy in all quantitative studies are significantly related to e-health success and many qualitative studies report on value, benefits, and relevance to the professional, *the value proposition remains under-developed in healthcare.* Moreover, even if the value of e-health is evident, there is much difficulty in implementing these systems due to lack of participation and resources. The risks on the group, organizational and (inter) national level are high with many stakeholders with many different interests.

In recent years, the international level and specifically the digital divide, has become a theme in e-health evaluation. Transferring knowledge across the digital divide will be an important subject on the international calendar. Also international comparisons might strengthen national initiatives when cultural differences are considered.

Results show a multitude of methodologies varying from quantitative psychological studies to qualitative demographic case studies to design science. The span and divergence of research methods underscore the complexity of this context and the fact that a multitude of studies and methods are needed to gain understanding. Though the scope of each individual study is limited, the collection of studies call researchers to consider mixed methodologies. The presence of design science pieces demonstrates that tools, techniques, and frameworks acknowledge the need for a planned and organized method of approaching the challenges of, and many variables involved in, implementation and evaluation in practice.

In addition to the many messages discussed above, readers should interpret this communication as a welcoming call to the many opportunities that are available in e-health research. The wide range of research approaches and levels of analysis should be appealing to a broad set of researchers, as we work toward improving the adoption and evaluation of Information Technology and its eventual benefit to improved societal healthcare.

ACKNOWLEDGMENT

We would like to thank all authors and referees for contributing to our successful Hawaii International Conference on System Science minitrack and hope to work with you in the future.

REFERENCES

"Academic Conference". (2008). Wikipedia. Retrieved October 1, 2008, from http://en.wikipedia.org/wiki/Academic_conference

Ajzen, I., & Madden, T. J. (1986). The Prediction of Goal Directed Behavior: Attitudes, Intentions and Perceived Behavioral Control. *Journal of Experimental Psychology*, *22*, 453-474.

Ayal, M., & Seidmann, A. (2009). On the Economic Role of Ris/Pacs in Healthcare: An Empirical Study. *Proceedings of the Hawaii International Conference on Systems Sciences*, Hawaii.

Bhattacherjee, A., & Hikmet, N. (2007). Physicians' Resistance toward Healthcare Information Technologies: A Dual-Factor Model. *Proceedings of the Hawaii International Conference on Systems Sciences*, Hawaii.

Brown, H. G., Deng, L., Poole, M. S., & Forducey, P. (2005). Towards a Sociability Theory of Computer Anxiety: An Interpersonal Circumplex Perspective. *Proceedings of the Hawaii International Conference on Systems Sciences*, Hawaii.

Burley, L., Scheepers, H., & Owen, L. (2008). The Internal Value of Mobile Computing in Emergency Medical Services: An Australian Case Study. *Proceedings of the Hawaii International Conference on Systems Sciences*, Hawaii.

Chiasson, M., Reddy, M., Kaplan, B., & Davidson, E. (2007). Expanding Multi-Disciplinary Approaches to Healthcare Information Technologies: What Does Information Systems Offer Medical Informatics. *International Journal of Medical Informatics*, *76*(S), 89-96.

Chismar, W. G., & Wiley-Patton, S. (2003). Does the Extended Technology Acceptance Model Apply to Physicians. *Proceedings of the Hawaii International Conference on Systems Sciences*, Hawaii.

Cho, S., Mathiassen, L., & Gallivan, M. (2008). From Adoption to Diffusion of a Tele-health Innovation. *Proceedings of the Hawaii International Conference on Systems Sciences*, Hawaii.

Davis, F. D. (1989). Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology. *MIS Quarterly*, *13*(3), 319-340.

Delone, W. H., & Mclean, E. R. (2002). Information Systems Success Revisited. *Proceedings of the Hawaii International Conference on System Sciences*, Hawaii.

Dhillon, H., & Forducey, P. G. (2006). Implementation and Evaluation of Information Technology in Telemedicine. *Proceedings of the Hawaii International Conference on Systems Sciences*, Kauai.

Fitch, C. J. (2004). Information Systems in Healthcare: Mind the Gap. *Proceedings of the Hawaii International Conference on System Science*, Hawaii.

Fruhling, A., Tyser, K., & De Vreede, G.-J. (2005). Experiences with Extreme Programming in Tele-health: Developing and Implementing a Biosecurity Health Care Application. *Proceedings of the Hawaii International Conference on Systems Sciences*.

Gagnon, M.-P., Lamothe, L., Fortin, J.-P., Cloutier, A., Godin, G., Gagné, C., & Reinharz, D. (2004). The Impact of Organizational Characteristics on Tele-health Adoption by Hospitals. *Proceedings of the Hawaii International Conference on Systems Sciences*.

Goh, J. M., & Agarwal, R. (2008). Taking Charge of Your Health: The Drivers of Enrollment and Continued Participation in Online Health Intervention Programs. *Proceedings of the Hawaii International Conference on Systems Sciences*.

Harle, C., Downs, J., & Padman, R. (2009). Design, Implementation, and Preliminary Evaluation of a Web-Based Health Risk Calculator. *Proceedings of the Hawaii International Conference on Systems Sciences*, Hawaii.

Hartswood, M., Procter, R., Slack, R., Voß, A., Büscher, M., Rouncefield, M., & Rouchy, P. (2002). Co-Realisation: Towards a Principled Synthesis of Ethnomethodology and

Participatory Design. *Scandinavian Journal of Information Systems*, *14*(2), 19-30.

Hevner, A., March, S., Park, J., & Ram, S. (2004). Design Science in Information Systems Research. *MIS Quarterly*, *28*(1), 75-105.

Horan, T. A., Tulu, B., Hilton, B., & Burton, J. (2004). Use of Online Systems in Clinical Medical Assessments: An Analysis of Physician Acceptance of Online Disability Evaluation Systems. *Proceedings of the Hawaii International Conference on Systems Sciences*, Hawaii.

Hu, P. J., Liu Sheng, P. Y. K., & Tam, K. Y. (1999). Examining the Technology Acceptance Model Using Physician Acceptance of Telemedicine Technology. *Journal of Management Information Systems*, 16(2), 91-112.

Ilie, V., Courtney, J., & Van Slyke, C. (2007). Paper Versus Electronic: Challenges Associated with Physicians' Usage of Electronic Medical Records. *Proceedings of the Hawaii International Conference on Systems Sciences*, Hawaii.

Jaana, M., Paré, G., & Sicotte, C. (2009). It Capacities Assessment Tool: A Survey of Hospitals in Canada. *Proceedings of the Hawaii International Conference on Systems Sciences*, Hawaii.

Khoumbati, K., Themistocleous, M., & Irani, Z. (2005). Integration Technology Adoption in Healthcare Organisations: A Case for Enterprise Application Integration. *Proceedings of the Hawaii International Conference on Systems Sciences*, Hawaii.

Kifle, M., Mbarika, V. W. A., Tsuma, C., Wilkerson, D., & Tan, J. (2008). A Telemedicine Transfer Model for Sub-Saharan Africa. *Proceedings of the Hawaii International Conference on Systems Sciences*, Hawaii.

Kiura, S. M. (2006). Project Establishment in the Context of Participatory Design: Experience from a Hospital Information System Development Project in a Developing Country. *Proceedings of the Hawaii International Conference on Systems Sciences*, Kauai.

Laforge, R. (1977). *Interpersonal Check List (Icl)*. In J. J. J. Pfeiffer (Ed.), *The Annual Handbook for Group Facilitators* (pp. 89-96). La Jolla: University Associates Publishers.

Lapointe, L., Lamothe, L., & Fortin, J.-P. (2002). The Dynamics of It Adoption in a Major Change Process in Healthcare Delivery. *Proceedings of the Hawaii International Conference on Systems Sciences*, Hawaii.

Leavitt, H. J. (1965). *Applied Organisational Change in Industry: Structural Technological and Humanistic Approaches*. In J. G. March (Ed.), *Handbook of Organizations* (pp. 1144-1170). Chicago: Rand-McNally.

Lerouge, C., & Hevner, A. R. (2005). It's More Than Just Use: An Investigation of Telemedicine Use Quality. *Proceedings of the Hawaii International Conference on Systems Sciences*, Hawaii.

Maass, M., & Eriksson, O. (2006). Challenges in the Adoption of Medical Information Systems. *Proceedings of the Hawaii International Conference on Systems Sciences*, Kauai.

Maass, M. C., & Suomi, R. (2004). Adoption-Related Aspects of an Information System in a Health Care Setting. *Proceedings of the Hawaii International Conference on Systems Sciences*, Hawaii.

Mackinnon, W. & Wasserman, M. (2009). Integrated Electronic Medical Record Systems: Critical Success Factors for Implementation. *Proceedings of the Hawaii International Conference on Systems Sciences*, Hawaii.

Mantzana, V., & Themistocleous, M. (2006). A Method for the Identification of Actors Involved in the Adoption of Innovations in Healthcare Organizations. *Proceedings of the Hawaii International Conference on Systems Sciences*, Kauai.

March, S., & Smith, G. (1995). Design and Natural Science Research on Information Technology. *Decision Support Systems*, 15, 251-266.

Mcleod, A. J., & Clark, J. G. (2007). Identifying the User in Healthcare Information Systems Research. *Proceedings of the Hawaii International Conference on Systems Sciences*, Hawaii.

Meso, P., Mbarika, V., Kifle, M., Okoli, C., & Nwabueze, S. (2009). The Effects of Culture of Adoption of Telemedicine in Medically Underserved Communities. *Proceedings of the Hawaii International Conference on Systems Sciences*, Hawaii.

Padmanabhan, N., Burstein, F., Churilov, L., Wassertheil, J., Hornblower, B., & Parker, N. (2006). A Mobile Emergency Triage Decision Support System Evaluation. *Proceedings of the Hawaii International Conference on Systems Sciences*, Kauai.

Paré, G., Jaana, M., & Girouard, D. (2008). Prioritizing Clinical Information System Project Risk Factors: A Delphi Study. *Proceedings of the Hawaii International Conference on Systems Sciences*, Hawaii.

Paré, G., Sicotte, C., Chekli, M., Jaana, M., & Blois, C. D. (2009). Evaluation of the Impacts of a Provider-Focused Tele-homecare Intervention: A Pre-Post Study. *Proceedings of the Hawaii International Conference on Systems Sciences*, Hawaii.

Perry, I. F. (2007). Process, Knowledge, Touchpoints in Mental Health Communities of Practice. *Proceedings of the Hawaii International Conference on Systems Sciences*, Hawaii.

Raitoharju, R. (2005). When Acceptance Is Not Enough - Taking Tam-Model into Healthcare. *Proceedings of the Hawaii International Conference on Systems Sciences*, Hawaii.

Reardon, J. L., & Davidson, E. (2007). How Do Doctors Perceive the Organizing Vision for Electronic Medical Records? Preliminary Findings from a Study of Emr Adoption in Independent Physician Practices. *Proceedings of the Hawaii International Conference on Systems Sciences*, Hawaii.

Roberts, L., Ward, M., Brokel, J., Wakefield, D., Crandall, D., & Conlon, P. (2009). Methodological Approaches to Measuring the Effects of Implementation of Health Information Technology (Hit). *Proceedings of the Hawaii International Conference on Systems Sciences*, Hawaii.

Rogers, E. M. (1995). *Diffusions of Innovations.* New York: The Free Press.

Ryan, J., Doster, B., Daily, S., & Heslin, M. (2008). Soft Innovation as Data-Driven Process Improvement Exploited Via Integrated Hospital Information Systems. *Proceedings of the Hawaii International Conference on Systems Sciences*, Hawaii.

Schaper, L. K., & Pervan, G. P. (2007). An Investigation of Factors Affecting Technology Acceptance and Use Decisions by Australian Allied Health Therapists. *Proceedings of the Hawaii International Conference on Systems Sciences*, Hawaii.

Schmidt, R. (1997). Managing Delphi Surveys Using Nonparametric Statistical Techniques. *Decision Science*, *28*(3), 763-774.

Schuring, R. W., & Spil, T. A. M. (2002). Explaining Plateaued Diffusion by Combining the User-It-Success Factors (Usit) and Adopter Categories: The Case of Electronic Prescription Systems for General Practitioners. *International Journal of Healthcare Technology and Management*, *4*, 303-318.

Sherlock, S., & Chismar, W. G. (2006). What Airline Reservation Systems Tell Us About the Future of Ehrs. *Proceedings of the Hawaii International Conference on Systems Sciences*, Kauai.

Sood, S. P., Nwabueze, S. N., Mbarika, V. W. A., Prakash, N., Chatterjee, S., Ray, P., & Mishra, S. (2008). Soft Innovation as Data-Driven Process Improvement Exploited Via Integrated Hospital Information Systems. *Proceedings of the Hawaii International Conference on Systems Sciences*, Hawaii.

Svendsen, G. B., Søholt, Y., Munch-Ellingsen, A., Gammon, D., & Schurmann, A. (2009). The Importance of Being Useful and Fun: Factors Influencing Intention to Use a Mobile System Motivating for Physical Activity. *Proceedings of the Hawaii International Conference on Systems Sciences*, Hawaii.

Thatcher, J. B., & Perrewe, P. L. (2002). An Empirical Examination of Individual Traits as Antecedents to Computer Anxiety and Computer Self-Efficacy. *MIS Quarterly*, (pp. 381-391).

Topacan, U., Basoglu, N. and Daim, T. (2009). Health Information Service Adoption: Case of Telemedicine. *Proceedings of the Hawaii International Conference on Systems Sciences*, Hawaii.

Trimmer, K., Beachboard, J., Wiggins, C., & Woodhouse, W. (2008). Electronic Medical Records Use – an Examination of Resident Physician Intentions. *Proceedings of the Hawaii International Conference on System Sciences*, Hawaii.

Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User Acceptance of Information Technology: Toward a Unified View. *MIS Quarterly*, *27*(3), 425-478.

Wiggins, C., Pumphrey, L., Beachboard, J., & Trimmer, K. (2006). Entrepreneurial Governance in a Rural Family Practice Residency Program. *Proceedings of the Hawaii International Conference on Systems Sciences*, Kauai.

Wiggins, C., Trimmer, K., Beachboard, J., Woodhouse, W., & Peterson, T. (2009), Prior Experience and Physicians' intentions to Adopt EMR. *Proceedings of the Hawaii International Conference on Systems Sciences*, Hawaii.

Wood, J., & Silver, D. (1995). *Joint Application Development* (2nd ed.). New York: John Wiley & Sons.

Wu, J.-H., Wang, S.-C., & Lin, L.-M. (2005). What Drives Mobile Health Care? An Empirical Evaluation of Technology Acceptance. *Proceedings of the Hawaii International Conference on Systems Sciences*, Hawaii.

Yusof, M. M., Paul, R. J., & Stergioulas, L. K. (2006). Towards a Framework for Health Information Systems Evaluation. *Proceedings of the Hawaii International Conference on Systems Sciences*, Kauai.

ENDNOTE

[1] This track has undergone some minor name changes over the years.

APPENDIX A. TABLE OF PAPERS REVIEWED

Title of Paper	Author	Year	Dependent Variable	Research Method	Research Design	Data Source
The Dynamics of IT Adoption in a Major Change Process in Healthcare Delivery	Liette Lapointe, Lisa Lamothe, Jean-Paul Fortin	2002	Implementation	Qualitative	Multi case study - Mixed- Observation, Interviews, Documentation	Caregivers, promoters, consultants, patients, and hospital management
Does the Extended Technology Acceptance Model Apply to Physicians	William G. Chismar, Sonja Wiley-Patton	2003	Adoption	Quantitative and Qualitative	Survey	Pediatricians
The Impact of Organizational Characteristics on Tele-health Adoption by Hospitals	Marie-Pierre Gagnon, Lise Lamothe, Jean-Paul Fortin, Alain Cloutier, Gaston Godin, Camille Gagné, Daniel Reinharz	2004	Adoption, Implementation	Quantitative and Qualitative	Survey and semi-structured interviews	Directors of Professional Services
Use of Online Systems in Clinical Medical Assessments: An Analysis of Physician Acceptance of Online Disability Evaluation Systems	Thomas A. Horan, Bengisu Tulu, Brian Hilton, Jacqueline Burton	2004	Evaluation	Quantitative	Survey	Physicians
Adoption-related Aspects of an Information System in a Health Care Setting	Marianne C. Maass, Reima Suomi	2004	Implementation, Adoption and Evaluation	Quantitative	Mixed - cost analysis, workflow modeling, customer satisfaction survey,	Physicians and nurses
Information Systems in Healthcare: Mind the Gap	C.J. Fitch	2004	Implementation and Use	Design Science	N/A	N/A
It's More than Just Use: An Investigation of Telemedicine Use Quality	Cynthia LeRouge, Alan R. Hevner	2005	Telemedicine use quality	Qualitative	Multi-case study Qualitative methods (observation, focus group, and interviews) and Quantitative methods (survey)	Patients, physician, other medical providers (e.g., nurses), IT personnel, support staff
Experiences with Extreme Programming in Tele-health: Developing and Implementing a Biosecurity Health Care Application	Ann Fruhling, Kimberly Tyser, Gert-Jan de Vreede	2005	Implementation and Evaluation	Qualitative -	Action Research - Direct observation, interviews, usabiliity evaluation, review of documentation	System development team

APPENDIX A. CONTINUED

Title of Paper	Author	Year	Dependent Variable	Research Method	Research Design	Data Source
What Drives Mobile Health Care? An Empirical Evaluation of Technology Acceptance	Jen-Her Wu, Shu-Ching Wang, Li-Min Lin	2005	Use	Qualitative	Mixed - Survey and interview	Users - physicians, medical technicians, nurses
When acceptance is not enough – taking TAM-model into healthcare	Reetta Raitoharju	2005	Adoption, Evaluation	Conceptual Paper	N/A	N/A
Integration Technology Adoption in Healthcare Organisations: A Case for Enterprise Application Integration	Khalil Khoumbati, Marinos Themistocleous and Zahir Irani	2005	Adoption	Conceptual Paper	N/A	N/A
Towards a Sociability Theory of Computer Anxiety: An Interpersonal Circumplex Perspective	Houghton G. Brown, Liqiong Deng, Marshall Scott Poole. Pamela Forducey	2005	Evaluation	Quantitative	survey	Physical therapists
Towards a Framework for Health Information Systems Evaluation	Maryati Mohd. Yusof, Ray J. Paul, Lampros K. Stergioulas	2006	Evaluation, Implementation	Conceptual Paper	N/A	N/A
Challenges in the Adoption of Medical Information Systems	Marianne Maass, Owen Eriksson	2006	Adoption, Implementation	Quantitative and Qualitative	Longitutidinal Case study (consisting of statistical data, cost analysis, modeling, customer satisfaction inquirie time and motion studies) observation and staff interviews)	Management, Medical Staff
A Mobile Emergency Triage Decision Support System Evaluation	Neha Padmanabhan, Frada Burstein, Leonid Churilov, Jeff Wassertheil, Bernard Hornblower,Nyree Parker	2006	Evaluation	Experiment - Quantitative	Experiment	Nursing students
What Airline Reservation Systems Tell Us about the Future of EHRs	Sheila Sherlock, William G. Chismar	2006	Design and implementation	Conceptual Paper	N/A	N/A

APPENDIX A. CONTINUED

Title of Paper	Author	Year	Dependent Variable	Research Method	Research Design	Data Source
Implementation and Evaluation of Information Technology in Telemedicine	Harpal Dhillon,Pamela G. Forducey	2006	Evaluation and Implementation	Design Science	Verifying case study included review of reports generated from a telerehabilitation system; patient survey; provider satisfaction survey; hospital cost records	Patient, provider, system
Project Establishment in the Context of Participatory Design: Experience from a Hospital Information System Development Project in a Developing Country	Salesio Mbogo Kiura	2006	Implementation	Qualitative	Action research - using joint application design and STEPs	Hospital staff
Entrepreneurial Governance in a Rural Family Practice Residency Program	Carla Wiggins, Lela Pumphrey, John Beachboard and Kenneth Trimmer	2006	Adoption	Qualitative	Interviews and document analysis	Family practice residents
A Method for the Identification of Actors Involved in the Adoption of Innovations in Healthcare Organizations	Vasiliki Mantzana, Marinos Themistocleous	2006	Adoption	Design	Validating case study included interviews, documentation, observation	Hospital management, staff, and medical providers
Paper versus Electronic: Challenges Associated with Physicians' Usage of Electronic Medical Records	Virgiia Ilie, Jim Courtney, Craig Van Slyke	2007	Adoption	Qualitative	Case study - Semi strucured interviews and direct observation	Attending physicians and residents
Identifying the User in Healthcare Information Systems Research	Alexander J. McLeod Jr, Jan Guynes Clark	2007	Evaluation	Conceptual Paper	N/A	N/A
An investigation of factors affecting technology acceptance and use decisions by Australian allied health therapists	Louise K. Schaper, Graham P. Pervan	2007	Use, Adoption	Quantitative and Qualitative	National survey and logititudinal case study	Occupational therapists, hospital management, staff, and medical providers at a community based health care center

APPENDIX A. CONTINUED

Title of Paper	Author	Year	Dependent Variable	Research Method	Research Design	Data Source
How Do Doctors Perceive the Organizing Vision for Electronic Medical Records? Preliminary Findings from a Study of EMR Adoption in Independent Physician Practices	John Lee Reardon, Elizabeth Davidson	2007	Adoption	Quantitative	Survey	representative of independent physician practice
Physicians' Resistance toward Healthcare Information Technologies: A Dual-Factor Model	Anol Bhattacherjee and Neset Hikmet	2007	Use	Quantitative	Survey	Practicing physicians
Process, Knowledge, Touchpoints in Mental Health Communities of Practice.	Ivor F. Perry	2007	Knowledge transfer	Qualitative	Interviewed	Nursing staff
Prioritizing Clinical Information System Project Risk Factors: A Delphi Study	Guy Paré, Mirou Jaana, David Girouard	2008	CIS project success	Quantitative and Qualitative	Delphi	Experienced clinical information systems project managers,
The Internal Value of Mobile Computing in Emergency Medical Services: an Australian Case Study	Liz Burley, Helana Scheepers, Libby Owen	2008	Evaluation	Qualitative	Case study - Semi strucured interviews,	IT personnel, ambulance service management, clinical support officers, paramedics
A TeleMedicine Transfer Model for Sub-Saharan Africa	Mengistu Kifle,Victor W.A. Mbarika, Clive Tsuma, Derkirra Wilkerson , Joseph Tan	2008	Social outcomes of TM, level of IÇT infrastructure, TM capabilities	Quantitative	Survey	Physicians and PhDs in healthcare related specialities
Taking Charge of Your Health: The Drivers of Enrollment and Continued Participation in Online Health Intervention Programs	Jie Mein Goh, Ritu Agarwal	2008	Use (enrollment)	Quantitative and Qualitative	Archival data	System - Health program provider health portal

APPENDIX A. CONTINUED

Title of Paper	Author	Year	Dependent Variable	Research Method	Research Design	Data Source
Electronic Medical Records Use – An Examination of Resident Physician Intentions	Ken Trimmer, John Beachboard, Carla Wiggins, William Woodhouse	2008	Evaluation,	Qualitative	Case study - Interviews - interpretive	Resident Physicians
Soft Innovation as Data-driven Process Improvement Exploited via Integrated Hospital Information Systems	Jim Ryan, Barbara Doster, Sandra Daily, and Marty Heslin	2008	Origins of soft innovation	Qualitative	Longitutidinal positivist Case study (interviews, field surveys, site observations, field notes, archival records, and document reviews)	Hospital management, staff, and medical providers
Electronic Medical Records: A Review Comparing the Challenges in Developed and Developing Countries	Sanjay P. Sood, Stacie N. Nwabueze, Victor W.A. Mbarika, Nupur Prakash, Samir Chatterjee, Pradeep Ray, Saroj Mishra	2008	Review	Conceptual Paper	Literature review -	N/A
From Adoption to Diffusion of a Tele-health Innovation	Sunyoung Cho, Lars Mathiassen , Mike Gallivan	2008	Diffusion	Qualitative	Longitutidinal Case study (systems documentation, public articles, stakeholder interviews, and workshops)	Physicians, administrative staff, IT staff, nurses, radiology technician
Health Information Service Adoption: Case of Telemedicine	Umit Topacan, Nuri Basoglu, Tugrul Daim	2009	Adoption	Qualitative	Interview	Physicians and nurses
Evaluation of the Impacts of a Provider-Focused Tele-homecare Intervention: A Pre-Post Study	Guy Paré, Claude Sicotte, Mohamed Chekli, Mirou Jaana, Céline De Blois	2009	Evaluation	Quantitative and Qualitative	Quasi-experiment in the field (semi-structured interviews, structured questionnaires, and managerial reports)	Nurses
The Importance of Being Useful and Fun: Factors Influencing Intention to Use a Mobile System Motivating for Physical Activity	Gunnvald B. Svendsen, Yngvil Søholt, Arne Munch-Ellingsen, Deede Gammon, Anders Schurmann	2009	Adoption	Quantitative	Survey	Health consumers (not ill)

APPENDIX A. CONTINUED

Title of Paper	Author	Year	Dependent Variable	Research Method	Research Design	Data Source
IT Capacities Assessment Tool: A Survey of Hospitals in Canada	Mirou Jaana, Guy Paré, Claude Sicotte	2009	Evaluation	Design	Validation method - survey	IT directors
Prior Experience and Physicians' Intention to Adopt EMR	Carla Wiggins, Ken Trimmer, John Beachboard, William Woodhouse, Teri Peterson	2009	Adoption	Quantitative	Survey	Physicians
Integrated Electronic Medical Record Systems: Critical Success Factors for Implementation	William MacKinnon, Michael Wasserman	2009	Implementation	Qualitative	Interview (telephone)	Physicians, regional sales manager of electronic medical record system, independent electronic medical record system consultant, CEO of a medical group practice, project coordinator, office manager
On The Economic Role of RIS/ PACS in Healthcare: An Empirical Study	Moshe Ayal, Abraham Seidmann	2009	Evaluation	Quantitative	Case study (survery, review of operational data for processing times, and revenue)	Radiology staff and customers
The Effects of Culture of Adoption of Telemedicine in Medically Underserved Communities	Peter Meso, Victor Mbarika, Mengistu Kifle, Chitu Okoli, Stacie Nwabueze	2009	Use, Adoption	Quantitative	Survey	Physicians (actual and potential users)
Methodological Approaches to Measuring the Effects of Implementation of Health Information Technology (HIT)	Lance Roberts, Marcia Ward, Jane Brokel, Douglas Wakefield, Donald Crandall, Paul Conlon	2009	Implementation - adverse drug events	Design	Review of algorithmic evaluation methods for health technologies, recommendation, and case study demonstrating recommendations using pre and post implementation measures	Operational data

This work was previously published in Int. J. of Healthcare Information Systems and Informatics, 4(3), edited by J. Tan, pp. 69-96, copyright 2009 by IGI Publishing (an imprint of IGI Global).

Chapter 1.8

Health Infonomics:
Intelligent Applications of Information Technology

Michael Mackert
The University of Texas at Austin, USA

Pamela Whitten
Michigan State University, USA

Bree Holtz
Michigan State University, USA

ABSTRACT

Researchers are currently challenged to document the economic aspects of information across an array of contexts. While some lessons can be applied generally, certain contexts present unique challenges for researchers interested in the acquisition, management, and use of information. Health is one such field currently undergoing a revolution driven by new applications of information-based technologies and services. This chapter provides background on health informatics and current issues as health informatics impacts the provision of health in doctors' offices, shifts the provision of healthcare services into patients' homes, and presents new opportunities to address public health concerns. An outline of a future research agenda in health informatics and a look at the prospect of health informatics applications provides the necessary foundation for focused work on the economic impact of this information-driven transformation in healthcare delivery.

DOI: 10.4018/978-1-60566-890-1.ch012

INTRODUCTION

Informatics, the maximization of data use and acquisition through the intersection of information and computer science, is becoming commonplace across a range of applications that interface with everyday life. Currently, researchers are challenged to document economic aspects of information across a vast array of decision-making contexts. There are important general lessons that can be applied across applications from the field of infonomics, but context can also drive the impact and evolution of information use in distributed business environments.

Healthcare is one such context uniquely poised for transformation based on informatics and the economic aspects of information-driven changes in the provision of healthcare. The delivery of health services represents one of the more complex examples of distributed decision making as multiple stakeholders - providers, patients, family caregivers, insurance payers, and government regulators - have interests in individuals' health decisions and treatments.

Prompted by rising healthcare costs and concerns over quality, there is significant pressure to reform healthcare in both developed and developing countries. Stakeholders are looking to a wide array of information technologies to address challenges in health delivery, including access to care, medical errors, cost efficiencies, health outcomes, patient and provider satisfaction, demographic challenges such as aging populations, and provider shortages. Such challenges are particularly pressing given the unprecedented strain the health care industry will face due to an aging global population. The United Nations projects that by 2050 the number of older people (60 years or older) will outnumber younger people worldwide, due to people around the world living longer and having fewer children (United Nations, 2002).

While informatics may not present a solution to every problem in healthcare, appropriate applications of new information technology to the provision of health can indeed present promising strategies for addressing shortcomings in the healthcare system or advancing the practice of medicine. The sheer quantity of information necessary to practice medicine and to be an informed patient is rapidly increasing. Health informatics systems can serve as gateways for this vast amount of information to be utilized and managed by both providers and patients.

In line with the recognition that information technology can be used as a tool to address the challenges in healthcare, there is also a growing movement for paradigmatic shifts in the very nature of healthcare provision. For example, the movement toward “patient-centered care” seeks to provide health services that explore a patient’s main reason for a health visit, concerns, and need for information; gain an integrated understanding of the patient’s emotional needs and life issues, find common understandings of the etiology of the problem, allow the patient and health provider to mutually agree on management; enhance prevention and health promotion; and reinforce the continuing relationship between the patient and health provider (Stewart, 2001). Health informatics can assist in this movement of patient-centered care, empowering patients and their communities so they can make informed decisions regarding their healthcare (Cornford & Klecun-Dabrowska, 2001). Operationalizing this concept calls for employing information technologies to meet the core goals of patient-centered care, namely (Sherer, 1993):

- Locating services as close as possible to patients
- Redefining work by desegregating job tasks and providing health workers with necessary support, skills, and training
- Meeting patient needs, rather than the needs of a department, discipline or field.

This chapter seeks to illustrate the evolution and impact of health informatics, review what research has taught us to date, and comment upon future directions to advance health informatics and infonomics research. The discussion will include the utilization of health informatics systems designed to assist healthcare providers in their work, technology to bring health services into patients’ homes, and population-based applications that can advance public health. A greater understanding of health informatics applications - what these systems are and how they could radically transform the healthcare system - can provide the foundation for studies of the economic impact of an information-driven revolution in healthcare delivery. While many of the statistics and examples cited in this chapter are drawn from the U.S., lessons learned and potential applications would be similar in international contexts. Differences between the U.S. and other countries are noted when relevant.

THE UNDERPINNINGS OF HEALTH INFORMATICS

Health informatics has emerged as a rapidly evolving scientific field that studies the interrelationship between information (e.g., computers and communications), science (e.g., engineering and technology) and health (practice, education, and research). Health informatics, by nature, encompasses multiple disciplines, including communication, economics, engineering, computer science, nursing, and medicine. This new academic domain includes multiple applications, such as:

- Development and delivery of public health information
- Design and analysis of electronic medical records and personal health records
- Evaluation of the impact of IT on the clinical processes, outcomes, and resources
- Telemedicine and remote monitoring
- Data management and database construction
- Development of terminology, coding, and classification schemes
- Process re-engineering
- Interactions and interfaces between technology, providers, and patients
- Implications for policy and ethics
- Bioinformatics
- Clinical decision tools and decision support systems
- Geographic Information systems

With its broad array of disciplines it should not be surprising that health informatics also encompasses a variety of terms referring to transferring data to maximize patient care. Terminology commonly used in the literature when discussion heath informatics includes electronic medical records (EMR), electronic health records (EHR), health information technology (HIT), health information network (HIN) and health information exchange (HIE).

Before EMRs, paper records were launched in the 19th century as the standard of recording patient data, treatments, and procedures (Shortliffe, 1999). Generally, EMRs simply refer to an individual record in which a healthcare provider records treatments, drugs, and future recommendations electronically. There are several advantages of an electronic record, including legible orders and the ability for quicker searches through the record (D. Bates, Ebell, Gotlieb, Zapp, & Mullins, 2003). While the terms EMR and EHR are often used synonymously, many consider EHRs to be more comprehensive (Busis & Hier, 2007). EHRs include individual patient information from a variety of sources, such as radiology (films), pharmacy (interaction checks), and specialist information (cardiologist, dermatologist, etc.).

Examining the broader scope of electronic health data management, HIT is defined by the Department of Health and Human Services as a "comprehensive management of medical information and its secure exchange between healthcare consumers and providers" (Department of Health and Human Services, 2008). HIT is being recognized as an extremely important tool for improving healthcare quality and outcomes, reducing costs, and improving access to care. HIEs or HINs are necessary when connecting all of the individual patient records across regions or organizations. Through the years these have also been coined CHINs (Community Health Information Network) or RHIOs (Regional Health Information Organization).

New health informatics applications are often cited in calls to improve the healthcare system, such as in the early 1990s when the Institute of Medicine called for the creation of computerized patient records nationally (Dick, Steen, & Detmer, 1991). While many healthcare professionals and policymakers at that point understood the benefit of sharing patient information among healthcare providers, a decade later it was necessary to produce more calls for the public to recognize the importance of information technology in healthcare as the Institute of Medicine published two additional reports *To Err is Human* (2000) and *Crossing the Quality Chasm* (2001). *To Err is Human* is now considered to be a seminal report on restructuring the healthcare system in order to improve health outcomes. That report declared that up to 98,000 people in the United States were dying due to medical errors each year. The report posited the entire healthcare system must be revised in order to meet six goals - to provide care that is safe, effective, patient-centered, timely, efficient, and equitable (Johnston, Pan, Walker, Bates, & Middleton, 2003; Kohn, Corrigan, & Donaldson, 2000). The report also asserted health informatics would be a key to resolving this crisis in healthcare (Johnston, et al., 2003; Kohn, et al., 2000). In *Crossing the Quality Chasm* a strategic plan was proposed to address the problems highlighted in *To Err is Human*. In it, health informatics is positioned as being able to facilitate in addressing all six goals of improving healthcare.

Three years later, in 2004, President George Bush declared by 2014, most Americans should have a national EHR and created the position of the National Health Information Technology Coordinator (Blumenthal & Glaser, 2007). Still, almost a decade after *Crossing the Quality Chasm*, researchers and practitioners are still no closer to implementing national EHRs (Miller & Sim, 2004). A study conducted through 2005, demonstrated less than twenty-four percent of physicians used EHRs in an ambulatory setting, only five percent of hospitals had a computerized physician order entry (CPOE) system, and less than two percent of the hospitals were actively using CPOE systems (Holbrook, 2006; Jha, et al., 2006). This is despite the fact that HIT has been found to improve patient care and quality (Chaudhry, et al., 2006). The challenges faced by implementation of a nationwide health network were also noted in the IOM's 2001 report, these issue consist of interoperability, standardization, privacy, regulatory, human factors and the large financial investment requires (Institute of Medicine, 2002). Even today these barriers remain as key hurdles facing IT diffusion in healthcare, though progress is being made - 29.2% of office-based physicians were using EMRs in 2006, a 22% increase from 2005 and 60% increase since 2001 (Hing, Burt, & Woodwell, 2007).

Some of the key challenges facing these projects include cost, lack of reimbursement, technical issues, system interoperability, legal and policy issues, and concerns over security, privacy, and confidentiality (Hersh, 2004; Schoenman, Keeler, Moiduddin, & Hamlin, 2006; Whitten, Buis, & Love, 2007). Physicians are often expected to front upwards of $24,000 to install and implement a HIT system with little return on investment (ROI) (Hersh, 2004; Johnston, et al., 2003; Kleinke, 2005). Insurers, laboratories, patients and others generally uninvolved in the payment for electronic systems assume the remainder of the ROI (Hersh, 2004; Whitten, Buis, & Love, 2007). Any type of health information technology application generally involves systems with high complexity that must be customized to a particular clinic or office (Whitten, Buis, & Mackert, 2007). Hersh (2004) suggested that health care facilities, especially those in rural or underserved areas, adopt a simple and inexpensive solution to HIT. System interoperability is also a concern regarding the adoption of HIT in the health field. Most information is inaccessible from one system to the next, making a cohesive record for patients impossible, lowering the incentives for single physician offices or small clinics to implement this type of technology (Hersh, 2004, 2006; Kleinke, 2005; Walker, et al., 2005). Security, privacy, and confidentiality are an important topic when dealing with HIT, as many studies report that electronic data have more security features than traditional paper records (Hersh, 2004). In general, patients do not perceive security issues as a major barrier, whereas clinicians are extremely concerned (Whitten, Buis, & Love, 2007).

Some of the challenges facing the rollout of health technology in the U.S., specifically the fragmented healthcare system, are not present in other countries. Indeed, many other countries, specifically those with more centralized systems of health care – the United Kingdom, Canada, Norway, Singapore, etc. – have been able to advance far ahead of the U.S. (E. Shortliffe, 2005). Overall, the governments of those countries have initiated programs to advance HIT and most are at least six years ahead of the United States (Anderson, Frogner, Johns, & Reinhardt, 2006). While many countries are further along in their implementation, they are still facing a myriad of hurdles to full adoption and diffusion. Many of these countries' programs started with disjointed and unstandardized systems but discovered that such a strategy hindered adoption. Some countries adopted standards set by the eEurope 2002 and eEurope 2005 Action Plans. Many other countries have adopted the Health Level Seven (HL7) standards, including Canada, Germany, the United Kindgom, and the U.S. (Anderson, et al., 2006). HL7 "provides standards for interoperability that improve care delivery, optimize workflow, reduce ambiguity and enhance knowledge transfer among …healthcare providers, government agencies, the vendor community" (HL7, 2009).

In the past, there has been a fundamental assumption that health informatics will inherently improve the quality of healthcare (Heathfield, Pitty, & Hanka, 1998; Kaplan, 2001). Above and beyond improvements potential improvements in healthcare, health informatics research involves understanding the implementation and utilization of these technologies while also examining the actual use by the healthcare workers in their health specialty (Kaplan, 2001; Lærum, Ellingsen, & Faxvaag, 2001). Many researchers studying health informatics now understand that human factors, organizational institutionalism, and medical specialty contribute in the overall diffusion and success of these tools. The following section provides an overview of recent research in health informatics.

CURRENT ISSUES IN HEALTH INFORMATICS

Health informatics systems span the healthcare system, from hospitals and doctors' offices to patients' homes to the efforts of public health officials to improve population-level health indicators. Informatics in health offers the opportunity to study large scale information systems based on human-centered considerations. As there are multiple types of large scale information systems in the health context, special consideration must be paid to the unique nuances of these information-based services. This section highlights study of US-based applications.

EHRs and Healthcare Quality

Widespread deployment and adoption of EHR systems is one important step toward improving healthcare in the U.S., an important goal given that U.S. adults only receive approximately half of the care they should (McGlynn, et al., 2006). As stated earlier, adoption of EHRs in the U.S. has been quite slow, however, with 25-30% of practices currently making use of such systems (Berner, Detmer, & Simborg, 2005; Burt & Sisk, 2005; Gans, Kralewski, Hammons, & Dowd, 2005).

There are numerous reasons that EHR adoption has been slow, including difficulty in making the business case for EHRs and incentive systems that do not reward healthcare providers for adopting EHRs (Middleton, Hammond, Brennan, & Cooper, 2005; E. Shortliffe, 2005). Additional structural barriers within the healthcare system provide further hurdles to EHR adoption, such as difficulties arriving at technical and administrative standards (E. Shortliffe, 2005); the U.S.'s relative lack of a national structure could be one reason that health systems that are more centrally coordinated (e.g., Sweden, Australia, and Denmark) have had comparatively greater success adopting EHR systems (Harris Interactive, 2002). Assuming the context within which EHR systems are implemented improves to favor adoption, studying current EHR efforts sheds light on additional issues likely to arise as healthcare organizations seek to install an EHR system. These include a fear among providers that EHRs might depersonalize the delivery of healthcare (Aydin, Rosen, & Felitti, 1994) and reluctance to spend sufficient time learning the actual technology (Overhage, Tierney, McDonald, & Pickett, 1991). It is important to recognize that such barriers are indeed significant and can impact the perceived benefits to widespread EHR adoption.

Providers are certainly aware of the benefits EHRs might offer, including quicker reviews of charts and improved patient privacy and security (Massachusetts Medical Society, 2003; E. H. Shortliffe, 2005). Other advantages to EHR deployment include cost savings for healthcare providers (Ash & Bates, 2005), increased continuity of care (Kibbe, Jr., & Green, 2004), and reduced medical errors (Hillestad, et al., 2005). Recent work has demonstrated that provider acceptance is largely dependent on providers' perceptions regarding the overall benefits of widespread EHR adoption – those providers who perceive the greatest benefits are most likely to endure temporary, personal troubles associated with EHR adoption in their own practices (Whitten, Buis, & Mackert, in press). Even if the current healthcare system is not driving health providers to adopt EHRs, that could change in the coming years as the Institute of Medicine has called for increased transparency, including public reporting of healthcare quality and increased payments to those providers offering superior care (Institute of Medicine, 2002).

In the end, of course, widespread EHR adoption will depend primarily on proving the success of such systems in improving patient outcomes. In providing the rationale for a study of EHR use on the quality of ambulatory care in the U.S., Linder et al. (2007) point to the often-conflicting results regarding impact of EHRs on healthcare quality. This could be due to the fact that many of the studies reporting positive findings come from a relatively small number of institutions that have developed internal EHR systems (Chaudhry, et al., 2006). As such, the basic justification of EHRs could be based on a shaky foundation.

Given the key role that widespread adoption of EHRs will play in a national effort to improve healthcare through the use of new health informatics systems, the current state of affairs leaves significant room for improvement. Continued improvements in design, research into impacts on healthcare quality, and better training projects are needed if EHRs are to fulfill their potential as a core element of healthcare systems.

E-Health and the Provision of Healthcare

Shifting from healthcare providers' use of health informatics to a patient-centered view, the spread of broadband Internet access has made possible two phenomena with particularly important implications for the U.S. healthcare system – widespread use of the Internet to obtain health information and the provision of healthcare services to the home via telemedicine.

One of the more accepted definitions of e-health is supplied by Eysenbach (2001):

> *e-health is an emerging field in the intersection of medical informatics, public health and business, referring to health services and information delivered or enhanced through the Internet and related technologies. In a broader sense, the term characterizes not only a technical development, but also a state-of-mind, a way of thinking, an attitude, and a commitment for networked, global thinking, to improve healthcare locally, regionally, and worldwide by using information and communication technology.*

With more than 70% of American adults going online in general, data also indicate that a whopping 80% of these users are specifically looking for health-related information e-health increasingly ubiquitous (Fox, 2006; Pew Internet and American Life Project, 2007). People venturing online can make use of a variety of e-health applications, from systems designed to connect patients and providers via e-mail to online support groups (Arrington, 2004; May, Finch, Mair, & Mort, 2005). For patients interested in maintaining their own Personal Health Record (PHR), e-health applications such as Google Health (Google, 2008) and Microsoft HealthVault (Microsoft, 2008) allow users to organize their health information in one central location. Such systems raise important questions regarding ownership and access to data, as well as the quality and accuracy of patient-entered information. Widespread adoption of PHRs does introduce a variety of patient privacy and data protection issues, though a majority of respondents in one recent survey expressed a willingness to share health information if it meant better healthcare (Ball & Gold, 2006; California HealthCare Foundation, 2005).

Health communication researchers have established significant benefits to these types of e-health applications in providing health interventions. Users benefit from increased access to information from a variety of sources, as well as the anonymity that some patients value when dealing with certain health issues (Willis, Demiris, & Oliver, 2007). Information providers can benefit from the ability to tailor information to better match the cultural values and needs of users (Oenema, Brug, & Lechner, 2001). Indeed, research has demonstrated e-health applications can educate low health literate individuals, and such interventions are useful and appreciated even among more literate audiences (Mackert, Whitten, & Garcia, 2008; Whitten, Love, Buis, & Mackert, in press).

At the same time, e-health applications permit healthcare consumers to reach out in search of effective strategies for managing their own health.. Telemedicine, one of those applications, makes it possible to provide healthcare services directly into patients' homes. Telemedicine, defined broadly, is the provision of healthcare services via telecommunication technology. The earliest work in telemedicine took place in the 1960s (Wittson, Affleck, & Johnson, 1961), and has since grown to the point that it is no longer possible to quantify the number of systems operating in the U.S.(Whitten & Kuwahara, 2003)

Initially, telemedicine typically employed some form of videoconferencing to link a health provider at a hospital to a patient at a remote clinical setting. Such videoconferencing could take place via low-bandwidth phone lines or higher-bandwidth Integrated Services Digital Network (ISDN), though advances in Internet Protocol (IP) networking solutions have dramatically increased the speed, flexibility, and cost-effectiveness of telemedicine systems in recent years.

Today, telemedicine has expanded beyond videoconferencing to include the exploding application of remote monitoring, the home-based monitoring of patients with chronic diseases; related systems let caregivers remotely monitor patients' compliance taking their medications. Telemedicine has demonstrated its efficacy in an assortment of medical applications, including dermatology (Chen, See, & Shumack, 2002), psychiatry (Kuulasmaa, Wahlberg, & Kuusimaki, 2004), and physical therapy (Rizzo, Strickland, & Bouchard, 2004), to name a few. Telemedicine researchers continue to explore innovative and efficacious methods of providing healthcare at a distance, so the capabilities of the technology and range of uses will continue to improve. This is particularly true as advances in information storage and transmission will make it easier, and more cost effective, to use telemedicine technology for store-and-forward imaging systems (e.g., teleradiology). Advances in mobile technology, such as cellular phones with built-in video cameras, will present telemedicine researchers with platforms on which they can build innovative telemedicine systems to meet patients' healthcare needs.

Above and beyond the technological capacity of existing and future e-health and telemedicine systems, the impact of these technologies on the doctor-patient relationship must be considered. Even within a single study, patients' perceptions of the interplay between online sources of information and the doctor-patient interaction can vary significantly (Kahlor & Mackert, in press). The takeaway lesson, as with the introduction of any technology into the healthcare system, appears to be that there is no simple answer; thus the more flexible that e-health and telemedicine systems can be designed, to let providers and patients customize their own experience with the technology, the more likely it is that such systems will achieve sustained usage.

Health Informatics and Public Health

The rationale for implementing new telemedicine and e-health systems in patients' homes often involves the goal of eliminating health disparities resulting from uneven access to healthcare services. There are a variety of reasons such disparities might be present, including significant differences that often exist between urban and rural areas. Improvements in Geographic Information Systems (GIS) tools have made it possible to further investigate the efficacy and equity of the healthcare system and public health efforts, moving beyond urban-rural disparities (Noor, Zurovac, Hay, Ochola, & Snow, 2003).

As an example of the application of GIS to public health, Gordon-Larsen et al. found that inequality in the built environment (e.g., parks and other recreational areas) resulted in disparities in physical activity and increased obesity among lower-income and minority populations (Gordon-Larsen, Nelson, Page, & Popkin, 2006). Such findings from GIS-based research can help public health professionals to design and effectively target interventions designed to reduce the prevalence and impact of health disparities. GIS systems can be used to track the spread of infectious and acute diseases, in addition to the incidence and distribution of chronic conditions (Croner, Sperling, & Broome, 1996).

Some of the more significant benefits to GIS-based research and interventions can only come about by sharing the information contained in databases by various state and national government agencies. Effectively merging the information managed by the Centers for Disease Control and the U.S. Environmental Protection Agency, for example, could make it possible to study the impact of pollution and environmental quality at the population-level.

Widespread deployment of EHRs and patient-controlled PHRs could provide invaluable information to researchers and healthcare agencies using GIS tools to investigate public health. While the benefits to public health are clear, there are indeed potential concerns regarding privacy and how such information might be used. Public health interventions based on GIS data are likely to be welcomed by the public, but concerns over how insurance companies could potentially use such information are valid and likely to counterbalance those benefits for some healthcare professionals and members of the general public for some time to come.

A RESEARCH AGENDA TO ADVANCE HEALTH INFORMATICS AND HEALTH INFONOMICS

As health informatics has the potential to alter the healthcare system in a variety of positive ways, it is imperative that scholars continue to advance research regarding health informatics as nations around the world struggle to improve services while managing costs to both healthcare consumers and national budgets. And while health informatics and practice moves forward, the ability to tease out the economic impact of new health information and strategies for managing that information will become more pronounced.

As EHRs can be viewed as the foundation upon which many other systems can be built, any research agenda to advance health informatics can productively begin with EHRs. Given the fact that many of the positive results from EHR deployments come from leading healthcare institutions and providers, it is important to expand studies of EHRs into a variety of other settings. If the only healthcare providers that can achieve significant economic or quality improvements through the use of EHRs are premier institutions, that could suggest some fundamental issues that need to be addressed as policymakers push for widespread adoption of EHRs. Related to this, comparative studies of different national programs for promoting EHR adoption are needed to codify and improve upon the best policies for promoting EHR adoption across national healthcare systems.

Healthcare providers and consumers are seeking new ways of improving access to health information for all. Some of these efforts are being advanced by healthcare providers (e.g., remote monitoring of patients in the home), while others are driven by consumers' desire to become active participants in their own health (e.g., e-health applications like HealthVault and Google Health). In either case, there is a real need for research into what factors most strongly influence provider and patient acceptance, in addition to elements of system design that might contribute significantly to successful deployment (e.g., interoperability with other e-health applications, perceived usefulness, perceived ease of use). Research from related fields, such as Information Systems can provide a starting point for such investigations. Similarly, work in economics, specifically Transaction Cost Economics, has the potential for direct application to the sharing of information among healthcare institutions (Coles & Hesterly, 1998; Hodgkin, Horgan, & Garnick, 1997; Williamson, 1996). Additionally, policy and ethics researchers could productively explore the privacy and security issues surrounding the widespread adoption of e-health applications, whether such technologies are embraced voluntarily by healthcare consumers or brought to them as standard care without their approval.

As EHRs and e-health systems begin to accumulate more and more data about populations - either nationally or at the local/regional level - the potential for GIS-based public health investigations will continue to grow. But the promise of improved health interventions must be balanced against less acceptable uses of such technology, such as insurers determining coverage based on GIS data and trends. How will healthcare consumers balance the positives and negatives of such technology? It is entirely possible – if not likely – that the average healthcare consumer is unqualified to have an informed opinion on such issues. Policy and ethics researchers must continue to debate the public health benefits that could result from widespread use of GIS-based systems and the potential downside to this information as it might impact individual people. Additionally, more work must be done to assess the public's understanding of health and privacy issues, as well as their willingness to share private health information in exchange for improvements in healthcare services. Of course, this is just one part of the much larger issue of healthcare decisions and responsibility in general being shifted to patients.

Another need, across all kinds of health informatics applications, is to study differences in how larger and smaller institutions adopt these systems, as well as how the economic costs and benefits of implementing informatics applications varies among different institutions. Bates (2009) recently suggested that some kinds of applications – such as order entry and decision support systems – are sufficiently mature to merit widespread adoption among larger healthcare institutions. The benefits of these systems in smaller healthcare institutions, as well as the benefits of other informatics applications, are less clear. As health infonomics research advances it must focus on helping to provide answers to practitioners on when a particular informatics application is likely to provide economic benefits to an institution - with the final answer depending on factors such as size of the institution, the particular application, and the designer of the system (vendor vs. in-house).

Finally, a significant need across all research areas in health is an increased focus on projects that, while perhaps not complete failures, certainly do not represent complete successes or examples of best practices. As important as it is to learn what works, it is equally vital that researchers and professionals have more opportunities to find out what has not worked. The *Journal of Telemedicine and Telecare*, an international journal focusing on telemedicine and e-health, dedicates a supplement each year specifically to successes and failures in this area. Topics covered include elements of projects that if neglected can virtually ensure significant problems (e.g., Mackert & Whitten, 2007) and systematic reviews of the quality of studies investigating both success and failures in telehealth projects (e.g., Bensink, Hailey, & Wootton, 2007). Researchers much continue to share the causes and results of less successful projects if the field is to advance as smoothly and quickly as possible.

As important as it is to pursue a productive research agenda in health informatics and infonomics, it must be recognized that these advances are dependent upon contributions from a variety of fields. Researchers from medicine, nursing, communication, information technology, economics, public health, and computer science are all essential to advancing the design and application of health informatics systems. Thorough studies of health informatics and infonomics almost by definition will be interdisciplinary, thus providing opportunities for collaboration among academics from a variety of specialties.

A LOOK TOWARD HEALTH INFORMATICS AND INFONOMICS OF THE FUTURE

A range of illustrious publications have called for investment and implementation of various health informatics solutions to address health quality, access and cost issues. Even though a host of barriers have impeded diffusion to date, there are few who doubt the inevitable transition to a wide-scale infonomics phenomenon in health. This evolution will not occur in isolation of the contextual factors that drive health services today and tomorrow.

Health infonomics must operate in a setting that serves more patients. In many developed countries, baby boomers are transitioning from middle to old age in record numbers. With this aging population comes increased disease incidence as well as expectations for prolonging life. Along with the increase in patients will come more technologies leading to increased amounts of information from which health providers and patients must manage health events. Electronic technologies offer a solution to improving efficiency for a new continuum of care. The role of the patient will change as we witness increased self-diagnosis and self-care as patients and their family caregivers obtain more information. We will see a shift as hospitals become the site for the extremely ill as more people are able to remain at home. The enhanced availability of data to the public and health providers will cause improvements in processes and outcomes. As a result, we may witness a significant change in the delivery model where care becomes more routinized for more common diseases.

Currently, health informatics systems for the exchange of information are typically designed and deployed with local utilization in mind. Typical exchange interoperability challenges are addressed through tailoring the software to address such issues as differences in the data structures and ambiguous interpretation from implied metadata. However, problems increase exponentially when a new party seeks access to the informatics-based data, the number of users and need for records increases, and when clinical structures evolve over time. All of these challenges will call for generic interfaces that can comply and adapt with these changes, as well as built in mechanisms to find the location of the needed data items. The bottom line is the future informatics solutions will differentiate the users and the data location. This infonomic infrastructure will require communication between the systems to be based on the needs of the healthcare worker and/or patient; however, the actual location of the information will be transparent and less important (van der Linden, Kalra, Hasman, & Talmon, 2008). Such large-scale infrastructure will also make it possible for health infonomics researchers to consider the economic tradeoffs evident in any health policy decision, such as the increased costs associated with a particular medical advance or the ability to maintain a particular level of care at a reduced cost.

Perhaps the most important future shift to be noted concerns the pattern and style of interactions rather then any technology-related detail. Healthcare workers in the early 21st century communicate in ways that parallel human conversation - one person defines and requests information. In fact, current information retrieval from established standards such as HL7 and archetype 13606 is based upon this paradigm. However, expectations and communication patterns are slowly shifting as we employ an Internet that makes it so simple to move from a one-to-one exchange to a one-to-many exchange. In addition, we are now recognizing the unnecessary need to store everything locally. Instead, health infonomics will demonstrate the enhanced efficiencies of retrieving all forms of data only when they are needed from any secure storage location.

CONCLUSION

Few dispute the inevitable shift to adoption and dependence of informatics to a degree that reshapes the very foundation of health infonomics. As presented in this paper, there are a range of specific applications to operationalize this shift such as EHRs, e-health activities, and GIS services to impact public health. Typically, arguments concerning positive impacts on costs and health outcomes dominate the call for adoption and diffusion of these technology-based solutions. We concur, noting the need for ongoing documentation of these important impacts. However, this essay must acknowledge the role and importance of human perceptions that will drive health infonomics. Indeed, attaining a deep understanding of the usage of health informatics systems, as well as challenges these systems face, is necessary before the full economic impact of information-driven healthcare can be pursued and recognized.

Health advocates commonly call for a revised role for the health consumer. For example, Garson and Levin (2001) predict that we are witnessing a shift whereby the patient will eventually be the ultimate consumer and measures of patient satisfaction and other patient-oriented report cards will assume growing importance. With this in mind, we wish to close by acknowledging the potential perceptions of patients who experience healthcare in an environment that makes wide use of information technology applications. Whitten and colleagues (2007) conducted a study where they investigated the relationship between investment in health information technology and patient satisfaction in the hospital context. This study analyzed patient satisfaction data for hospitals that were included in the 2005 *Hospitals & Health Networks* annual list of the “100 most wired hospitals and health systems.” Specifically, they assessed the level of satisfaction from multiple angles between patients from the most wired hospitals and patients who had used a hospital not included in this list. Analyses from this study found that patients from the most wired hospital group reported higher levels of global satisfaction than did patients from the other group of hospitals. Patients from the most wired hospitals also reported higher satisfaction related to the admission process, their experiences with physicians, and personal issues such as sensitivity and pain. In addition, higher satisfaction scores were associated with most wired hospital status more so than for any specific demographic variable tested. The results of this study suggest that among the longer-term benefits of IT investment in hospitals may actually be issues related to patient satisfaction. These data imply that IT enhancements affect the way patients receive and perceive their care.

As we move toward a new paradigm of health delivery necessitated by public and private desires to contain health costs and improve health outcomes, we are witnessing a reality where patients will be more knowledgeable about managing healthcare, better informed about the benefits, risks, costs and alternatives for treatments, more technologically savvy, and more engaged in decision-making. The implications for health infonomics are critical. The superhighway for health information exchange will be crowded with multiple stakeholders driving our future course in this crucial area of infonomics.

REFERENCES

Anderson, G. F., Frogner, B. K., Johns, R. A., & Reinhardt, U. E. (2006). Health care spending and use of information technology in OECD countries. *Health Affairs*, *25*(3), 819–831. doi:10.1377/hlthaff.25.3.819

Arrington, M. I. (2004). The role of the Internet in prostate cancer survivors' illness narratives. In P. Whitten & D. Cook (Eds.), Understanding health communication technologies (pp. 181-186). San Francisco, CA: Jossey-Bass.

Ash, J., & Bates, D. (2005). Factors and forces impacting EHR system adoption: Report of a 2004 ACMI discussion. *Journal of the American Medical Informatics Association*, *12*(1), 8–12. doi:10.1197/jamia.M1684

Aydin, C. E., Rosen, P. N., & Felitti, V. J. (1994). Transforming information use in preventive medicine: Learning to balance technology with the art of caring. Paper presented at the Eighteenth Annual Symposium on Computer Applications in Medical Care, Washington, DC.

Ball, M. J., & Gold, J. (2006). Banking on health: Personal records and information exchange. *Journal of Healthcare Information Management*, *20*(2), 71–83.

Bates, D., Ebell, M., Gotlieb, E., Zapp, J., & Mullins, H. (2003). A proposal for electronic medical records in U.S. primary care. *Journal of the American Medical Informatics Association*, *10*, 1–10. doi:10.1197/jamia.M1097

Bates, D. W. (2009). The effects of health information technology on inpatient care. *Archives of Internal Medicine*, *169*(2), 105–107. doi:10.1001/archinternmed.2008.542

Bensink, M., Hailey, D., & Wootton, R. (2007). A systematic review of successes and failures in home telehealth. Part 2: Final quality rating results. *Journal of Telemedicine and Telecare*, *13*(S3), 10–14. doi:10.1258/135763307783247121

Berner, E. S., Detmer, D. E., & Simborg, D. (2005). Will the wave finally break? A brief view of the adoption of electronic medical records in the United States. *Journal of the American Medical Informatics Association*, *12*(1), 3–7. doi:10.1197/jamia.M1664

Blumenthal, D., & Glaser, J. (2007). Information technology comes to medicine. *The New England Journal of Medicine*, *356*, 2527–2534. doi:10.1056/NEJMhpr066212

Burt, C. W., & Sisk, J. E. (2005). Which physicians and practices are using electronic medical records? *Health Affairs*, *24*(5), 1334–1343. doi:10.1377/hlthaff.24.5.1334

Busis, N. A., & Hier, D. (2007). How to get your electronic health records in order. *Neurology Today*, *7*, 16. doi:10.1097/01.NT.0000296515.14653.5f

California HealthCare Foundation (2005). National Consumer Health Privacy Survey 2005.

Chaudhry, B., Wang, J., Maglione, M., Mojica, W., Roth, E., & Morton, S. C. (2006). Systematic Review: Impact of health information technology on quality, efficiency, and costs of medical care. *Archives of Internal Medicine*, *144*(10), 742–752.

Chen, K., See, A., & Shumack, S. (2002). Website discussion forums: Results of an Australian project to promote telecommunication in dermatology. Journal of Telemedicine and Telecare, 8(Suppl 3), S3:5-6.

Coles, J., & Hesterly, W. S. (1998). The impact of firm-specific assets and the interaction of uncertainty: An examination of make or buy decisions in public and private hospitals. *Journal of Economic Behavior & Organization*, *36*, 383–409. doi:10.1016/S0167-2681(98)00102-4

Cornford, T., & Klecun-Dabrowska, E. (2001). Telehealth technology: Consequences for structure through use. *Medinfo*, *10*(pt 2), 1140–1144.

Croner, C. M., Sperling, J., & Broome, F. R. (1996). Geographic information systems (GIS): New perspectives in understanding human health and environmental relationships. *Statistics in Medicine*, *15*(18), 1961–1977. doi:10.1002/(SICI)1097-0258(19960930)15:18<1961::AID-SIM408>3.0.CO;2-L

Department of Health and Human Services. (2008). Health information technology home. Retrieved from http://www.dhhs.gov/healthit/

Dick, R. S., Steen, E. B., & Detmer, D. E. (Eds.). (1991). The computer-based patient record: An essential technology for health care. Washington, DC: National Academy Press.

Eysenbach, G. (2001). What is e-health? *Journal of Medical Internet Research*, *3*(2), e20. doi:10.2196/jmir.3.2.e20

Fox, S. (2006). Online Health Search 2006. Washington, DC: Pew Internet & American Life Project.

Gans, D., Kralewski, J., Hammons, T., & Dowd, B. (2005). Medical groups' adoption of electronic health records and information systems. *Health Affairs*, *24*(5), 1323–1333. doi:10.1377/hlthaff.24.5.1323

Garson, A. Jr, & Levin, S. A. (2001). The 10-year trends for the future of healthcare: Implications for academic health centers. *The Ochsner Journal*, *3*(1), 10–15.

Google (2008). Google Health. Retrieved September 28, 2008, from https://www.google.com/health

Gordon-Larsen, P., Nelson, M. C., Page, P., & Popkin, B. M. (2006). Inequality in the built environment underlies key health disparities in physical activity and obesity. *Pediatrics*, *117*(2), 417–424. doi:10.1542/peds.2005-0058

HL7. (2009). Health Level 7. Retrieved from http://www.hl7.org

Harris Interactive. (2002). European Physicians Especially in Sweden, Netherlands and Denmark, Lead U.S. in Use of Electronic Medical Records. Retrieved February 20, 2006, from http://www.harrisinteractive.com/news/newsletters/healthnews/HI_HealthCareNews2002vol2_Iss16.pdf

Heathfield, H., Pitty, D., & Hanka, R. (1998). Evaluating information technology in health care: Barriers and challenges. *British Medical Journal*, *316*, 1959–1961.

Hersh, W. (2004). Health care information technology: Progress and barriers. *Journal of the American Medical Association*, *292*(18), 2273–2274. doi:10.1001/jama.292.18.2273

Hersh, W. (2006). Who are the informaticians? What we know and should know. *Journal of the American Medical Informatics Association*, *13*(2), 166–169. doi:10.1197/jamia.M1912

Hillestad, R., Bigelow, J., Bower, A., Girosi, F., Meili, R., & Scoville, R. (2005). Can electronic medical record systems transform health care? Potential health benefits, savings, and costs. *Health Affairs*, *24*(5), 1103–1117. doi:10.1377/hlthaff.24.5.1103

Hing, E. S., Burt, C. W., & Woodwell, D. A. (2007). Electronic medical record use by office-based physicians and their practices. *Advance Data*, *393*, 1–7.

Hodgkin, D., Horgan, C., & Garnick, D. (1997). Make or buy: HMO's contracting arrangement for mental health care. *Administration and Policy in Mental Health*, *24*(4), 359–376. doi:10.1007/BF02042519

Holbrook, S. (2006). Clinical portals: A win for providers. *Electronic Healthcare*, *4*, 104–106.

Institute of Medicine (2002). Leadership by example: Coordinating government roles in improving health care quality.

Jha, A., Ferris, T., Donelan, K., DesRoches, C., Shields, A., & Rosenbaum, S. (2006). How common are electronic health records in the United States? A summary of evidence. *Health Affairs*, *25*, 496–507. doi:10.1377/hlthaff.25.w496

Johnston, D., Pan, E., Walker, J., Bates, D. W., & Middleton, B. (2003). The value of computerized provider order entry in ambulatory settings. Wellesley, MA: Center for IT Leadership.

Kahlor, L., & Mackert, M. (in press). Perceived helpfulness of information and support sources and associated psychosocial outcomes among infertile women. *Fertility and Sterility*.

Kaplan, B. (2001). Evaluating informatics application: Clinical decision support system literature review. *International Journal of Medical Informatics*, *64*, 15–37. doi:10.1016/S1386-5056(01)00183-6

Kibbe, D. C. Jr, R. L. P., & Green, L. A. (2004). The continuity of care record. *American Family Physician*, *70*(7), 1220–1222.

Kleinke, J. D. (2005). Dot-Gov: Market failure and the creation of a national health information system. *Health Affairs*, *24*(5), 1246–1262. doi:10.1377/hlthaff.24.5.1246

Kohn, L., Corrigan, J., & Donaldson, M. (2000). To err is human: Building a safer health system. National Academies Press.

Kuulasmaa, A., Wahlberg, K. E., & Kuusimaki, M. L. (2004). Videoconferencing in family therapy: A review. *Journal of Telemedicine and Telecare*, *10*(3), 125–129. doi:10.1258/135763304323070742

Lærum, H., Ellingsen, G., & Faxvaag, A. (2001). Doctors' use of electronic medical records in hospitals: Cross sectional survey. *British Medical Journal*, *323*, 1344–1348. doi:10.1136/bmj.323.7325.1344

Linder, J. A., Ma, J., Bates, D. W., Middleton, B., & Stafford, R. S. (2007). Electronic health record use and the quality of ambulatory care in the United States. *Archives of Internal Medicine*, *167*(13), 1400–1405. doi:10.1001/archinte.167.13.1400

Mackert, M., & Whitten, P. (2007). The relationship between healthcare organizations and technology vendors: An overlooked key to telemedicine success. *Journal of Telemedicine and Telecare*, *13*(S3), S50–S53. doi:10.1258/135763307783247419

Mackert, M., Whitten, P., & Garcia, A. (2008). Evaluating e-health interventions designed for low health literate audiences. *Journal of Computer-Mediated Communication*, *13*(2), 504–515. doi:10.1111/j.1083-6101.2008.00407.x

Massachusetts Medical Society. (2003). MMS Survey: Most doctors are slow to incorporate technology into practices. Retrieved February 21, 2006, from http://www.massmed.org/AM/Template.cfm?Section=Search&template=/CM/HTMLDisplay.cfm&ContentID=10048

May, C., Finch, T., Mair, F., & Mort, M. (2005). Towards a wireless patient: Chronic illness, scarce care and technological innovation in the United Kingdom. *Social Science & Medicine*, *61*(7), 1485–1494. doi:10.1016/j.socscimed.2005.03.008

McGlynn, E. A., Asch, S. M., Adams, J., Keesey, J., Hicks, J., & DeCristofaro, A. (2006). The quality of health care delivered to adults in the United States. *The New England Journal of Medicine*, *348*(26), 2635–2645. doi:10.1056/NEJMsa022615

Microsoft (2008). HealthVault. Retrieved September 28, 2008, from http://www.healthvault.com/

Middleton, B., Hammond, W. E., Brennan, P. F., & Cooper, G. F. (2005). Accelerating U.S. EHR adoption: How to get there from here. Recommendations Based on the 2004 ACMI Retreat. *Journal of the American Medical Informatics Association*, *12*(1), 13–19. doi:10.1197/jamia.M1669

Miller, R., & Sim, I. (2004). Physicians' use of electronic medical records: Barriers and solutions. *Health Affairs*, *23*, 116–126. doi:10.1377/hlthaff.23.2.116

Noor, A. M., Zurovac, D., Hay, S. I., Ochola, S. A., & Snow, R. W. (2003). Defining equity in physical access to clinical services using geographical information systems as part of malaria planning and monitoring in Kenya. Tropical Medicine and International Health, 8(10), 917-926(910).

Oenema, A., Brug, J., & Lechner, L. (2001). Web-based tailored nutrition education: Results of a randomized controlled trial. *Health Education Research*, *16*(6), 647–660. doi:10.1093/her/16.6.647

Overhage, J., Tierney, W., McDonald, C., & Pickett, K. (1991). Computer-assisted order entry: Impact on intern time use. *Clinical Research*, *39*(3), 794A.

Pew Internet and American Life Project. (2007). E-patients with a disability or chronic disease. Washington, D.C.

Rizzo, A. A., Strickland, D., & Bouchard, S. (2004). The challenge of using virtual reality in telerehabilitation. *Telemedicine Journal and e-Health*, *10*(2), 184–195. doi:10.1089/tmj.2004.10.184

Schoenman, J., Keeler, J., Moiduddin, A., & Hamlin, B. (2006). Roadmap for the adoption of health information technology in rural communities. Washington, DC: Office of Rural Health Policy.

Sherer, J. L. (1993). Putting patients first: Hospitals work to define patient-centered care. *Hospitals*, *67*, 14–19.

Shortliffe, E. (2005). Strategic action in health information technology: Why the obvious has taken so long. *Health Affairs*, *24*(5), 1222–1233. doi:10.1377/hlthaff.24.5.1222

Shortliffe, E. H. (1999). The evolution of electronic medical records. *Academic Medicine*, *74*, 414–419. doi:10.1097/00001888-199904000-00038

Stewart, M. (2001). Towards a global definition of patient centred care. *British Medical Journal*, *32*, 444–445. doi:10.1136/bmj.322.7284.444

United Nations. (2002). World Population Ageing: 1950-2050. Retrieved from http://www.un.org/esa/population/publications/worldageing19502050

van der Linden, H., Kalra, D., Hasman, A., & Talmon, J. (2008). Inter-organizational future proof of HER systems: A review of the security and privacy related issues. *International Journal of Medical Informatics*, *78*(3), 141–160. doi:10.1016/j.ijmedinf.2008.06.013

Walker, J., Pan, E., Johnston, D., Adler-Milstein, J., Bates, D., & Middleton, B. (2005). The value of health care information exchange and interoperability. *Health Affairs*, *W5*, 10–18.

Whitten, P., Buis, L., & Love, B. (2007). Physician-Patient e-visit program. *Disease Management & Health Outcomes*, *14*(4), 207–214. doi:10.2165/00115677-200715040-00002

Whitten, P., Buis, L., & Mackert, M. (2007). Factors impacting providers' perceptions regarding Midwestern EMR deployment. Telemedicine and e-Health, 13(4), 391-398.

Whitten, P., & Kuwahara, E. (2003). Telemedicine from the payor perspective: Considerations for reimbursement decisions. *Disease Management & Health Outcomes*, *11*(5), 291–298. doi:10.2165/00115677-200311050-00002

Whitten, P., Love, B., Buis, L., & Mackert, M. (in press). Health education online for individuals with low health literacy: Evaluation of the diabetes and you website. *Journal of Technology in Human Services*.

Williamson, O. (1996). Transaction cost economics. The Mechanisms of Governance (pp. 54-92). Oxford University Press.

Willis, L., Demiris, G., & Oliver, D. (2007). Internet use by hospice families and providers: A review. *Journal of Medical Systems*, *31*(2), 97–101. doi:10.1007/s10916-006-9033-0

Wittson, C., Affleck, D., & Johnson, V. (1961). Two-way television in group therapy. *Mental Hospitals*, *12*, 22–23.

KEY TERMS AND DEFINITIONS

E-Health: Health services and information delivered or enhanced by the Internet and related technologies

Electronic Medical Record (EMR): Individual record in which healthcare providers record treatments, drugs, and future recommendations electronically

Electronic Health Record (EHR): Electronic record that includes patient information from a variety of sources, such as radiology (films), pharmacy (interaction checks), and specialist information (cardiologist, dermatologist, etc.)

Healthcare Information Technology (HIT): Technology used to store, manage, and transmit information between healthcare providers and consumers

Informatics: The intelligent management of information to maximize data acquisition and usage

Personal Health Record (PHR): E-health tools that let patients manage all of their health information in one location

Telemedicine: Provision of healthcare services via telecommunication technology

This work was previously published in Infonomics for Distributed Business and Decision-Making Environments: Creating Information System Ecology, edited by M. Pankowska, pp. 217-232, copyright 2010 by Business Science Reference (an imprint of IGI Global).

Chapter 1.9

Benefits and Barriers to Adoption of Information Technology in U.S. Healthcare

James G. Anderson
Purdue University, USA

ABSTRACT

Information technology such as electronic medical records (EMRs), electronic prescribing, and clinical decision support systems are recognized as essential tools in all developed countries. However, the U.S. lags significantly behind other countries that are members of the Organization for Economic Cooperation and Development (OECD). Significant barriers impede wide-scale adoption of these tools in the U.S., especially EMR systems. These barriers include lack of access to capital by healthcare providers, complex systems, and lack of data standards that permit exchange of clinical data, privacy concerns and legal barriers, and provider resistance. Overcoming these barriers will require subsidies and performance incentives by payers and government, certification and standardization of vendor applications that permit clinical data exchange, removal of legal barriers, and convincing evidence of the cost-effectiveness of these IT applications.

DOI: 10.4018/978-1-60566-356-2.ch014

INTRODUCTION

Information technology has been proposed as an essential tool in solving the problem of fragmented and inaccessible clinical information (Kohn, Corrigan & Donaldson, 1999). The current largely paper-based system adversely affects both the cost and quality of health care as well as compromises patient safety (Leaning, 1993; Dick & Steen, 1997; President's Information Technology Advisory Committee, 2004a,b). Information technologies (IT) such as electronic health records, e-prescribing, clinical decision support systems, electronic management of chronic disease, and bar coding of drugs and biological products have been proposed as ways to reduce health care costs and improve patient safety (Agency for Healthcare Research and Quality, 2001; Aspden, Corigan, Wolcott & Erickson, 2004) . For example, a Rand study estimated that the potential savings of widespread adoption of EMRs in the U.S. could be as much as $81 billion annually (Hillestad, Bigelow, Bower et al., 2005). However, critics question these estimates arguing that the reality of health care practice in the U.S. will make it difficult to realize savings of this magnitude (Goodman, 2005; Walker, 2005; Himmelstein & Woolhandler, 2005; Miller, West, Brown et al., 2005).

As many as three quarters of a million people are injured or die each year from adverse drug events (ADEs) (Bates, 1996; Lazarou, Pomeranz & Corey, 1998). It has been estimated that adverse drug events (ADEs) occur in from two to seven out of every 100 patients admitted to a hospital in the USA (Bates, Cullen, Laird, et al.., 1995; Classen, Pestotnik, Evans, Lloyd, & Burke, 1997). The annual cost of morbidity and mortality due to drug therapy in 1995 for the U.S. may be as much as $76.6 billion. (Bates, Spell, Cullen, et al., 1997; Johnson and Bootman, 1995).

ADEs also occur among outpatients. One study estimates a rate of 5.5 per 100 patients (Honigman, Lee, Rothschild, et al., 2001). Another analysis of hospital emergency departments in the U.S. estimated that ADEs account for 2.4 out of every 1,000 visits (Budnitz, Pollock, Weidenbach, Mendelsohn, Schroeder, & Annest, 2006).

Information technology has been shown to be effective in preventing serious medication errors (Anderson, Jay, Anderson &Hunt, 2002; Bates, Evans, Murff et al., 2003a,b; Bates & Gawande, 2003). A review of research of the effects of computerized physician order entry (CPOE) and clinical decision support systems (CDSSs) on medication error rates found evidence that both CPOE and CDSSs can substantially reduce medication error rates (Kaushal, Shojaania & Bates, 2003). Also electronic prescribing has been shown to reduce prescription errors and improve compliance with managed care formularies (Galanter, Didomenico, & Polikaitis, 2005). Point-of-care decision support tools can provide providers with alerts for contraindicated medications (Miller, Gardner, Johnson & Hripcsak, 2005).

A number of countries that are members of the Organization for Economic Cooperation and Development (OECD) have experienced widespread implementation of information technology. The Harvard School of Public Health and the Commonwealth Fund's International Symposium survey of primary care physicians in 2001 found the following use of electronic medical records among primary care physicians: U.S. (17%), Canada (14%), Australia (25%), New Zealand (52%), and the U.K. (59%). The use of electronic prescribing by primary care physicians was: U.S. (9%), Canada (8%), Australia (44%), New Zealand (52%), and the U.K. (87%) (Harris Interactive, 2001). Only three OECD countries, Portugal, France and Spain lag behind the U.S. (Harris Interactive, 2002).

By 2006, the gap between physicians in the U.S. and other OECD countries had widened. Table 1 shows the results of a survey of U.S. primary care physicians (Anderson & Balas, 2006). Overall only about one out of four primary care physicians reported that they had implemented electronic medical records or clinical decision support tools in their practices. Even fewer physicians surveyed reported using electronic prescribing (20.1%) in practice. Internists were the most likely to have implemented these information technology tools in their practices; obstetricians and gynecologists were the least likely.

When compared to the results of a recent study of primary care physicians in seven countries (Australia, Canada, Germany, New Zealand, the Netherlands and the U.K.), the U.S continues to trail European countries in the use of information technology in patient care. U.S. physicians were the least likely to have clinical information systems in their offices; while ninety percent or more of physicians in the Netherlands, New Zealand and the U.K. use electronic medical records in their practices (Schoen, Osborn, Huynh, Doty, Peugh, J. & Zapert, 2006). The majority of physicians in these countries also reported routinely using electronic prescribing and electronic access to test results. In contrast our survey found that only 28% of U.S. physicians reported using EMR; 20% used electronic prescribing of medications; and 22% accessed test results electronically. The functionality of these EMR systems varies

Table 1. Use of information technology by primary care specialty (%). Other = Geriatrics, Occupational Medicine, etc.

Application	Family Practice	Internal Medicine	Pediatrics	Obstetrics and Gynecology	Other	Total
Electronic Medical Records						
Implemented	23.2	31.2	23.0	16.4	40.6	25.8
Electronic Prescribing						
Implemented	17.7	26.4	20.4	13.3	24.0	20.1
Decision Support Tools						
Implemented	27.6	25.7	24.0	15.6	30.8	25.1
Electronic Communication						
Implemented	25.5	26.6	20.4	21.2	26.2	23.2

greatly from country to country. Physicians in the Netherlands were the most likely to report that their EMR systems enabled them to share patient records with other physicians; whereas physicians in New Zealand were the most likely to report that they could access patient records from outside of their offices. Utilization rates of all types of IT are lowest in Canada and the U.S. where EMRs are concentrated in larger physician groups.

Despite its potential to improve efficiency and quality of care, investment in information technology in health care lags behind other sectors of the economy in the U.S. Most of the $20 million invested in health care information technology in 2001 was used to computerize financial systems (Goldsmith, Blumenthal, & Rishel, 2003). In comparison to six countries, the U.S. total investment in health information technology per capita in 2005 was $0.43. This compares to $4.93 in Australia and $192.79 in the U.K. (Anderson, Frogner, Johns & Reinhardt, 2006).

All of these countries have well established federally coordinated and partially funded health information technology programs. Germany completed a national network in 2006. The Canadian government has invested $1.5 billion Canadian in health information technology in an effort to catalyze investment by requiring matching funds (Commission, 2003). Canada's Health Infoway program expects to implement electronic health records for half of its population by 2009. The U.K. has an ambitious IT project underway and hopes to have a network available to all health care providers by 2014. The United Kingdom's government has allocated 8 billion pounds to health information infrastructure (Brewin, 2003). The system will include electronic health records for everyone and an electronic prescription transmission system. The U.S. only recently passed the Wired for Health Care Quality Act that will establish collaboration and authorize grants to encourage the adoption of health information technology (Anderson, et al. 2006).

Adoption of information technology such as EMRs and computerized physician order entry by U.S. hospitals has also been limited (AHA, 2005). Surveys indicate that less than 15 percent of U.S. hospitals have implemented computerized physician order entry systems (CPOE) (Ash, Gorman & Hersh, 1998; Pederson, Schneider & Santell, 2001). A recent report commissioned by the Health Information Network Europe (HINE) indicates that hospitals in 15 European nations spend only 1.8% of total revenue on information technology. As a result IT use in hospitals in Europe is similar to the U.S. Only 2.2% of European hospitals have implemented computer-

Table 2. Perceived benefits of implementing IT applications (%)

Benefit	High/Medium	Low/None
Patients assume responsibility for monitoring symptoms/disease	62.3	37.7
Shorter consultations	46.1	53.9
Patients not seeking medical care when it was not needed	50.7	49.3
Patients coming in sooner for necessary treatment	63.4	36.6
Fewer unnecessary tests	57.3	42.7
Fewer unnecessary treatments	57.7	42.3
Fewer errors	74.8	25.2
Increased productivity	69.5	30.5
Reduced costs	63.0	37.0

ized physician order entry systems with clinical decision support compared to 2.5% of American hospitals (Versel, 2005).

Until recently, IT products available for healthcare providers were mostly designed for large organizations and were costly. Recent advances in technology have made IT applications more available to primary care physicians in smaller practices (McDonald & Metzger, 2002). Despite its potential to improve efficiency and quality of care, use of information technology in health care lags behind other sectors of the economy in the U.S. In 2001 most of the $20 million invested in health care information technology was used to computerize financial systems (Goldsmith, Blumenthal & Rishel, 2003). Less than 10 percent of U.S. hospitals had adopted electronic medical record systems and less than 5 percent had implemented computerized physician order entry by 2001.

The following section reviews the evidence regarding benefits from information technology. Potential benefits include reduced cost, increased productivity, improvements in patient safety, and the enhancement of patient responsibility for marinating their health.

BENEFITS OF HEALTH INFORMATION TECHNOLOGY

Physicians, in general, perceive potential benefits from implementing IT (Table 2). A recent survey of U.S. primary care physicians found that almost 75% indicated that these applications could reduce errors (Anderson & Balas, 2006). Almost 70% perceived information technology as potentially increasing their productivity; over 60% indicated that IT tools have the potential to reduce costs and help patients assume more responsibility. At the same time about half of the primary care physicians surveyed indicated that they did not perceive that information technology applications would result in shorter consultations, reduction in unnecessary care, patients seeking needed care earlier, and reduction in unnecessary tests and treatment.

There is evidence to support these perceptions. Balas and others (1996) reviewed 98 randomized clinical trials that examined the efficacy of clinical information systems. The review found evidence that provider reminders, computer-assisted treatment planners, interactive patient education and patient reminders all were effective in improving the outcomes of family medicine. A second review of controlled clinical trials of clinical decision support system (CDSSs) found positive effects on physician performance (Hunt, Haynes, Hanna &

Smith, 1998). In particular drug dosing systems, diagnostic aids and preventive care systems were found to enhance patient care.

There is additional evidence that information technology can significantly improve patient safety (Anderson (2004a,b; 2008; Bates, 2000; Bates, Cohen, Leape et al., 2001). The studies reviewed have demonstrated that information technology applications can detect and prevent medication errors and adverse drug events. The positive effects of information technology on medication safety in both inpatient and outpatient settings have been demonstrated. In particular studies have shown that computerized physician order entry can be effective in preventing medication errors. A study in a large tertiary care hospital found that the implementation of a computerized physician order entry (CPOE) on all hospital units decreased serious medication errors by 55%. The CPOE system included dose selection, drug allergy and drug-drug interaction checking, and required physicians to indicate route and frequency of doses (Bates, Leape, Cullen et al., 1998).

Other IT applications have been shown to be efficacious in preventing errors. Electronic prescribing systems that provide computer-based support for the creation, transmission, dispensing and monitoring of drug therapies have been shown to increase patient safety (Miller, Gardner, Johnson & Hripcsak, 2005). Alerts generated by a clinical decision support system were effective in decreasing the ordering and administering of drugs that were contraindicated due to renal insufficiency (Galanter, Diidomenico & Polikaitis, 2005).

Information technology has also been shown to improve care for chronic illness. One study reviewed 109 articles that described information systems designed to assist providers in the care of patients with diabetes, heart disease and mental illness (Dorr, Bonner, Cohen et al., 2007). These studies assessed the impact of IT applications on guideline adherence, visit frequency, documentation, treatment adherence, rates of referral, appropriateness of screening and testing, and cost. The majority of these studies revealed a positive impact of IT on the process of care for patients with chronic illnesses.

In the next section we discuss major barriers to the implementation and utilization of information technology in practice. Barriers include initial costs and uncertain financial benefits for providers, changes in practice patterns, technology, inadequate technical support, physician attitudes, privacy and security.

BARRIERS TO IMPLEMENTATION OF HEALTH INFORMATION TECHNOLOGY

A key barrier to implementation of electronic medical records and other clinical information technology applications appears to be the high initial costs and uncertain payoffs to physicians. Over 80% of primary care physicians surveyed reported the lack of financial support for IT applications as a major barrier to adoption (Anderson & Balas, 2006). Moreover, physicians who perceived lack of financial support and high investment costs required to implement IT were significantly less likely to have implemented EMRs, electronic prescribing and decision support tools. Upfront costs of EMRs in ambulatory care are estimated to range from $16,000 to $36,000 per physician. Additional costs are incurred for maintenance of the system and decreased revenue from patients during the transition from the paper chart to the EMR (Miller and Sim, 2004; Miller, Sim & Newman, 2003). Cost-benefit analyses have shown that physicians who invest in EMR systems derive little more than ten percent of the benefits. Most of the savings from improved efficiency go to payers and purchasers (Walker, Pan, Johnston et al., 2005; Wang et al., 2003).

Changes in practice patterns brought about by the implementation of electronic medical record also constitute a barrier to adoption. Many physicians report that they spend more time with each patient following the implementation of an EMR. This results in longer workdays and fewer patients seen during the initial period following implementation.

A second barrier is the complexity of EMRs and clinical IT applications. Our survey found that physicians cite the time and effort involved in learning to use these technologies as a significant barrier. Eighty-six percent of the physicians surveyed stated that vendor's inability to deliver acceptable products as a significant barrier to implementation of IT in their practices (Anderson & Balas, 2006). In general, physicians perceived these barriers as difficult to overcome. Almost two-thirds of the physicians surveyed also cited the lack of a strategic plan for implementing applications and difficulty in recruiting experienced IT personnel as major barriers while over one-half cited lack of sufficient knowledge of IT as a barrier to implementation. Other studies have found problems with usability of EMRs. Poorly designed screens and difficulties in entering progress notes require physicians to spend extra time entering patient data. Maintenance of IT systems is another concern for physicians. Small practices lack the technical support personnel needed to maintain the system. Also vendors in general provide relatively little support for their products or charge high maintenance fees. Because of the many vendors, interoperability represents another major barrier to implementation of EMRs and other IT applications. Lack of ability to exchange clinical data with laboratories and hospitals is a major impediment for smaller physician practices.

Unlike the health care systems of many western countries, the U.S. system is composed of private, independent individual and group providers, hospitals, ambulatory care and long term care centers that compete with one another. The system is non-centralized with multi-payers. Information technology adoption decisions are made independently and there are few if any incentives to share information concerning patient care. Moreover, there are many competing vendors each with their own products. In contrast, in the U.K. a research team developed the PRODIGY system specifications and knowledge base and the five largest General Practice system suppliers covering 85 percent of the market integrated the software into their clinical systems. Currently this system is being implemented by all 27, 000 General Practitioners in the U.K. (Purves, Sugden, Booth & Sowerby, 1999).

Privacy concerns are another barrier hindering implementation of IT. Both physicians and the public are concerned about potential breeches of confidentiality. Since many EMR systems are Web-based, many physicians and patients fear that medical records may not be secure. This is even more of a concern when wireless Internet is used to transmit records to multiple locations (Rash, 2005).

Security breaches of data banks are far more frequent in the U.S. than in Europe. This is due to the fact that European countries have a comprehensive set of national privacy laws and offices of data protection (Dash, 2005). In contrast the U.S. has a confusing, sometimes conflicting, patchwork of federal and state laws and agencies that deal with the protection of data. Also, the U.S. has a large private data collection industry with companies like ChoicePoint and Acxiom, that collect, analyze and sell consumer data. In Europe, private companies are severely restricted from collecting personal data without individual consent.

Legal barriers to IT adoption also exist in the U.S. (Bates, 1997) Various laws related to fraud and abuse, antitrust, federal income tax, intellectual property, liability and malpractice and state licensing create a climate of uncertainty for health care providers in implementing IT (U.S. Government Accountability Office, 2004). For example the physician self-referral law and the anti-kickback law present barriers to hospitals that would like to pay for electronic software for affiliated physicians. (See Table 3)

Table 3. Perceived barriers to implementing IT applications (%)

Barriers	No Barrier or Easily Overcome	Overcome with some or great effort or insurmountable
Lack of financial support	12.6	87.3
Vendors inability to deliver acceptable products	20.7	79.3
Acceptance by staff	41.7	58.3
Difficulty proving quantifiable benefits	32.8	67.2
Lack of strategic plan for implementing	34.9	65.1
Recruiting experienced IT personnel	39.6	60.4
Retaining experienced personnel	42.5	57.5
Insufficient knowledge of IT applications	37.5	62.5
Considerable investment in IT applications	13.0	87.0

OVERCOMING BARRIERS

Overcoming the cost barrier will be difficult and may require incentives by payers and the government. An example is New Zealand, Australia and the U.K. that have introduced government funding programs to stimulate adoption and use of EMRs (Harris Interactive, 2001). Canada and the U.K. have made significant investments in a health information infrastructure (Commission, 2003; Brewin, 2003). Professional associations can also facilitate adoption of IT. Professional physician organizations played a key role in the development and rapid implementation of the national electronic medical record system in the U.K. Currently over 95 percent of General Practitioner practices in the U.K. are computerized (Purves, 1998). In the U.S. the American Academy of Family Physicians through a nonprofit foundation is developing low-cost, open-source EMR software that will be available to physicians with no licensing fee.

Financial incentives may also accelerate adoption of EMRs and other IT applications. A 2006 survey of primary care physicians in seven countries found quality improvement efforts in all of the countries (Schoen et al, 2006). Pay-for-performance approaches to motivating physicians to improve care and to hold them accountable for the quality of care have been adopted in several countries. Doctors in the U.K. are significantly more likely to be participating in incentive programs than doctors in other countries. The U.K. program rewards performance on the basis of 146 indicators that measure clinical and preventive care, organization and patient satisfaction (Doran et al., 2006). Thirty percent of GPs' salaries are based on their performance on a set of measures computed by the EMR (NHS Connecting for Health). Financial incentives are also widespread in Australia and New Zealand.

The U.S. and Canada do not have national initiatives. A number of purchasers, health plans, and employers are initiating quality-based reimbursement programs. These plans encourage HIT adoption through additional payments and reimbursement for virtual physician visits (Health Strategies Consultancy, 2004). In Canada the Primary Health Care Transition Fund provides funds for the creation of new primary care models (Weatherill, 2006). House resolution 747 introduced into the 2005 U.S. Congress also would make zero interest loans available to provider groups and would reward those who use EMRs (Gonzalez et al., 2005).

Incentives could also be provided in the U.S. through Medicare, the national social insurance program that provides medical insurance coverage for over 41 million seniors aged sixty-five and over and people with disabilities in the U.S. Medicare is the largest purchaser of health services in the U.S. and has the power to promote adoption of health information technology (Rosenfeld, Bernasek & Mendelson, 2005; Hackbarth & Milgate, 2005). The Center for Medicare and Medicaid Services (CMS) could require participating physicians to adopt health information technology. Additional payments could be provided for physicians who use specific certified IT applications.

Certification of vendors' applications may help to overcome another barrier to implementation. Other countries have identified a few vendors for a region and required that they meet certain standards to facilitate transfer of clinical information among health care providers. The development of community-wide data exchanges also can stimulate the adoption of EMRs (Miller & Sim, 2004). These exchanges allow clinicians to view all of their patients' data regardless of provider and care site and thus decrease physicians' time and increasing financial benefits.

Despite the call for implementation of electronic medical records by the Institute of Medicine, adoption in practice in the U.S. has been slow (Dick & Steen, 1991). Acceptance of IT in practice depends on more than dissemination of information about their availability and potential benefits (Anderson, 1997, 1999, 2003). IT applications such as EMRs and CDSSs alter traditional practice patterns, work flow and relationships with other health care providers. They change the way that physicians care for their patients. Acceptance of these systems is shaped by physicians' perceptions of how they will affect the accomplishment of their professional goals. Several decades of experience suggest that physicians will accept applications that enhance their ability to manage patient care but will tend to oppose applications that they perceive as primarily benefiting health care organizations and payers.

Experience suggests several factors that may increaser acceptance and utilization of IT applications in practice. Broad participation of physicians in the selection and implementation of applications is essential. Systems that are implemented without broad physician involvement are likely to fail. Moreover, it is essential to consider in advance how the IT application will affect work flow and routine practice patterns. Physicians will use applications that assist them in providing better patient care. Applications that primarily benefit the administration of health care and/or payers will not motivate physicians to change their established practice behavior.

CONCLUSION

It has been estimated that the net cumulative savings from adopting EMR systems in U.S. hospitals over 15 years could be as much as $371 billion and the net cumulative savings from physician adoption could be $142 billion (Hillestad, Bigelow, Bower et al., 2005). But significant barriers impede wide-scale adoption and use of EMR systems (Leape &Berwick, 2005). These barriers include lack of access to capital by health care providers, complex systems and lack of data standards that permit exchange of clinical data, privacy concerns and legal barriers and provider resistance. Overcoming these barriers will require subsidies and performance incentives by payers and government. Currently costs of implementing health information technology are incurred by individual providers while the benefits accrue to many others. The private sector in the U.S. is unlikely to accelerate the adoption of IT unless there is significant public sector investment and incentives. It has been estimated that a national heath information network would cost $156 billion in capital investment over 5 years. Annual operating costs are estimated to be $48 billion (Kaushal et al. 2005).

Certification and standardization of vendor applications that permit clinical data exchange will be required to achieve greater interoperability.

Legal barriers will need to be removed and greater security of medical data must be guaranteed. Also, convincing evidence of the cost-benefit of these applications will need to be provided in order to convince practitioners and patients of the value of information technology in practice.

ACKNOWLEDGMENT

Portions of this chapter are based on Anderson (2007, 2008) and Anderson & Balas (2006) with permission from Elsevier publishing and Idea Group Publishing, respectively. I wish to acknowledge the assistance of Marilyn Anderson with the preparation of this chapter.

REFERENCES

Agency for Healthcare Research and Quality. (2001). *Reducing and preventing adverse drug events to decrease hospital costs. Research in action issue 1*. Rockville, MD: AHRQ Publication Number 01-0020.

American Hospital Association. (2005). *Forward momentum: Hospital use of information technology*. Retrieved on June 19, 2007, from http://www.aha.org/aha/content/2005/pdf/FINALNonembITSurvey105.pdf

Anderson, G. F., Frogner, B. K., Johns, R. A., & Reinhardt, U. E. (2006). Healthcare spending and use of information technology in OECD countries. *Health Affairs*, *25*(3), 819–831. doi:10.1377/hlthaff.25.3.819

Anderson, J. G. (1997). Clearing the way for physicians' use of clinical information systems. *Communications of the ACM*, *40*, 83–90. doi:10.1145/257874.257895

Anderson, J. G. (1999). Increasing the acceptance of clinical information systems. *M.D. Computing*, *16*, 62–65.

Anderson, J. G. (2003). A systems approach to preventing adverse drug events. In S. Krishna, E. A. Balas, & S. A. Boren (Eds.), *Information technology business models for quality healthcare: An EU/US dialogue* (pp. 95-102). Amsterdam*:* IOS Press.

Anderson, J. G. (2004a). Using IT for medication safety: Systems available. *Hospital Pharmacy Europe, July/August*, 1-2.

Anderson, J. G. (2004b). Information technology for detecting medication errors and adverse drug events. *Expert Opinion on Drug Safety*, *3*(5), 1–7. doi:10.1517/14740338.3.5.449

Anderson, J. G. (2007). Social, ethical, and legal barriers to e-health. *International Journal of Medical Informatics*, *76*, 480–483. doi:10.1016/j.ijmedinf.2006.09.016

Anderson, J. G. (2008). Improving patient safety with information technology. In M. Khosrow-Pour (Ed), *Encyclopedia of information science and technology, 2nd edition*, Hershey, PA: IGI Global.

Anderson, J. G., & Balas, E. A. (2006). Computerization of primary care in the United States . *International Journal of Healthcare Information Systems and Informatics*, *1*(3), 1–23.

Anderson, J. G., Jay, S. J., Anderson, M. M., & Hunt, T. J. (2002). Evaluating the capability of information technology to prevent adverse drug events: A computer simulation approach. *Journal of the American Medical Informatics Association*, *9*, 479–490. doi:10.1197/jamia.M1099

Anderson, J. G., Ramanujam, R., Hensel, D., & Siro, C. A. (Manuscript submitted for publication). Reporting trends in a regional medication error data-sharing system. *Journal of the American Medical Informatics Association*.

Ash, J. S., Gorman, P. N., & Hersh, W. R. (1998). Physician order entry in U.S. hospitals. In *Proceedings of the AMIA Symposium* (pp. 236-239).

Aspden, P., Corrigan, J. M., Wolcott, J., & Erickson, S. M. (Eds.). (2004). *Patient safety: Achieving a new standard for care*. Washington, DC: The National Academies Press.

Balas, E. A., Austin, S. M., Mitchell, J. A., Ewigman, B. G., Bopp, K. D., & Brown, G. D. (1996). The clinical value of computerized information services: A review of 98 randomized clinical trials. *Archives of Family Medicine*, *5*(5), 271–278. doi:10.1001/archfami.5.5.271

Bates, D. W. (1996). Medication errors: How common are they and what can be done to prevent them? *Drug Safety*, *5*, 303–310. doi:10.2165/00002018-199615050-00001

Bates, D. W. (1997). Quality, costs, privacy, and electronic medical data. *The Journal of Law, Medicine & Ethics*, *25*(2-3), 111–112, 182. doi:10.1111/j.1748-720X.1997.tb01886.x

Bates, D. W. (2000). Using information technology to reduce rates of medication errors in hospitals. *British Medical Journal*, *320*, 788–791. doi:10.1136/bmj.320.7237.788

Bates, D. W. (2005). Physicians and ambulatory electronic health records. *Health Affairs*, *24*(50), 1180–1189. doi:10.1377/hlthaff.24.5.1180

Bates, D. W., Cohen, M., & Leape, L. L. (2001). Reducing the frequency of errors in medicine using information technology. *Journal of the American Medical Informatics Association*, *8*, 299–308.

Bates, D. W., Cullen, D., & Laird, N. (1995). Incidence of adverse drug events and potential adverse drug events: Implications for prevention. *Journal of the American Medical Association*, *274*, 29–34. doi:10.1001/jama.274.1.29

Bates, D. W., Evans, R. S., Murff, H., Stetson, P. D., Pizziferri, L., & Hripcsak, G. (2003a). Detecting adverse events using information technology. *Journal of the American Medical Informatics Association*, *10*, 115–128. doi:10.1197/jamia.M1074

Bates, D. W., Evans, R. S., Murff, H., Stetson, P. D., Pizziperri, L., & Hripcsak, G. (2003b). Policy and the future of adverse drug event detection using information technology. *Journal of the American Medical Informatics Association*, *10*, 226–228. doi:10.1197/jamia.M1268

Bates, D. W., & Gawande, A. A. (2003). Improving safety with information technology. *The New England Journal of Medicine*, *348*(25), 2526–2534. doi:10.1056/NEJMsa020847

Bates, D. W., Leape, L. L., & Cullen, D. J. (1998). Effect of computerized physician order entry and a team intervention on prevention of serious medication errors. *Journal of the American Medical Association*, *280*, 1311–1316. doi:10.1001/jama.280.15.1311

Bates, D. W., Leape, L. L., Cullen, D. J., Laird, N., Petersen, L. A., & Teich, J. M. (1998). Effect of computerized physician order entry and a team intervention on prevention of serious medication errors. *Journal of the American Medical Association*, *280*, 1311–1316. doi:10.1001/jama.280.15.1311

Bates, D. W., Spell, N. S., & Cullen, D. J. (1997). The costs of adverse drug events in hospitalized patients. *Journal of the American Medical Association*, *277*, 307–311. doi:10.1001/jama.277.4.307

Budnitz, D. S., Pollock, D. A., Weidenbach, K. N., Mendelsohn, A. B., Schroeder, T. J., & Annest, J. L. (2006). National surveillance of emergency department visits for outpatient adverse drug events. *Journal of the American Medical Association*, *296*(15), 1858–1866. doi:10.1001/jama.296.15.1858

Classen, D. C., Pestotnik, S. L., Evans, R. S., & Burke, J. P. (1991). Computerized surveillance of adverse drug events in hospital patients. *Journal of the American Medical Association*, *266*, 2847–2851. doi:10.1001/jama.266.20.2847

Dash, E. (2005, August 7). Europe zips lips; U.S. sells ZIPs. *New York Times*, 1.

Dick, R. S., & Steen, E. B. (1997). *The computer-based patient record: An essential technology for healthcare*. Washington, D.C.: National Academy Press.

Doran, T. (2006). Pay-for-performance programs in family practice in the United Kingdom. *The New England Journal of Medicine*, *355*(4), 375–384. doi:10.1056/NEJMsa055505

Dorr, D., Bonner, L. M., Cohen, A. N., Shoal, R. S., Perrin, R., Chaney, E., & Young, A. S. (2007). Informatics systems to promote improved care for chronic illness: A literature review. *Journal of the American Medical Informatics Association*, *14*(2), 156–163. doi:10.1197/jamia.M2255

Galanter, W. L., Didomenico, R. J., & Polikaitis, A. (2005). A trial of automated decision support alerts for contraindicated medications using computerized physician order entry. *Journal of the American Medical Informatics Association*, *12*(3), 269–274. doi:10.1197/jamia.M1727

Goldsmith, J., Blumenthal, D., & Rishel, W. (2003). Federal health information policy: A case of arrested development. *Health Affairs*, *22*(4), 44–55. doi:10.1377/hlthaff.22.4.44

Gonzalez, C. A., et al. (2005). National Health Information Incentive Act of 2005, HR 741, 109th Congress, 1st session.

Goodman, C. (2005). Savings in electronic medical record systems? Do it for the quality. *Health Affairs*, *24*(5), 1124–1126. doi:10.1377/hlthaff.24.5.1124

Gurwitz, J. H., Field, T. S., Avorn, J., McCormick, D., Jain, S., & Eckler, M. (2000). Incidence and preventability of adverse drug events in nursing homes. *The American Journal of Medicine*, *109*(2), 87–94. doi:10.1016/S0002-9343(00)00451-4

Gurwitz, J. H., Field, T. S., Harrold, I. R., Rothschild, J., Debellis, K., & Seger, A. C. (2003). Incidence and preventability of adverse drug events in among older persons in the ambulatory setting. *Journal of the American Medical Association*, *289*(9), 1107–1116. doi:10.1001/jama.289.9.1107

Harris Interactive. (2001, October 1). U.S. trails other English speaking countries in use of electronic medical records and electronic prescribing. *Harris Interactive Healthcare News, 1*(28).

Harris Interactive. (2002, August 8). European physicians especially in Sweden, The Netherlands, and Denmark lead U.S. in use of electronic medical records. *Harris Interactive Healthcare News, 2*(16).

Health Strategies Consultancy. (2004). *Financial incentives: Innovative payment for health information technology*. Washington, D.C.: eHealth Initiative.

Hillestad, R., Bigelow, J., Bower, A., Girosi, F., Meili, R., Scoville, R., & Taylor, R. (2005). Can electronic medical record systems transform health care? Potential health benefits, savings, and costs. *Health Affairs*, *24*(5), 1103–1117. doi:10.1377/hlthaff.24.5.1103

Himmelstein, D. U., & Woolhandler, S. (2005). Hope and hype: Predicting the impact of electronic medical records. *Health Affairs*, *24*(5), 1121–1123. doi:10.1377/hlthaff.24.5.1121

Honigman, B., Lee, J., & Rothschild, J. (2001). Using computerized data to identify adverse drug events in outpatients. *Journal of the American Medical Informatics Association*, *8*, 254–266.

Hunt, D. L., Haynes, R. B., Hanna, S. E., & Smith, K. (1998). Effects of computer-based clinical decision support systems on physician performance and patient outcomes: A systematic review. *Journal of the American Medical Association*, *280*, 1339–1346. doi:10.1001/jama.280.15.1339

Johnson, J. A., & Bootman, J. L. (1995). Drug-related morbidity and mortality: A cost of illness model. *Archives of Internal Medicine*, *155*, 1949–1956. doi:10.1001/archinte.155.18.1949

Kaushal, R., Shojania, K. G., & Bates, D. W. (2003). Effects of computerized physician order entry and clinical decision support systems on medication safety. *Archives of Internal Medicine*, *163*, 1409–1416. doi:10.1001/archinte.163.12.1409

Kohn, L. T., Corrigan, J. M., & Donaldson, M. S. (Eds.). (1999). *To err is human: Building a safer health system*. Washington, D.C.: National Academy Press.

Lazarou, J., Pomeranz, B. H., & Corey, P. N. (1998). Incidence of adverse drug reactions in hospitalized patients: A meta-analysis of prospective studies. *Journal of the American Medical Association*, *279*, 1200–1205. doi:10.1001/jama.279.15.1200

Leaning, M. (1993). The new information management and technology strategy of the NHS. *British Medical Journal*, 217. doi:10.1136/bmj.307.6898.217

Leape, L. L., & Berwick, D. M. (2005). Five years after to err is human: What have we learned. *Journal of the American Medical Association*, *293*, 2384–2390. doi:10.1001/jama.293.19.2384

McDonald, K., & Metzger, J. (2002, September). Achieving tangible IT benefits in small physician practices. *California HealthCare Foundation, ihealth Report*.

Medicare Payment Advisory Commission. (1999). *Report to the Congress: Selected Medicare issues*. Washington, D.C.: Medicare Payment Advisory Commission.

Medication Errors Reduction Act of 2001. (2001). S 824, 107th Congress. 1st Session.

Miller, R. A., Gardner, R. M., Johnson, K. B., & Hripcsak, G. (2005). Clinical decision support and electronic prescribing systems: A time for responsible thought and action. *Journal of the American Medical Association*, *12*(4), 403–409. doi:10.1197/jamia.M1830

Miller, R. H., & Sim, I. (2004). Physicians' use of electronic medical records: Barriers and solutions. *Health Affairs*, *23*(2), 116–126. doi:10.1377/hlthaff.23.2.116

Miller, R. H., Sim, I., & Newman, J. (2003). *Electronic medical records: Lessons from small physician practices*. Oakland, CA: California HealthCare Foundation.

Miller, R. H., West, C., Brown, T. M., Sim, I., & Ganchoff, C. (2005). The value of electronic health records in solo or small group practices. *Health Affairs*, *24*(5), 1127–1137. doi:10.1377/hlthaff.24.5.1127

Miller, R. H., West, C., Brown, T. M., Sim, I., & Ganchoff, C. (2005). The value of electronic health records in solo or small group practices. *Health Affairs*, *24*(5), 1127–1137. doi:10.1377/hlthaff.24.5.1127

NHS Connecting for Health. *What is QMAS?* Retrieved from www.connectingforhealth.nhs.uk/programmes/qmas

Pederson, C. A., Schneider, P. J., & Santell, J. P. (2001). ASHP national survey of pharmacy practice in hospital settings: Prescribing and transcribing–2001. *American Journal of Health-System Pharmacy*, *58*, 2251–2266.

President's Information Technology Advisory Committee. (2004, April 13). *Health Care Delivery and Information Technology (HIT) Subcommittee: Draft Recommendations*. Retrieved from www.nitrd.gov/pitac

President's Information Technology Advisory Committee. (2004). *Revolutionizing healthcare through information technology*. National Coordination Office for Information Technology Research and Development, Arlington, VA.

Purves, I. N. (1998). *General practice computerisation national survey 1996*, NHS executive, Leeds.

Purves, I. N., Sugden, B., Booth, N., & Sowerby, M. (1999). The PRODIGY project–the iterative development of the release one model. In *Proceedings AMIA Annual Symposium* (pp. 359-363).

Rash, M. C. (2005, April 4). Privacy concerns hinder electronic medical records. *The Business Journal of the Greater Triad Area*.

Rosenfeld, S., Bernasek, C., & Mendelson, D. (2005). Medicare's next voyage: Encouraging physicians to adopt health information technology. *Health Affairs*, *24*(5), 1138–1146. doi:10.1377/hlthaff.24.5.1138

Schoen, C., Osborn, R., Huynh, P. T., Doty, M., Peugh, J., & Zapert, K. (2006). On the front lines of care: Primary care doctors' office systems, experiences, and views in seven countries. *Health Affairs*, *25*, W555–W571. doi:10.1377/hlthaff.25.w555

U.S. Government Accountability Office (GAO). (2004, August). *HHS's efforts to promote health information technology and legal barriers to its adoption, GAO-04-991R*. Retrieved from www.gao.gov

Versel, N. (2005, April 5). Europe's hospitals lag U.S. in adopting IT, study says. *Health IT World*. Retrieved from http://www.health-itworld.com/enews/04-05-2005_561.html

Walker, J., Pan, E., Johnston, D., Adler-Milstein, J., Bates, D. W., & Middleton, B. (2005). The value of healthcare information exchange and interoperability. *Health Affairs*, *24*(Suppl.1), W10–W18. doi:10.1377/hlthaff.24.5.1118

Walker, J. M. (2005). Electronic medical records and healthcare transformation. *Health Affairs*, *24*(50), 1118–1120. doi:10.1377/hlthaff.24.5.1118

Wang, S. J. (2003). A cost-benefit analysis of electronic medical records in primary care. *The American Journal of Medicine*, *114*(5), 397–403. doi:10.1016/S0002-9343(03)00057-3

KEY TERMS AND DEFINITIONS

Adverse Drug Events (ADE): A medication that results in unintended harm to a patient

Computerized Decision Support Systems: A computer-based system that consists of a knowledge base and an inference engine that generates advice to the providers

Computerized Physician Order Entry (CPOE): Clinical systems that electronically relay the physician's or nurse practitioner's diagnostic and therapeutic plan for action

Electronic Health Record (EHR): An electronic repository of information about a patient's health care and clinical information management tools that provide alerts, reminders and tools for data analysis

This work was previously published in Handbook of Research on Information Technology Management and Clinical Data Administration in Healthcare, edited by A. Dwivedi, pp. 217-229, copyright 2009 by Medical Information Science Reference (an imprint of IGI Global).

Chapter 1.10

Ageing, Learning, Technology, and Health Management

Gillian M Boulton-Lewis
Queensland University of Technology, Australia

Laurie Buys
Queensland University of Technology, Australia

Sylvia L. Edwards
Queensland University of Technology, Australia

Helen Partridge
Queensland University of Technology, Australia

ABSTRACT

The world's population is ageing rapidly. Ageing has an impact on all aspects of human life, including social, economic, cultural, and political. Understanding ageing is therefore an important issue for the 21st century. This chapter will consider the active ageing model. This model is based on optimising opportunities for health, participation, and security in order to enhance quality of life. There is a range of exciting options developing for personal health management, for and by the ageing population, that make use of computer technology, and these should support active ageing. Their use depends however on older people learning to use computer technology effectively. The ability to use such technology will allow them to access relevant health information, advice, and support independently from wherever they live. Such support should increase rapidly in the future. This chapter is a consideration of ageing and learning, ageing and use of computer technology, and personal health management using computers.

AGEING AND LEARNING[1]

Globally the population is ageing. Worldwide the proportion of people aged 60 and over is growing faster than any other age group. In 2025 there will be a total of 1.2 billion people over the age of 60 (World Health Organisation, WHO, 2002, p6). McFadden (2002) noted that this is now a portion of the life span never before experienced by so many people and that consequently we need new models of ageing to deal with this. The notion of active ageing has been proposed as one such model.

Active Ageing is a relatively recent global approach to older people achieving healthy, productive, safe and fulfilling lives. Active ageing is the 'process of optimising opportunities for health, participa-

DOI: 10.4018/978-1-60566-356-2.ch042

tion and security in order to enhance quality of life as people age' (World Health Organisation, WHO, 2002, p.12). Active ageing reflects not only the continuation of physical activity in later life, but also the continued participation in social, economic, cultural, spiritual, and civic affairs. WHO challenged all countries to implement the concept of active ageing within the cultural and demographic realities of their populations. In Australia two studies have recently explored the concept of active ageing: the Australian Active Ageing survey (National Seniors Productive Ageing Centre, 2005) investigated the contributors to and meaning of active ageing for older adults; and research undertaken by the Department for Community Development, Government of Western Australia (2006) developed and implemented an Active Ageing Benchmark Indicators. Both studies conceptualised active ageing for older people in terms of being proactive in keeping healthy, being physically and mentally active, engaging in learning, living in safe environments, working, and actively participating in family and community life. In the USA older adults themselves defined successful ageing as multidimensional including physical, functional, psychological and social health (Phelan, Anderson, LaCroix & Larson, 2004). In Britain, Bowling & Iliffe (2006) found that a multi dimensional lay model of ageing predicted quality of life more powerfully than unidimensional models (e.g. biomedical, sociological).

Learning

Education and learning are assumed to be important factors in facilitating participation and allowing adults to enjoy a positive quality of life as they age (WHO, 2002, p16). Participation within the broader community is important purely for enjoyment and recreation, and also to allow older people to adapt to changes within the environment in areas such as technology, lifestyle, finances and health. The ability to solve problems and adapt to change are strong predictors of active ageing and longevity according to Smits et al, (1999), cited in WHO (2002: 26). Butler (2002) cites the MacArthur Study on Aging as confirming that engagement in meaningful activities contributes to good health, satisfaction with life, and longevity as well as reducing the costs of physical and emotional illness. It is clear that learning plays an important role in productive ageing (Ardelt, 2000; Dench & Regan: 2000, Glendenning, 1997; Withnall, 2000) and therefore it is important for us to understand more about the phenomenon of learning by older people.

Barriers to Learning

Research in learning by older adults is, unfortunately, dominated by identification of obstacles to to the process caused by mental and physical deterioration. For example Driscoll, Hamilton, Petropoulos, Yeo, Books, Baumgartner & Sutherland (2003) described the ageing hippocampus and its effects on learning and memory. They reported in addition that cognitive tests to assess information-processing speed, working memory capability and declarative learning, administered to adults aged 17 to 86 years old, found significant age-related decrements in all three constructs (Kirasic, Allen, Dodson, & Binder, 1996). Boulton- Lewis (1997) concluded from a review of the literature 'that most adults, as they age usually process less information and do it in a slower and less efficient manner'. However 'knowledge that has been already acquired, the ability to retrieve it, as well as visual and auditory sensory capabilities are maintained for the most part, into the sixties' at least. Unfortunately, an outcome of the focus on problem-oriented research on ageing has helped create an image of older people as `being over the hill, out of date, out of touch, frail, sick and in need of services and support' (Kerschner & Pegues, 1998).

A Positive Approach to Learning

Taking a positive approach one can assert that older adults can and do acquire new knowledge outside of their domains of expertise. Researchers have found that with extra practice an older adult will perform as well as an unpractised younger adult (Charness 1992). For example, Rabbit, Diggle, Holland & McInnes (2004) found that on intelligence tests substantial practice effects counteracted true declines of ageing which remained significant even with intervals of seven years between tests. They also noted that variability between individuals was seen to increase as the sample aged. Charness (1992) suggested that the critical issue, in terms of age and performance is how the older person compensates for changes in processing speed and working memory to maintain performance. Boulton-Lewis (1997) proposed that given time and sufficient motivation older adults are able to achieve equivalent learning outcomes to younger learners. Obviously the nature and amount of learning achieved in early and middle life impacts significantly on the capacity of older adults when learning new skills and knowledge in later life.

Motivation to Learn as People Age

Motivation and confidence are critical to learning at any age, and particularly so as people become older. Purdie and Boulton-Lewis (2001) found that: the least important learning needs identified by older people were those associated with technology. They stated that their most important learning needs were associated with transportation, health and safety, In earlier interview data however participants had suggested that use of technology was an important area for new learning. The strongest barriers to such learning were those associated with physical disabilities; the weakest barriers were those associated with interaction with other people. In general participants were confident that they could successfully address the learning needs related to health, safety, leisure and transportation but not those associated with technology. Boulton-Lewis, Buys & Lovie-Kitchin (2006) asserted that older adults learn more slowly, need more practice, and their interests will vary, but in most cases motivation will be strong enough to learn new skills and to continue living fully through learning. They found that significant factors for learning activities were being female, having good physical health, level of prior education, good mental/emotional health, being younger, living in regional areas, not being retired, and being a high income earner. The Australian Active Ageing (Triple A) study (Buys, Lovie-Kitchin, Nayak, Boulton-Lewis, Tedman-Jones, Anderson, Edwards, Courtney, & Zlobicki, 2005) also found that in addition to good health an individual's attitude to learning was most important in active ageing; they generally agreed that they needed and wanted to learn about new things such as technology, new activities and leisure interests; respondents aged 50-64 were more likely to be interested, need and want to learn to keep up to date with new technology, and make an effort to learn new things. Therefore negative attitudes to learning by older people need to be examined. It should be generally acknowledged that older people are active and useful citizens who want to keep living their lives as fully as possible. If indeed learning keeps peoples' minds active and helps them in problem solving then it should make them less dependent and actually save governments money.

In summary learning is important to active ageing and there are some obstacles to learning as people age. However older adults can acquire new knowledge if they make the time and effort. If the motivation to learn is strong enough then we can assume that older people will effectively undertake new learning.

AGEING AND USE OF COMPUTER TECHNOLOGY[2]

A significant phenomenon of this century is the rapid and continuing increase in knowledge and the use of technology. For individual older users communication technologies have the potential to minimize social isolation and improve quality of life (Swindell, 1993). It is recognized in government and related documents that it is important for older adults to have abilities and opportunities to use new technologies to support and improve their quality of life and their participation in society (Department of Health and Ageing,The National Strategy for an Ageing Australia, 2001). These abilities would include allowing them to find and use information for personal health management.

Learning in a Modern Society

Health professionals express concern about connecting with older adults in new ways in order to increase their ability to engage in learning about health management (Kerschner & Pegues, 1998; Crane, 2001). Professionals are particularly concerned about the need for older people to learn about technology if they are to maintain their connections with community and societal developments, and to take advantage of the benefits technology offers. For example, inter alia, online management of health that becomes increasingly relevant to people as they age, is available only to those who have access to the Internet and have basic computer literacy.

Literacy, health literacy, and information literacy are three other related areas that must be considered when trying to encourage older adults to learn about and engage with, their personal health management in an online environment. Parjkh, Parker, Nurss, Baker and Williams (1996) interviewed 202 patients in a public hospital in Atlanta, Georgia, and reported that 42.6% had inadequate or marginal functional health literacy. They found that a significant number of these patients were ashamed to tell their family and that most of these patients actively sought to hide their low literacy skills. The patients with the lowest literacy were more likely to be males, over the age of 60, who had less than a high school education. A recent study by the Australian Bureau of Statistics (2006) confirmed that health literacy is a significant issue there also. A survey of over 9000 adults found that six in 10 people aged between 15 and 74 do not have the basic knowledge and skills to take care of their health and prevent disease. The findings revealed that many adults were not aware when they needed to contact a doctor, were unable to understand instructions on prescribed medication, and were unable to interpret food labels in order to follow a special diet such as low fat or low sugar. The health literacy problems of older adults are well documented. The 2003 US National Assessment of Adult Literacy (2007) included the first-ever national assessment of health literacy, which found that adults aged 65 and older have lower health literacy scores than all other age groups surveyed. Only 3 percent of the older adults who were surveyed were measured as proficient.

Linked to the issue of health literacy is that of information literacy. The Medical Library Association (MLA) has defined Health Information Literacy as the ‘set of abilities needed to recognize a health information need; identify likely information sources and use them to retrieve relevant information; assess the quality of the information and its applicability to a specific situation; and analyse, understand and use the information to make good health decisions’ (2003, para 5). Undoubtedly, much of the available health information that older adults need may require them to be able to use or access electronic tools and applications.

Older People and Computer Use

The current generation of older Australians has a relatively low rate of use of electronic tools and applications (COTA, 2004, p4). Factors such as education, income, age, ethnicity, and geographical location are likely to result in disadvantage for some groups (OECD, 2001). Issues of social exclusion have been identified in many investigations and commentaries about older people and information technology (Barnett & Adkins, 2001; Cameron, Marquis & Webster, 2001; Foskey, 2002; Scott, 1999; Steinberg, Walley, Najman& Donald, 1999; Tay, 2001). Lloyd and Hellwig (2000) found in Australia that retirees were the group most likely to remain without an Internet connection; 63% were unconnected compared with 29% of all groups who were not connected. This is similar to the figures for the United States where Rideout and Newman (2005) found that less than one-third of seniors have ever gone online and fewer than half have ever used a computer. In Europe in 2006 only 18% of people aged 65-74 had used a computer and only 13% had used the Internet within the past year (Ala-Mutka & Punie, 2007). It has been suggested that older adults were less likely than younger adults to use technology in general (Czaja, Charness, Fisk & Hertzog, 2006). Statistics show that, as age increases, the likelihood of using a computer decreases, yet in the age group 65 years and over, the number of adults accessing the Internet has more than doubled since 1999 (ABS, 2004). In 2002, for example, 13% of adults aged over 65 years accessed the Internet (Australian Bureau of Statistics, 2003). These older people used Internet technology mainly for the purpose of communication but should be able to learn to use it for many other purposes. The use of computers by older people should increase as the present generation of computer users age. However action needs to be taken to enable older people now to benefit from the use of technology.

Benefits of Using Computer Technology

Research confirms that there are beneficial outcomes of using a "home" computer for people who are likely to experience increased vulnerability as they age. In residential care situations, for instance, computer learning programs were associated positively with skills and confidence in spite of older adults own health perceptions; they were also beneficial in reducing depression (Timmermann, 1998; McConatha, McConatha, Deaner and Deigny, 1995). Computers in the homes of older people can provide significant benefits that improve their lives as they age. A study of frail older people's attitudes found that their use of a computer to maintain their home health care networks improved their self-esteem, particularly when they received appropriate training support in their own homes (Billipp, 2001). Studies that indicate positive outcomes for older people who use technology are particularly important to the policy of 'ageing in place'. Mynatt and Rogers (2002) found that technology use could potentially support the functional independence of older people and thus enable them to continue living independently in their own homes. Furlong (1997) described the creation of an online community for the third age where members would be able to address questions such as financial decisions, healthy lifestyle, management of disabilities and illness, friendships, relationships, passions, hobbies, work, and connection with family and friends. Billipp (2001) found however that while there were good reasons for including computers in home environments, some older people were more likely than others to respond positively to such an intervention strategy.

Attitudes to Computer Use

Some older people have a favourable disposition towards computers, while others may respond negatively to the design and operational features

(West, 2002). Zajicek (2004) suggests that age-related impairments such as vision, hearing and memory loss, and loss of mobility, contribute to "loss of confidence and difficulties in orientation and absorption of information". Barriers to such learning included attitudinal aspects such as being too old, embarrassment with lack of abilities, short-term memory loss, declines of manual dexterity and visual acuity (p. 62). Marqui, Jourdan-Boddaert & Huet (2002) studied young and old computer users and found that among the older group 'non-cognitive factors, such as fears of computerisation and its consequences in the workplace, age-related negative stereotypes, attitudes and lack of confidence' impacted on the success of their mastery of new computer technology. Purdie and Boulton-Lewis (2003) found, for adults over 70 years of age, that the most frequently mentioned learning *needs* were how to use a computer for e-mails and financial matters. However this ability was rated quite low as a priority for what they *wanted* to learn, probably because of a range of perceived difficulties. Respondents also indicated that they would prefer to learn in a one-to-one situation, preferably with a friend or family member rather than in a class. For some the cost of computer purchase and Internet access was also a problem. A study of older adults in South England and Wales found that, rather than resisting new computer technology, older people's non-use was mostly caused by the perceived irrelevance of ICT in their lives, with 78% of non users stating they had no need, and no interest in using computers (Selwyn, Gorard, Furlong and Madden, 2003).

A Hong Kong study by Lam and Lee (2006) found that Internet self-efficacy was the primary predictor in whether older adults used the Internet in a community ICT centre. Over 1000 adults aged 55 years and over participated in the study. A study by Partridge (2007a; 2007b) explored the factors that influence an individual's decision to use the Internet. Conducted in the US and Australia, the study found that Internet self-efficacy, or a belief in one's ability to use the Internet, was the only factor that predicted Internet use when socioeconomic variables were controlled (i.e. age, gender, income, education, employment). The study revealed that regardless of age an individual will use the Internet only if they have developed a high level of Internet self-efficacy. An individual can increase their Internet self-efficacy by watching similar others successfully use the Internet, being told that they can successfully use the Internet, and having past success in using the technology. Interestingly the study did find that age was a predictor on Internet self-efficacy, with younger individuals reporting higher levels of self-efficacy beliefs. Thus, the key to Internet use is self-efficacy not age but in instances where older adults have a low level of self-efficacy strategies can be implemented that will help them to increase their self-efficacy beliefs. In short, adults of all ages can learn how to integrate the Internet as part of their everyday life information worlds.

Boulton-Lewis, Buys, Lovie-Kitchin, Barnett, & David, (2007) in a study in Australia found that interest in learning, keeping up to date, valuing communication, being younger, and being male are predictors of learning about technology. Older adults used technology for a range of purposes but there was not much emphasis on its relevance to health management. On the other hand Campbell (2004) in the USA found that of 70 self-volunteers 58 were women; and that highly educated women who own or have access to a computer, have low levels of anxiety towards computers, strong feelings of self-efficacy towards computers and the Internet, and an internal locus of control are more willing than men to find medical information to manage a chronic health problem. The attitudes and needs described above present a challenge in terms of convincing older adults that they can benefit from and be comfortable with computer technology, in particular women, those with low incomes, little relevant education, or those from ethnic minorities.

However, many studies also attest to the capacities and abilities of older people to learn how to use the technology (Williamson, Bow & Wale, 1997; Scott, 2001). Older people have been encouraged to use ICT (Information Computer Technology) in specific settings such as computer clubs and libraries (Williamson et al, 1997). Such opportunities are often in provided in group situations and are not always accessible or suitable for older people. There are also a number of older people who are completely computer literate and keenly interested in promoting computer education and tuition among their peers (Hazzlewood & Kilpatrick, 2001; Swindell & Vassella, 1999). Groups such as ASCCA (the Australian Seniors' Computers Clubs Association), COTA (the Council on the Ageing), U3A (University of the Third Age), and SeniorNet in the US (Grodsky & Gilbert, 1998) for example, actively promote computer tuition by older people for older people. These approaches focus on complete beginners who may be fearful of the technology (Barker, 2000). There are initiatives also involving younger adults and children as computer tutors for older people.

The rate of computer use by older people is relatively low however there are well documented studies of the benefits of computer use by people as they age. Whether older people do in fact use computer technology will depend on their attitudes, needs, availability of tuition, willingness to learn, and their access to computers.

PERSONAL HEALTH MANAGEMENT THROUGH ONLINE ACTIVITY

One aspect threatening the quality of life of older people is exclusion from information in an increasingly digital world. This includes independent access to relevant health information, advice and support. Research described above confirms that there are beneficial outcomes from using a home computer for people who are likely to experience increased vulnerability as they age. Recent developments suggest that computers can be useful for health management for older people in creative ways such as obtaining medical data from patients, connecting to personal records, getting prescriptions online, and empowering patients to obtain health information in detail at their own pace in their own homes.

The Internet has rapidly become the primary vehicle for information and communication. It is therefore not surprising that it has become a common source for locating health information. A variety of media exist through which individuals can access health information online. These include websites, online support groups, chat rooms, instant messaging, e-lists and email. In many ways the Internet is an ideal tool for disseminating health information (Flynn, Smith & Freese, 2006). It provides individuals with privacy, immediacy, convenience, anonymity, a wide variety of information, and diversity of perspectives (Cotton & Gupta, 2004). Wagner and Wagner (2003) noted that older adults benefit by accessing health information online in three ways. Firstly, older adults may be more motivated to get health information because they are at greater risk than younger adults for illness. Secondly, because of retirement or a reduced workload, older adults may have more time than younger adults to examine health information. Finally, older adults may have only limited access to other health care sources and this difficulty in reaching a provider may be the result of limited mobility, remote location or loss of social network. Although there are many advantages to online health information seeking, disadvantages are also apparent. Credibility of the health information available is perhaps one of the more notable concerns (Cotton & Gupta, 2004). In recent years a small but growing number of studies have demonstrated that older adults are beginning to use computers and Internet technology to locate health information and to assist in the personal health management. (Moore, 2005; Morrell, Mayhorn & Bennett, 2000; Wagner & Wagner, 2003).

Technology Tools for Health Management

Siminerio (2005) asserts that as demands on today's health systems increase creative ways of using technology to explore health care are being explored. She describes those tools that are already possible in the USA at least. For example electronic medical records that collate information from a range of sources are replacing paper records. These save time and give prompts to doctors. Video setups can be used to beam doctors into patient's televisions and picture phones. Telephone modems can be used to feed information from blood glucose and blood pressure monitors directly to doctors and nurses. She suggests that the next steps might be: development of patient portals to allow a person to connect directly to their own records to get repeat prescriptions, check test results and get online advice; health cards which could be used to connect in a similar way to banking cards used in a ATM; and kiosk stations such as those in airports which could transmit blood pressure results directly to the doctor's records. Since this paper was released some of these technology tools have been developed, tools that will help patients and doctors to communicate better about health care issues as well as maintaining confidentiality, even between the office and the patients home (Reuters, 2008). Some of Siminerio's predictions remain fanciful but as similar technology exists for other purposes, the move of this into the health domain is highly likely. Bates and Komaroff (2006) also discuss paperless medicine that should allow people's records to be available wherever they are needed. They say that (in the USA): whilst only 24% of medical providers use electronic records in their offices the number is increasing and institutions are building systems with common coding that allows them to exchange data; technology is making it easier for patients to communicate with doctors and participate in their treatment; computers can provide doctors with up to date drug information; and that in the long term computerizing medical care will be expensive but it should provide savings, safety, and increased quality and efficiency. Bauer (2006) presents forecasts, implications and responses for the future of healthcare based on digital transformation. He suggests that the most powerful trend for healthcare is a revolution in medical science made possible by networked computers and that developments in technology will bring changes through new potentially beneficial tools. Whilst some of these tools do not at present allow older people to personally manage their own health needs some personal involvement is possible and should increase. Requardt (2006) argued that IT would be the biggest challenge in contemporary health care. IT will introduce a new paradigm shift in medicine and public health that will have many benefits. For example, 'the patient of the future will no longer rely just on the individual experience of his physician, but on the entire medical knowledge that is available' through intelligent patient databases (p. 22). IT will however also bring with it many new problems such as data protection and ethics that will need to be addressed.

Resources and Reliability

Anyone who can search the Web independently can find an enormous amount of information about health issues by themselves. A simple search for self help around health management in a search engine will provide thousands of links to self-help groups, self-help manuals, resources from health funds, or guides on how to lose weight and exercise. Some of this can be too detailed, depressing or from a non-reputable source. Cohen (2001) notes that the elderly can become adept Internet surfers; and whilst there are financial and physical obstacles, they can use this powerful tool to participate in their own healthcare; however seniors accessing this information need some personal guidelines about how much information they want, where the most dependable information is to be found, and how to judge the content of the Websites they visit. There are good and bad Websites in this respect and people can obtain and use information that is questionable unless they have some knowledge of medical matters or know how to evaluate the resources they find.

Becker (2004) notes that whilst the Internet provides an extraordinary opportunity for older adults to access health information, providing online health resources however does not guarantee that older adults will be successful at accessing or understanding the information they seek. Websites that do not meet the online needs of targeted users may pose virtual barriers that prevent the information seeker from attaining their goals. Using the National Institute of Ageing web guidelines Becker assessed the usability of 125 web sites offering health resources. The results of the study showed that many of the sites were not 'senior friendly' with specific improvements needed in order to accommodate the vision, cognition or motor skills of the older adult users.

Dishman (2004) describes Intel's Proactive Health lab that emerged from a study of householders who were early adopters of broadband technology. As a result of requests for help with care of ageing parents Intel is applying digital home technologies to the development of personal health systems for ageing in place. These applications include wireless sensors, adaptive interfaces, real-time data capture, and context aware feedback. They assert that they support an alternative to costly mainframe healthcare and help us all to personally manage our health better. There is also software available, accessible by the Internet, that allows patients and medical teams to access health records and assessment outcomes, consider treatment options, and communicate via e-mail (VisionTree Software).

Wilbert (2007) describes results from a survey of baby boomers in Minnesota, USA, that found many are actively ageing, planning to continue to live independently by investing in technology to help them. Businesses in the local area have already begun to respond, with a "senior-living community" of 325,000 square feet established, which includes common areas for socialization, housing for 250 people, a fitness center, plus the usual amenities of any housing community. The group is seeking to actively partner with health technology providers to equip and maintain these styles of communities on a broader scale, supporting the ageing baby boomers to continue living independently while properly supported in personal health management.

Gillaspy (2005) believes that recent changes have created an impact on libraries that provide consumer health information to the public. These include increased Internet connectivity, the quality and amount of consumer health information available, the realization that the American lifestyles could be causing health problems, maturation of the consumer health movement, and acceptance of it by health care professionals, emphasis on health literacy, and the events of September 11th. Whilst these changes are not specific to older consumers the issues of ageing baby boomers, their impact on health care financing, the lack of time for doctors and nurses to provide adequate health and patient information during scheduled visits, and the boom in complementary therapies all make it more important for public libraries to provide access to health information.

Strategies for Improving Computer Use and Applying Skills to Health Management

The purpose of this chapter has been to explore the range and use of the exciting options that are developing for personal health management by the ageing population, that make use of computer technology, and that should support active ageing. The exploration outlined in this chapter must be considered in light of its existing limitations. Firstly, whilst ageing is a global issue the exploration outlined in this chapter has focused solely on how the issue is experienced within developed countries. Secondly, research into ageing is many and varied, the breadth and depth of studies available has meant that the current chapter has only been able to provide a snap shot of some of the key commentaries in the field.

Active ageing promotes the continued engagement of older people in their communities in order to lead fulfilling lives. The more engaged people are and the more networks that they have, generally the better off they are as they age. There are strong links between participation, health and security. It is important make sure that older adults remain as healthy as possible, as good health is a significant variable in their ability to participate in wider activities. In order to stay healthy older people need to have access to health and health services. In the future many health services will be delivered through electronic methods and will require, at minimum, basic computer and technology literacy. This is where learning is involved. Older adults can and do learn. Most have a strong desire and ability to do so. They want to learn about a wide variety of things including technology operation. Learning basic computer literacy is within the capacity of most of the older population of developed countries at least. Thus we need to support programs that directly assist older adults to use technology, particularly in accessing information.

Boulton-Lewis, Buys, Lovie-Kitchin, Barnett and David (2007) found that the older people who use computer technology have a range of motivations to do so. The connection between learning and technology seems to be underpinned by a positive attitude towards the future and continued engagement with a range of learning issues. Men are more likely to feel at ease in using such technology. Given that it has been asserted that there is a close relationship between quality of life and use of computer technology with regard to issues including healthy lifestyle, management of disabilities and illness, it seems that there is a need to promote computer use with older people despite their possible fears and perceptions of lack of relevance in their lives. This is particularly important for women because they may be less inclined to use computers, generally live longer and often alone, and need to be able to personally manage their own health.

Facilitating Computer Use

There is a range of initiatives to promote access to computer use by older people. Computer companies and peer teaching (Grodsky and Gilbert, 1998) are two such activities. Many seniors' organisations in Australia such as ASCCA, COTA, University of the Third Age, and SeniorNet actively promote computer tuition by older people for older people. It seems that these programs are particularly important for females who want to learn generally, want to learn about technology and are not as likely to be currently using it (Boulton-Lewis et al., 2007). The need for access to computers for people with lower incomes also needs to be addressed.

Livingston (2007) described recent developments in ICT for older users allowing them to attend to solutions including health care. In a similar vein Czaja and Lee (2007) discussed the impact of ageing on access to technology and asserted that successful use of technology for older adults is predicated on systems that are designed to accommodate their needs and preferences. They suggest guidelines for system design based on assessing the cognitive and perceptual demands placed on the learner. Ala-Mutka and Punie (2007) suggest that older adults should be involved in the design of computer systems and programs that are suitable for them. They also suggest that older people could more easily take up a familiar tool such as digital television.

CONCLUSION

In summary this chapter has clearly shown that there are already developments that allow older adults to partially manage their personal health online. These are likely to increase exponentially. We are only just beginning to develop a picture of how the ageing population is using computer technology to manage their personal health. This chapter reveals the vibrant and diverse nature of active ageing research. Further research is needed to explore the main consequences and implications associated with older adults using an ever-changing array of technology (ie iPods, mobile phones) for their personal health care and management. Research in this field should be multi-disciplinary in nature, collaborative, and have a focus on learning.

Addressing the issue of healthy and productive ageing (Department of Health and Ageing, 2003, pi) has been cited as one of the crucial concerns for Australia's future and as such is a 'matter of highest national importance' (Howard 2001, cited in Andrews, 2002). The Australian government has challenged the Australian research and health care communities to generate 'high quality research in healthy ageing' (Department of Health and Ageing, 2003, p. 55). The active ageing model presented in this chapter helps fulfil the government's challenge. We are living in an information rich and technology driven world. More and more individuals are being called upon to obtain their own health information, and in doing so, are confronted with a plethora of health information resources from ebooks to blogs to youtube to databases. But many lack the ability to find their way through the spate of the ever increasing number and variety of health related IT resources available. In order for older people to make full use of the available health information resources and tools they need to be willing to learn. We should implement strategies and procedures that will motivate older people to learn to use IT to facilitate personal health management. The active ageing model and associated studies outlined in this chapter are unique because they place the focus on learning for individual empowerment. The active ageing model, if implemented, will help community health services reduce health inequalities and improve the health of ageing Australians. Promoting active ageing will enable ageing Australians to be proactive in their health and lifestyle choices.

REFERENCES

Ala-Mutka, K. & Punie, Y. (2007). Ageing societies, learning, and ICT. *E-Learning papers, 6,* 1-8.

Andrews, K. (2002). *The next phase of the national strategy for an ageing Australia.* Retrieved on February 3, 2006, from http://www.health.gov.au/internet/wcms/publishing.nsf/Content/health-mediarel-yr2002-ka-kasp020217.htm

Ardelt, M. (2000). Intellectual vs. wisdom-related knowledge: The case for a different kind of learning in the later years of life. *Educational Gerontology*, *26*, 771–789. doi:10.1080/036012700300001421

Australian Bureau of Statistics. (2003). *Australian social trends: Household use of computers and the Internet*. Retrieved on October 6, 2004, from AusStats/abs@.nsf

Australian Bureau of Statistics. (2006) *Adult literacy and life skills survey, summary results*. Australia. ABS 4228.0.

Barker, N. (2000). *Computing for the mortally terrified and other fantastic futures*. Paper presented at the 2000 Fulbright Symposium: Implications for an Ageing Population, Perth, Western Australia.

Barnett, K., & Adkins, B. (2001, December 13-15). Social inclusion: Computer practices enabling older people's 'virtual mobility' between and communities. *TASA 2001 Conference*, Sydney, Australia.

Bates, D. W., & Komaroff, A. L. (2006). Digital age: Next: Paperless medicine. *Newsweek (US edition),* 148(14), 63.

Bauer, J. C. (2006). The future of healthcare: Forecasts, implications, and responses. *Healthcare Executive*, *21*(5), 14–20.

Becker, S. A. (2004). A study of Web usability of older adults seeking online health resources. *ACM Transactions on Computer-Human Interaction*, *11*(4), 387–406. doi:10.1145/1035575.1035578

Billipp, S. H. (2001). The psychosocial impact of interactive computer use within a vulnerable elderly population: A report on a randomized prospective trial in a home healthcare setting. *Public Health Nursing (Boston, Mass.)*, *18*(2), 138–145. doi:10.1046/j.1525-1446.2001.00138.x

Boulton-Lewis, G. (1997). Information processing, memory, age, and adult learning. In P. Sutherland (Ed.), *Adult learning: A reader*. London: Kogan Page.

Boulton-Lewis, G. M., & Buys, L., & Lovie-Kitchin. (2006). Learning and active ageing. *Educational Gerontology*, *32*(4), 271–282. doi:10.1080/03601270500494030

Boulton-Lewis, G. M., Buys, L., Lovie-Kitchin, J., Barnett, K., & David, L. N. (2007). Learning, ageing, and computer technology in Australia. *Educational Gerontology*, *33*(3), 253–270. doi:10.1080/03601270601161249

Bowling, A., & Iliffe, S. (2006). Which model of successful ageing should be used? Baseline findings from a British longitudinal survey of ageing. *Age and Ageing*, *35*(6), 607–614. doi:10.1093/ageing/afl100

Butler, R. N. (2002). The study of productive aging. *The Journals of Gerontology: Series B: Psychological Sciences as Sciences*, *57*(6), S323.

Buys, L., Lovie-Kitchin, J., Nayak, R., Boulton-Lewis, G., Tedman-Jones, J., Anderson, D., Edwards, H., Courtney, M., & Zlobicki, M. (2005). The predictors of active ageing of older Australians–the triple A study. *Gerontologist, 45*(Sp. Iss. 2), 423-423.

Cameron, D., Marquis, R., & Webster, B. (2001). Older adults' perceptions, experiences, and anxieties with emerging technologies. *Australasian Journal on Ageing, 20*.3 (2), 50-56.

Campbell, R. J. (2004). Older women and the Internet. *Journal of Women & Aging*, *16*(1/2), 161. doi:10.1300/J074v16n01_11

Charness, N. (1992). Age and expertise: Responding to Talland's challenge. In I. W. Poon, D. C. Rubin & B. A. Wilson (Eds.), *Everyday cognition in adulthood and later life.* Cambridge, UK: Cambridge University Press.

Cohen, C. (2001). Guiding seniors. *RN*, *64*(2), 50.

COTA. National Seniors. (2004). *Adult learning in Australia*. Submission to the department of education, science, and training. Retrieved on December 8, 2004, from www.cota.org.au/adultlng04.htm

Cotton, S. R., & Gupta, S. S. (2004). Characteristics of online and offline health information seekers and factors that discriminate between them. *Social Science & Medicine*, *59*(9), 1795–1806. doi:10.1016/j.socscimed.2004.02.020

Crane, P. B. (2001). I want to know: Exploring how older women acquire health knowledge after myocardial infarction. *Journal of Women & Aging*, *13*(4), 3. doi:10.1300/J074v13n04_02

Czaja, S. J., Charness, N., Fisk, A. D., & Hertzog, C. (2006). Factors predicting the use of technology: Findings from the center for research and education on ageing and technology enhancement (CREATE). *Psychology and Aging*, *21*(2), 333. doi:10.1037/0882-7974.21.2.333

Czaja, S. J., Lee, C. C. (2007). The impact of aging on access to technology. *Universal access in the information society, 5*(4), 341-350.

Dench, S., & Regan, J. (2000). *Learning in later life: Motivation and impact*. Nottingham: DfEE.

Department for Community Development, Government of Western Australia. (2006). *Western Australia's seniors active ageing benchmark indicators: An initiative of generations together-the Western Australian active ageing strategy*. Retrieved on March 4, 2008, from http://www.community.wa.gov.au/DFC/Communities/Seniors/Publications/Active_Ageing_Benchmark_Indicators.htm

Department of Health &Ageing (DHA). (2003). *Promoting healthy ageing in Australia*. Retrieved on Ferbruary 3, 2006, from http://www.health.gov.au/internet/wcms/publishing.nsf/Content/93AD4FAAC4AF69D4CA25708A0009F1EE/$File/phaia.pdf

Department of Health and Ageing. (2001). *National strategy for an ageing Australia: An older Australian challenges and opportunities for all.* Retrieved on March 15, 2008, from http://www.ifa-fiv.org/docs/National%20Strategy%20for%20an%20Ageing%20Australia.pdf

Dishman, E. (2004). Inventing wellness systems for aging in place. *Computer*, *37*(5), 34. doi:10.1109/MC.2004.1297237

Driscoll, I., Hamilton, D. A., Petropoulos, H., Yeo, R. A., Brooks, W. M., Baumgartner, R. N., & Sutherland, R. J. (2003). The ageing hippocampus: Cognitive, biochemical, and structural findings. *Cerebral Cortex (New York, N.Y.)*, *13*(12), 1344. doi:10.1093/cercor/bhg081

Flynn, K. E., Smith, M. A., & Freese, J. (2006). When do older adults turn to the Internet for health information? Findings from the Wisconsin longitudinal study. *Journal of General Internal Medicine*, *21*, 1295–1301. doi:10.1111/j.1525-1497.2006.00622.x

Foskey, R. (2002). *Making the connections: Nonmetropolitan older people and technology*. Armidale, NSW: The Rural Development Centre, University of New England.

Furlong, M. (1997). Creating online community for older adults. *Generations (San Francisco, Calif.)*, *21*(3), 33–35.

Gillaspy, M. L. (2005). Factors affecting the provision of consumer health. *Library Trends*, *53*(3), 480–496.

Glendenning, F. (1997). Why educational gerontology is not yet established as a field of study. *Education and Ageing*, *12*, 82–91.

Grodsky, T., & Gilbert, G. C. (1998). Seniors travel the information superhighway. *Parks and Recreation Arlington*, *33*(6), 70–74.

Hazzlewood, J., & Kilpatrick, S. (2001). *Seniors online: Learning outcomes from Internet access.* Launceston, Australia: Centre for Research and Learning in Regional Australia.

Kerschner, H., & Pegues, J. M. (1998). Productive aging: A quality of life agenda. *Journal of the American Dietetic Association*, *98*(12), 1445–1448. doi:10.1016/S0002-8223(98)00327-7

Kirasic, K. C., Allen, G. L., Dobson, S. H., Shannon, H., & Binder, K. S. (1996). Aging, cognitive resources, and declarative learning. *Psychology and Aging*, *11*(4), 658–670. doi:10.1037/0882-7974.11.4.658

Lam, J. C. Y., & Lee, M. K. O. (2006). Digital inclusiveness–longitudinal study of Internet adoption by older adults. *Journal of Management Information Systems*, *22*(4), 177–206. doi:10.2753/MIS0742-1222220407

Livingston, J. (2007). ICT design for elders. *Interaction*, *14*(4), 20. doi:10.1145/1273961.1273977

Lloyd, R., & Hellwig, O. (2000). *Barriers to the take-up of technology*. Discussion paper no 53. National Centre for Social and Economic Modelling: University of Canberra.

Marqui, J. C., Jourdan-Boddaert, L., & Huet, N. (2002). Do older adults underestimate their actual computer knowledge? *Behaviour & Information Technology*, *21*(4), 273–280. doi:10.1080/0144929021000020998

McConatha, J. T., McConatha, D., Deaner, S. L., & Dermigny, R. (1995). A computer-based intervention for the education and therapy of institutionalized older adults. *Educational Gerontology*, *21*(2), 129–138. doi:10.1080/0360127950210202

McFadden, S. H. (2002). Challenges and opportunities in the search for new models of aging. *The Gerontologist*, *42*(5), 705–709.

Medical Library Association (MLA). (2003). *Health information literacy*: *definitions.* Retrieved on Marcy 15, 2008, from http://www.mlanet.org/resources/healthlit/define.html

Moore, G. A. (2005). Online communities: Helping “senior surfers” find health information on the web. *Journal of Gerontological Nursing*, *31*(11), 41–48.

Morrell, R. W., Mayhorn, C. B., & Bennett, J. (2000). A survey of World Wide Web use in middle-aged and older adults. *Human Factors*, *42*(2), 175–182. doi:10.1518/001872000779656444

Mynatt, E. D., & Rogers, W. A. (2002). Developing technology to support the functional independence of older adults. *Ageing International*, *27*(1), 24–41. doi:10.1007/s12126-001-1014-5

National Seniors Productive Ageing Centre. (2005). Active and productive ageing: What is the real experience of Australians? *Research Bulletin (Sun Chiwawitthaya Thang Thale Phuket)*, *1*(1).

OECD. (2001). *Understanding the digital divide*. Retrieved from http://www.oecd.org/dataoecd/38/57/1888451.pdf

Parjkh, N. S., Parker, R. M., Nurss, J. R., Baker, D. W., & Williams, M. V. (1996). Shame and health literacy: The unspoken connection. *Patient Education and Counseling*, *27*(1), 33–39. doi:10.1016/0738-3991(95)00787-3

Partridge, H. (2007, October 19-24). *Redefining the digital divide. Attitudes do matter!* Paper presented at the ASIS&T 2007 Annual Meeting Joining Research and Practice: Social Computing and Information Science, Milwaukee, USA.

Partridge, H. (2007, June 30-July 4). Redefining the digital divide in the smart state. *13th Australasian World Wide Web Conference*, Coffs Harbour, NSW.

Phelan, E. A., Anderson, L. A., LaCroix, A. Z., & Larson, E. B. (2004). Older adults views of successful aging–how do they compare with researchers’ definitions? *Journal of the American Geriatrics Society*, *52*(2), 211–216. doi:10.1111/j.1532-5415.2004.52056.x

Purdie, N., & Boulton-Lewis, G. (2001). The learning needs of older adults. *Educational Gerontology*, *29*, 129–149. doi:10.1080/713844281

Rabbit, D., Diggle, P., Holland, F., & McInnes, L. (2004). Practice and drop-out effects during a 17-year longitudinal study of cognitive aging. *The Journals of Gerontology. Series B, Psychological Sciences and Social Sciences*, *59*(2), 84–97.

Requardt, H. (2006). Technology solutions for better outcomes: Integrated information management in key to productiviy increases in medicine. *The British Journal of Radiology*, *79*, 17–23. doi:10.1259/bjr/23726774

Reuters Press Release. (2008). Meridian health's digital healthcare solutions are being showcased at lunch at Piero's media event during CES 2008. Retrieved on March 15, 2008, from http://www.reuters.com/article/pressRelease/idUS114230+07-Jan-2008+PRN20080107

Rideout, V., & Newman, T. (2005). *E-Health and the elderly: How seniors use the Internet for health information, key findings from a national survey of older Americans*. Menlo Park, CA: Kaiser Family Foundation.

Scott, H. (1999a). *Information and older people–present and future*. Paper presented at STRAIT to the Future, 8th Asia-Pacific Specials, Health and Law Librarians Conference, Hobart, Australia.

Scott, H. (2001). *Old dogs learning new clicks–older Australians in the information age*. Council on the Ageing (Australia). Retrieved from http://ww.cota.org.au/econmerce.htm

Selwyn, N., Gorard, S., Furlong, J., & Madden, L. (2003). Older adults' use of information and communication technology in everyday life. *Ageing and Society*, *23*, 561–582. doi:10.1017/S0144686X03001302

Siminerio, L. M. (2005). Healthcare in cyberspace: The new frontier. *Diabetes Forecast*, *5*(2), 11.

Steinberg, M., Walley, L., Najman, J., & Donald, K. (1999). *Connected or disconnected? Are older people being marginalized through modern communication technologies?* Paper presented at the Fourth International Conference on Communication, Ageing, and Health: Communication for All Ages, Gold Coast, Queensland.

Swindell, R. (1993). U(3)A the university of the third age in Australia: A model for successful ageing. *Ageing and Society*, *2*(13), 245. doi:10.1017/S0144686X00000878

Swindell, R., & Vasella, K. (1999) *Older learners online: An evaluation of Internet courses for isolated older persons.* Brisbane, Australia: Griffith University.

Tay, A. (2001). Is there a slow lane on the information superhighway? Issues of exclusion and discrimination confronting older people in the information age. *Australasian Journal on Ageing, 20.3*(supplement 2), 42-49.

Timmermann, S. (1998). The role of information technology in older adult learning. *New Directions for Adult and Continuing Education*, *77*, 61–71. doi:10.1002/ace.7706

U.S. Department of Education. (2007). *Literacy in everyday life: Results from the 2003 national assessment of adult literacy*. Retrieved on March 12, 2007, from http://nces.ed.gov/Pubs2007/2007480.pdf

Vision Tree Software. (2006, April 30). Information technology: Vision tree launches online version of secure patient health management portal. *Ageing and elder health week,* 68.

Wagner, L., & Wagner, T. H. (2003). The effect of age on the use of health and self-care information: Confronting the stereotype. *The Gerontologist*, *43*(3), 318–324.

West, D. (2002). Paper presented at Electronic Networking 2002-Building Community-[conference proceedings; CD-ROM via www.ccnr.net/2002].

Wilbert, L. (2007). *Boomers study shows future demand for health technology. Changing aging: A place to share & discuss ideas, news, innovations, & opinions that are changing ageing.* Retrieved on March 15, 2008, from http://www.ecumen.org/changing-ageing/55/future-demand-for-health-technology/

Williamson, K., Bow, A., & Wale, K. (1997). Encouraging public Internet use by older people: A comparative study of city and rural area. *Rural Society*, *7*(3/4), 3–11.

Withnall, A. (2000). Older learners–issues and perspectives. *Working Papers of the Global Colloquim on Supporting Lifelong Learning.* Milton Keynes, UK: Open University. Retrieved on March 14, 2002, from http//www.open.ac.uk/lifelong-learning

World Health Organisation. (2002). *Active ageing: A policy framework.* Retrieved on April 15, 2007, from http://whqlibdoc.who.int/hq/2002/WHO_NMH_NPH_02.8.pdf

KEY TERMS AND DEFINITIONS

Active Ageing: Refers to the process of enhancing quality of life as people age by ensuring opportunities exist for health, participation and security.

Ageing: Refers to the process of becoming older.

Computer Technology: Is a broad term that refers to computer software and hardware.

Learning: Refers to the process of acquiring or developing new skills, knowledge and attitudes.

Motivation to Learn: Refers to attitude, desire, will to learn.

Older Adults: Older people, ageing persons, usually over 65 years.

Personal Health Management: Refers to an individual taking active responsibility for managing their own health care.

ENDNOTES

[1] Some of this section is derived from Boulton-Lewis, G.M., Buys, L, & Lovie-Kitchin. (2006). Learning and active aging. *Educational Gerontology,* 32(4), 271-282.

[2] Some of this section is derived from Boulton-Lewis, G. M., Buys, L., Lovie-Kitchin, J., Barnett, K., & David, L.N., (2007) Learning, ageing and computer technology in Australia. *Educational Gerontology,* 253-270.

This work was previously published in Handbook of Research on Information Technology Management and Clinical Data Administration in Healthcare, edited by A. Dwivedi, pp. 674-689, copyright 2009 by Medical Information Science Reference (an imprint of IGI Global).

Chapter 1.11

Evaluating Healthcare IT and Understanding the Work of Healthcare are Entangled Processes

Joseph Schulman
New York Presbyterian Hospital, USA

ABSTRACT

Parallel to the monumental problem of replacing paper- and pen-based patient information management systems with electronic ones is the problem of evaluating the extent to which the change represents an improvement. Meaningful and useful evaluation rests upon: a) explicitly conceptualizing the goals and tasks of the daily clinical work; b) thinking of electronic information management technology as a cognitive tool; c) explicitly representing in the tool the pertinent information elements; d) selecting among possibilities for representing a problem formulation so as to facilitate the solution; and e) appreciating the dynamic interaction between the work and the tool–that changing a tool necessarily changes the work. Anchored in the story of how one hospital committee learned to think about the purpose and impact of a patient information management system, this chapter gives practical insight to these evaluative considerations.

DOI: 10.4018/978-1-60566-030-1.ch002

INTRODUCTION

This chapter grew out of a story about how a committee of clinicians and information technology (IT) professionals learned to think more clearly about healthcare IT; to think about it in a somewhat deductive manner. Since healthcare IT is a tool to aid the work of healthcare, the group ultimately determined that critical reflection entails identifying what may be considered first principles that justify and inform the work itself. At the outset, the committee's task of characterizing IT success versus failure seemed perfectly clear. But only so until they began to understand the crucial distinction between healthcare system tasks and goals, and that activity without clarity of purpose may be activity without value. From these insights emerged an interrogative framework anchored in clear notions of purpose and designed to yield operational understanding. Over time, the essential idea became evident: clinical work and tools are calibrated to each other. The committee came to appreciate that a tool achieving quick user acceptance may be one that makes little use of its technological potential; and that workers may be unaware that their early opinions about new tools reflect their imposing the specifics of the previous work/tool interaction on the present one. The story of how this group learned to think about evaluating healthcare IT was originally published in the Journal of the American Medical Informatics Association and is reprinted here with permission: "Discovering how to think about a hospital patient information system by struggling to evaluate it: a committee's journal."(J. Schulman, G.J. Kuperman, A. Kharbanda, & R. Kaushal, 2007)

Of equal importance to understanding first principles that underpin the work of healthcare is an understanding of first principles for designing IT to aid that work. One such principle is the notion of a problem space – discussed in the committee's journal, later in this chapter. This chapter begins by examining additional foundational principles of IT design. These include the notion of a cognitive tool; exactly which information elements one ought to pay attention to; considerations for selecting among representational options so as to facilitate solving an information management problem; the vital importance of explicitly conceptualizing the bulk of the daily work in order to deftly manage it via database technology; and the idea that our tools generally determine how we think and work.

COGNITIVE TOOLS

IT is a cognitive tool. A cognitive tool is an artifact to represent and express what one knows; it may even help one to discover new knowledge. It is intended to aid human cognitive processing,(Jonassen) to extend and facilitate what one could otherwise achieve unaided. The point of such a tool is not to relieve health care providers of the actual task of cognitive processing, but to *extend* providers' cognitive abilities. Users should be able to process more information than if they had no tool. Note that whether or not such a tool is available, providers must think deeply about the information at hand. The tool should promote deeper, more critical reflection and help the user discover relevant ideas that might have been missed without the tool. Rather than solely make the current task array easier, cognitive tools should enable the user to perform additional tasks that were always pertinent to the work but otherwise unfeasible.(Jonassen) Moreover, since the truly intelligent system is the user – not the tool, the tool ought to be largely controlled by the user. In contrast, all too commonly current technology imposes constraints on exactly how the user may formulate and think about a problem.

WHICH ELEMENTS OF THE DAILY WORK SHALL WE ATTEND TO?

One way to think about IT as a tool to facilitate the daily clinical work – which largely entails formulating and solving problems – is to decompose the work into its component processes:(Robertson, Elliot, & Washington, 2007)

1. Seeking information
2. Presenting information
3. Organizing knowledge

Thus, IT affects cognition and ultimately action because it frames the way its users think. How does this happen? From a user perspective, a particular database software implementation is essentially a template of blanks to be filled in or to be viewed. Each template directs attention to particular aspects of work (formulating and solving problems) and to particular data elements – and discounts or ignores others. Templates underpin not only healthcare database software but also similarly intended word processor or spreadsheet applications; and to some extent, templates also underpin the mental models of providers who manage their patient information with pen and paper. In any case, rather than reflecting the real importance of the selected data elements, the framing and focus of such templates may derive from what is readily measured or represented or from what decision makers determine based on legacy and/or accepted belief. For some IT implementations, the framing and focus may be apropos for specific types of patients or pathophysiological conditions, but it may be uniformly applied to an inappropriately wide range of patients and conditions.

DOES HOW WE REPRESENT WHAT WE PAY ATTENTION TO, MATTER?

Whatever the framing and focus of an IT implementation, it amounts to a specific representational system; a map of the reality over which it is hoped the tool will provide greater mastery. Such a system includes:(Norman, 1993)

1. That which is to be represented
2. That which does the representing; symbols

This map – whether represented in consciousness or in a cognitive tool such as a database software application – must itself exist as a representation: a metarepresentation.(Norman, 1993) It is the meta-representation – the mental model of reality – that one tends to reflect upon.(Norman, 1993) Very importantly, often more than one way exists to represent the selected aspect of reality. So it is central to evaluative thinking to ask: How does one choose among the possibilities?

The answer entails evaluating the suitability of each representation for solving the associated problem. In the words of popular wisdom, "there's more than one way to skin a cat." It turns out that a problem's difficulty and its very nature are related to its representational or meta-representational specifics. This abstract idea becomes concrete and much clearer after considering two games: one called "15," and the second, the well-known "tic tac toe."(Guerlain, Hayes, Pritchett, & Smith, 2001; Norman, 1993)

The game of "15": Two players may select, without replacement, any of the nine digits – 1, 2, 3, 4, 5, 6, 7, 8, 9. A player may take one digit in turn. The aim is to be the first player to get any three digits that add up to 15.

Consider this game scenario:(Norman, 1993) Player A selects 8. Player B selects 2. On the second round, A selects 4 and B selects 3. On round three, A selects 5; now, what digit should B select next? Please pause and try to answer the question.

Most people find this a difficult problem to solve. It produces cognitive overload. Tasks include mentally keeping track of game rules; which player selected which digit; which digits remain; and which remaining combination is preferred: both players' numbers must be added in various combinations of three digits and then one must decide either to block the opponent or advance toward winning.

Now consider a second game.

The game of "tic tac toe": Most readers know this game from childhood. Played on a 3 X 3 matrix, the aim is to be the first player to position three identical symbols – either X's or O's – in a straight line.

Consider this game scenario: Player A uses X symbols and Player B uses O symbols. Figure 1 shows the game at round number 3; now, where should Player B place an O next? Again, please pause to answer the question.

Most readers (and children) find this problem easy to solve. They quickly determine that Player B should place an O in the lower right cell (Table 1).

Why does "15" seem difficult and "tic tac toe" easy? It is because the way the information about the "tic tac toe" game is represented enables one to see the solution "at a glance." No memory and little additional reflection are needed. In contrast, "15" as represented above provides no memory or other information processing aids.

But "15" need not be so difficult a game. As mentioned earlier, often more than one way exists to represent an aspect of reality; and that a task's

Table 1. Game scenario (Norman, 1993)

X	O	X
	X	
O		

difficulty and its very nature are related to its representation or meta-representation. The game “15” may be represented differently, graphically, as if it were “tic tac toe.” Imagine that player A and Player B played “15” such that they arranged the available digits as though they were X’s and O’s in “tic tac toe.” The upper portion of Table 2 illustrates one possible configuration reflecting the earlier game scenario:(Norman, 1993)

After referring to the matrix in the upper portion of Table 2 and the game in play in the lower right, it’s readily apparent that the digit Player B should select on round three is 6, in the lower right cell. The lower left portion of Table 2 highlights the parallel with “tic tac toe.”

PROBLEM ISOMORPHS

The games of “15” and “tic tac toe” illustrate a key first principle for healthcare IT design, the notion of problem isomorphs.(Norman, 1993; Simon, 1996) In each game, the problem, the essential question to be answered, is actually the same. The tasks involved in answering the essential question, and the attendant difficulty, differ greatly because of how the relevant aspect of reality was represented. For either “tic tac toe” or “15,” graphically representing the information as the matrix illustrated in Figure 2 aids the player by providing some “external memory.”(Guerlain et al., 2001) Note, however, that for a given problem the preferred representational choice may depend on whether a person or a computer is doing the data processing. Although it is easier for a person to solve “15” when graphically represented, it is easier for a computer to do so when it is arithmetically represented.(Norman, 1993) It is easier for a person to solve “tic tac toe” when spatially represented. However, many people would find it much more complicated and unintuitive to write a computer program for solving “tic tac toe.”(Norman, 1993) Thus, optimal representation depends on the available knowledge that may be brought to bear, the problem-solving algorithm applied, and the performance characteristics of the computational system.

The great variation in healthcare and the way it is documented, often with little association to outcomes (Blumenthal, 1994; The Center for the Evaluative Clinical Sciences, 1998), suggests that the notion of problem isomorphs could be

Table 2. Player A’s selections are bold; Player B’s selections are italics.

4	3	8
9	5	1
2	7	6

X	*O*	**X**
	X	
O		

4	*3*	**8**
	5	
2		

beneficial to usefully conceptualizing healthcare and evaluating healthcare IT. Eddy observed that "When different physicians are recommending different things for essentially the same patients, it is impossible to claim that they are all doing the right thing."(Eddy, 2005) Here is one elementary illustration of the relevance of problem isomorphs to healthcare IT evaluation. To answer a question or solve a problem, an IT user often must navigate among several windows on a computer monitor. This forces the user to rely on human memory and cancels some of the machine potential for leveraging recall. (Think again about the experience of playing the arithmetically represented game of "15.") In some software applications, once a particular view has opened the user can't go back to check another with related information without losing information already entered on the current screen view. Imagine how helpful it would be for clinicians if a specific array of data elements particularly pertinent to a patient's problem profile was available on a single screen view – something like the graphically represented game of "15."

In summary:

1. Try to discriminate bad representations that produce a cognitive quagmire from good representations that can point to the answer
2. Recognize that the very concept of the problem to be solved may change when workers have cognitive tools that expand their perceptual capability, their memory, and their computational skills

When the only tool you have is a hammer, everything looks like a nail ~Abraham Maslow

CAN WE RECOGNIZE IT SUCCESS WHEN WE LOOK AT IT?

Success vs. Failure: Is the Glass Half Empty or Half Full? (Reprinted from Schulman, 2006. Used with permission)

Van Der Meijden et al reviewed publications between 1991 and 2001 that evaluated inpatient information systems requiring data entry and retrieval by health care professionals.(Van Der Meijden, Tange, Troost, & Hasman, 2003) They found a plethora of studies extensively describing system failures but could find no study that explicitly defined system success. Indeed, health information systems are rather prone to failing. (Littlejohns, Wyatt, & Garvician, 2003) One fundamental for learning from an information system failure is to disentangle user resistance to change(Rogers, 1995) from suboptimal technical solutions. Those who protest the changes occurring in patient information technology must come to see that the real choice does not include the status quo.(Department of Health, 2002; Dick, Steen, Detmer, & eds., 1997) (Thompson & Brailer, 2004) Bearing in mind that user acceptance need not imply a problem successfully solved, see Lorenzi and Riley(Lorenzi & Riley, 2000) for a review of individual and organizational factors that influence people to accept new information technology.

Success/Failure Permutations

It is probably clear by now that "How to recognize IT success?" begs other questions: How well have the representations been matched to the tasks? Are the correct tasks being performed – how does one know? A variety of possibilities are possible:

1. A well-conceived and/or implemented software application of an adequately conceptualized work reality
2. A well-conceived and/or implemented software application of an inadequately conceptualized work reality
3. A poorly-conceived and/or implemented software application of an adequately conceptualized work reality
4. A poorly-conceived and/or implemented software application of an inadequately conceptualized work reality

A substantial portion of healthcare IT shortcomings may derive from the current work reality and how it is conceptualized.(C. Nemeth & Cook, 2005; C. P. Nemeth, Cook, & Woods, 2004) The daily work of healthcare may appear to unfold smoothly, but only because clinicians are doing many thing to make it appear so. Closer examination reveals an exceedingly complicated, vague, variable, inconsistent, and fast-paced reality.(C. Nemeth & Cook, 2005) Experienced clinicians know that clinical processes may be implicit or even ad hoc – and vary with each patient.(Joseph Schulman, 2004) These realities of under-conceptualization and procedural anarchy are "hiding in plain sight."(C. Nemeth & Cook, 2005) Those who cannot recognize what is actually unfolding before them cannot understand the work as it truly is and therefore cannot create appropriately supportive cognitive tools.(C. Nemeth & Cook, 2005) What is needed to move beyond this difficulty is to apply to healthcare IT cognitive engineering methods and meticulous observation of the clinical work as it actually is – in distinction to what workers would like to imagine it is.

A perhaps contrasting view is expressed in an intriguingly titled article, "Designs are hypotheses about how artifacts shape cognition and collaboration."(Woods, 1998) The author appears to assume that software designers begin with an adequately conceptualized work reality (possibilities #1 and #3 in the above list). He makes two points. First, our tools determine how we think and work – and how we do these things with our co-workers. Secondly, an implemented design's actual performance in aiding cognition and collaboration must be explicitly tested. Of course, testing the design hypothesis requires data describing appropriate outcome variables and predictor variables. This, in turn, requires a conceptual framework for that which we wish the tool to help us with.

Are we trapped in a conundrum of determining whether the chicken or the egg comes first? Here is how one group saw their way out.

DISCOVERING HOW TO THINK ABOUT A HOSPITAL PATIENT INFORMATION SYSTEM BY STRUGGLING TO EVALUATE IT: A COMMITTEE'S JOURNAL (REPRINTED FROM SCHULMAN, KUPERMAN, KHARBANDA, & KAUSHAL, 2007. USED WITH PERMISSION)

Alice came to a fork in the road. "Which road do I take?" she asked. "Where do you want to go?" responded the Cheshire cat. "I don't know," Alice answered. "Then," said the cat, "it doesn't matter." ~Lewis Carroll, Alice in Wonderland

As organizations transition from paper to electronic media for storing and managing patient information, front-line clinicians experience disquieting feelings that may range between vague distress and profound disruption of their world. These clinicians face "dilemmas of transformation in the age of the smart machine."(Zuboff, 1988) We think it is crucial that all involved in this transformation strive for clarity in understanding how technology restructures the work situation, how a computer-based patient information system can "abstract thought from action"(Zuboff, 1988) – not only automate but also *informate* (Zuboff, 1988) – reveal activities, events, entities, ideas, and information to some degree previously opaque; and how work tasks, work flow, and tools dynamically interact.

Hospital information technology (IT) committees represent a part of an organization's strategy for crossing the chasm separating the culture of paper media and the culture of electronic media. (Healthcare Information and Management Systems Society, 2006; Shortliffe, 2005; Wyatt, 1995) These committees commonly include front-line clinicians. These individuals may have little experience with either the potential or the pitfalls of the technology over which they adjudicate, and little experience in how to critically think about the issues. To draw attention to this aspect of the unfolding transformation and contribute to the conversation about how to make sense of it, we summarize our committee's early experience.

In the Beginning, the Task Seemed So Clear

We work at a large academic hospital. Our committee is comprised of administrators, clinicians including physicians, nurses and pharmacists, and IT specialists. Our charge is to improve our inpatient clinical IT systems by determining: desirable features for our electronic patient information management system; how to minimize work disruption during system implementation; and how to evaluate the consequences of replacing the previous technology. In particular, we were asked to suggest exactly what to measure in order to determine whether the IT system is successful. At the outset, this seemed rather straightforward to many members. So at the first meeting the group quickly crafted a list of "short term goals." These included assembling an inventory of resources from which we could obtain evaluation data, planning to assess the medical error reporting system for IT related events, and conducting an IT user survey.

Stepping Back

Then one of us spoke up. "These aren't goals. They're tasks. Before deciding what to do (task), shouldn't we say exactly what we want to achieve (goal)? For example, depending on our goal, we might prefer to track trigger events (sentinel metrics (Resar, Rozich, & Classen, 2003)) instead of analyzing data from the medical error reporting system."

Several of the clinicians, understandably, conceptualized the committee work as they do their clinical work. After a patient's history, physical exam, and ancillary data are presented on rounds, they often immediately rattle off the next lab studies and images to obtain. If pressed on this issue, they say they're so accustomed to their work that in the blink of an eye they (implicitly) determine the goals those labs and images are intended to promote. However, test this assertion by asking: "If the laboratory tests and images you need – for instance, a CBC, CRP, and a chest X-ray – provide the answers you seek, then precisely what is the question these answers inform?" Some workers simply respond with a puzzled look, some will articulate a reply; but the replies tend to vary among respondents – and infrequently are they framed as questions. Rarely, someone will articulate the question the studies, the "answers," indeed inform: "What is the estimated probability my patient has condition x, given the results of these studies?" Activity without clarity of purpose may be activity without value. If the estimated probability that a patient has condition x, given confirmatory study results, does not exceed a threshold value justifying the benefits/risks of treatment, the studies, the "answers," are unnecessary. Similarly, evaluation data should only be collected if they help to answer a specific question designed to explicitly probe goal achievement.

Identification of Purpose

At our next meeting, we tried again to articulate what we wanted to accomplish over the short-term: 1) We want to identify existing data sources that can inform evaluation of our work and to understand the sources' strengths and weaknesses. 2) As a foundation for evaluation, we want to enumerate the intended consequences of the current IT implementations and discover some of the unintended consequences. Although in hindsight #1 was still quite vague and #2 essentially stated that the goal was to create a list of goals, we pressed on.

"What are we trying to achieve in the long term?" 1) We want to be able to describe the effects of our clinical interventions, including otherwise unapparent effects we would not know of without analyzing aggregated patient data. 2) We want to use the potential of IT to improve the care we provide.

This sounded pretty good. Even so, we acknowledged the imprecision by following with the question embedded in our committee's charge: "How do we define success – how will we know when we have achieved these goals?" We did not appreciate at the time, that the idea we began to grapple with might be more usefully conceived as a continuous variable, a spectrum of "doing a good job," rather than binary, success/failure. (Aarts, Doorewaard, & Berg, 2004) Nor did we appreciate the need to operationally define "doing a good job"; or that crafting this definition was at the core of our measurement task; nor the need to consider the multiple evaluative perspectives from which achievement might be framed, for example, the committee's, the clinical staff's, the IT department, the organization. We did appreciate that answering the question entailed developing evaluative criteria for our information management tool, along with evaluative criteria for our clinical performance.

We were starting to get it: identifying what we measure comes *after* developing a clear, explicitly articulated idea of what we're trying to achieve. This idea of what we're trying to achieve must do more than sound lofty and laudable. It must describe what the system is to be about at the core. Without such clarity, we'd ultimately just collect lots of data without gaining knowledge. By this formulation we recognized too, that our work was enmeshed with that of another committee charged with developing clinical performance metrics. Although we actually were back where we started, we sensed that we could now make a more informed choice about the path to take.

Broad Goals

In discussing candidate goals, members indicated that IT was important because it represented a means for reducing errors. So we scrutinized a widely accepted definition of error:

"… all those occasions in which a planned sequence of mental or physical activities fails to achieve its intended outcome, and when these failures cannot be attributed to the intervention of some chance agency."(Reason, 1990)

Clearly, we needed to achieve much more conceptual clarity and specify our ideas in greater detail. The notion of error makes no sense until we precisely identify the intended outcome, i.e. the goal of the activity.

Our deliberations also led us to Norman's (Norman, 1993) and Zuboff's (Zuboff, 1988) notion of IT as a cognitive tool – something that should make us smarter than we are without it. Therefore, taking account of the various users at our hospital, we pondered how to think about the main features this cognitive tool should offer.

Herbert Simon helped point the way:

"Solving a problem simply means representing it so as to make the solution transparent… a problem space in which the search for the solution can take place… Focus of attention is the key to success –

focusing on the particular features of the situation that are relevant to the problem, then building a problem space containing these features but omitting the irrelevant ones." (Simon, 1996)

A new candidate goal and associated evaluative criteria were revealed. Now we asked, "To what extent does our tool aid in creating a productive problem space?"

By now, most of us had completely forgotten that we initially thought the committee's charge could be straightforwardly dispatched. We understood that it was so complex we must break it up into more manageable chunks. We identified broad categories within which to articulate hospital IT goals and problems

- Business, i.e. billing and collections
- Regulatory compliance
- Reporting
- Patient documentation
- Electronic prescribing
- Decision support and other cognitive enhancements
- Referrals
- Clinical performance evaluation and quality improvement
    - ◦ Exposure-outcome relationships
- Patient registries
- Workflow and efficiency

Criteria for Measures

We were beginning to share the view that collecting data is merely the tip of the iceberg that is IT measurement. Data collection is buoyed by a body of explicit performance questions whose answers have potential to advance our purpose. Proposed measures must plausibly inform those answers by withstanding rigorous and uniform scrutiny:

- What dimension of IT use or patient care does this measure inform us about?
    - ◦ With what overarching aim does this dimension resonate? That is, if a list of explicit aims and a fine-grained process map of our entire enterprise were spread before us, precisely which aim and process component(s) does this measure enable us to associate?
        - ▪ Such measurement activity should both derive from, and test hypotheses about causal sequences
- What results do we expect, i.e. what is our hypothesis?
- How would we interpret results that might be displayed? (This entails working with fabricated, "dummy data," during planning.)
- What might we do differently once we know this thing?
- What target performance range do we seek to achieve for this measurement variable?

This interrogative framework depends on clear notions of purpose, intended outcomes. However, systems may produce surprises: unintended, undesired outcomes. How might the committee learn about unintended consequences of IT? We discovered another daunting challenge. Sometimes, we wouldn't know in advance what to look for; even worse, we might not recognize what we were looking at after it occurred. As a first step, we would measure unintended IT consequences via some type of user survey. Practical considerations required that we draw a sample from all users. Therefore, we would have to determine how to sample. Our thoughts increasingly reflected our experience: "First, we should discuss detailed, explicit aims of the survey. That way, we'll have a clearer idea of what to do. For example, if one aim is to gain insight to whether responses might be biased by user's experience with antecedent technology, we might consider including complementary "fly-on-wall" observers' reports."

Learning from Others

We considered the wide range of IT already implemented – for which corresponding goals often appeared to be implicit at best. And we considered the practical reality that committee members could devote only a small fraction of their total work time to this effort. It seemed sensible to develop ever-more fine-grained goals in conjunction with accumulating insights via learning from what others have done in these areas. That is, we would start with others' evaluative frameworks, reflect on the goals they (at least implicitly) seek to establish, and over time, refine our own concept of our goals and how we determine that we achieve them.

We drew heavily from the excellent overview of Ash, Berg, and Coiera (Ash, Berg, & Coiera, 2004) to draft an extensive conceptual framework for probing clinicians' experience using our institution's patient information management system (Box 1). The work/tool interaction section of Box 1 merits additional discussion. The content and flow of the daily work – the tasks constituting the means of achieving the (hopefully explicit) aims – reflect what is possible and practical at the time. The tools are designed to facilitate the work, and similarly reflect what is possible and practical at the time. Thus the notion of what constitutes the daily work, operationally framed, varies over time. Note that the aims of the daily work tend to be more stable than the tasks selected to achieve the aims. To illustrate, in the days of paper-based patient records, clinicians would never dream of instantly computing a patient's post-test probability of a particular disease as soon as a test result is reported. Today, this is indeed possible. Although such Bayesian computation was always consistent with the aims of clinical work, it may become part of the daily work when it is possible and practical.

Our Revelation

The essential point is that clinical work and tools are calibrated to each other. If a tool is changed, the work flow and/or fine structure it is intended to support must necessarily change. (Aarts et al., 2004) Thus, stakeholders must consider as an aspect of progress the need to recalibrate work flow and/or fine structure to new tools' capabilities; ever mindful of the aims that motivate the work. A tool achieving quick user acceptance may be one that makes little use of its technological potential and correspondingly less likely to advance the goals or justify the investment. The "aha moment" arrives with the understanding that preserving existing problem solving approaches that suppress evident potential for more effectively and/or efficiently advancing the goals is antithetical to progress. A problem space with which workers are comfortable may, when new tasks are enabled, be rendered suboptimal. Therefore, in the context of the goals of the enterprise, we define user acceptance as a result of judging not a new tool in isolation, but a new work/tool dyad. A short "test drive" yields an answer to the wrong question.

Workers long accustomed to a particular way of working may have difficulty imagining new ways made possible by tools that enable things they never dreamed of. Indeed, workers may be unaware that their early opinions about new tools reflect their imposing the specifics of the previous work/tool interaction on the present one. To further illustrate this important idea of dynamically calibrating work and tools to each other, we invited members to consider this question: "If all you had to do was ask for it, what do you wish your patient information management tool could do?"

- Serve me new and relevant information without my having to open a specific patient's record – the information system should "find me" when necessary

- Support Bayesian decision making (compute post-test disease probability)
- Enable me to access it remotely (from home)
- Configure multiple windows into one coherent display, as I deem necessary
- Optimize the problem space in relation to the nature of the problem, rather than the same configuration for every patient
- Facilitate communication among consultants
- Improve communication efficiency; minimize interactions and interruptions
    - Communicate with other involved providers from within a patient record
        - Document communication and results
    - Prevent duplication of efforts, prevent memory lapse
- Promote an explicit list of patient-specific goals for the day, articulated as part of daily patient rounds
- Support a shared to-do list among all care providers

The point of this invitation was to illuminate the way one's conceptualization of work is molded by one's notion of what is possible. The aim was to highlight contrasts: the difference between the items enumerated on a current task list and a potential ideal task list; the gap between the way tasks are done and potentially more efficient/effective alternatives enabled by technological advancement. Pondering such contrasts promotes creativity in formulating a problem space and solution. (Simon, 1996) Although the invitation was not intended to encourage user expectations with which tool builders could not keep up, some low level of discord appears desirable for stoking the flame of continual improvement.

Lessons We Learned

In conclusion, although evaluating a clinical IT implementation is a daunting challenge, it is central to managing the organization. IT evaluation should be founded upon explicit understanding of the goals of the enterprise – *necessarily the first step in the process*, appreciating the incessant work/tool interaction, and expecting that these change over time. This view thus calls for:

- Persuading the user community that their choices do not include the status quo
- Discriminating user resistance to change from suboptimal technical solutions(Rogers, 1995; J. Schulman, 2006)
- Appreciating that user acceptance need not imply a problem successfully solved(Lorenzi & Riley, 2000; J. Schulman, 2006)
- Setting realistic expectations; understanding that early iterations of a solution may produce only tolerable or promising results, i.e. it is impossible to anticipate every issue that will arise after implementation.(J. Schulman, 2006)
- Appreciating that the appropriate evaluative study design may be a matter of controversy. Randomized controlled trials, though a gold-standard for discriminating an intervention effect, are typically infeasible. Some outcomes may not even be quantifiable; however, they may be analyzed using widely accepted qualitative methods.(Stoop, Heathfield, de Mul, & Berg, 2004)
- Periodically re-thinking the boundaries and elements of the problem space

Daunting as IT evaluation may be, it is unavoidable because, as our story illustrates, it is central to healthcare. Fortunately, as we engage with the challenge we become increasingly energized. We urge others to serve on committees such as ours

Box 1. Conceptual framework for probing clinicians' experience using a patient information management system

Dimension of IT tool use: Work Flow

- Data entry
    - Do we impose perceived additional work tasks?
    - Is information displayed in a visual format that facilitates the task?
        - Fonts
        - Background color
        - Content structure
        - Data retrieval
    - Individual patients
    - Aggregates of patients
    - How soon after creation is a record available?
- Interruptions: when distracted by a competing task, do users lose track of thoughts and where they were in the record by the time they return to it or does the tool remember for them?
- System response time; down time
- Ease of system access
- Feature navigation: ease, and possibility to toggle between features
- Juxtaposition error: is a data element so close to something else on the screen that the wrong option may easily be clicked or an item read in error?
- Have users devised workarounds? That is, have users devised strategies and tactics enabling them to live with the system despite demands they deem unrealistic, inefficient, or harmful?
- To what extent does this tool promote entering information only once, but enable presenting it in varied contexts?

Dimension of IT tool use: Cognitive enhancement/impedance

- Does this tool overwhelm users (cause cognitive overload) by overemphasizing
    - Structured and "complete" information entry
    - Alerts and reminders
    - If so, please provide detailed explanation
- Does this tool cleave information that belongs together, forcing users to switch between different screens, so that users feel deprived of the overview desired?
    - If so, please provide detailed explanation
- Standard phrases
    - Are readability and information value of reports diminished by over-use of standard phrases?
        - Does the availability of these standard phrases discourage users' composing thoughts and crafting meaning?
        - As users read a narrative, is understanding sometimes confounded by uncertainty whether a sentence or clause represents thoughtful word use – a spot-on description; or merely a conveniently available selection – a more or less apropos description?
- Have others over-used cut and paste or copy and paste text manipulation?
    - Redundant information
    - Inaccurate information
- Are data provided as abstract cues, or do they contain sufficient context to establish their referential function?(Zuboff, 1988)
- Do users feel they function more as data entry workers or as knowledge workers?

continued on following page

Box 1. Continued

  - Do users feel their identity as a professional has changed by using this tool?
    - If so, how?
- To what extent does this tool draw out users' intellect in working with the data and aid their creating meaning from it?(Zuboff, 1988)

Dimension of IT tool use: Communication

- To what extent do users think that another professional reviewing their entry will grasp the essence of what they intended to communicate?
  - Do users think that "entering" their contribution to the patient record replaces their previous means of initiating and communicating their plans?
  - Have users noticed a change in the amount of direct interaction among physicians, nurses, and pharmacy?
    - If so, in what direction?
    - Is this perceived to be in their patient's and their interests?
  - Has overall reliance on the computer system as a source of answers to clinical questions increased, decreased, or stayed the same?

Dimension of IT tool use: Work/tool interaction

- Does the tool seem to
  - Speed or slow the daily work?
  - Make users feel smarter or dumber?
  - Force users to change the way they think?
    - About the patient
    - About the work
    - If so, is the change good or bad?
- What do users need that they're not getting?
- What are users getting that they don't need?
- For each of the above, exactly how has the user determined this?

because the rewards of this arduous, often frustrating, endeavor are nothing less than greater clarity about the essence of our work in healthcare, greater mastery in achieving its purpose, and a greater sense of meaning in our daily tasks.

CONCLUSION

Evaluating healthcare IT and understanding the work of healthcare are entangled processes because clinical work and associated information management tools are calibrated to each other. The point of such tools is to extend providers' cognitive abilities: promote deeper, more critical reflection, and help the user discover relevant ideas that might have been missed without the tool; all the while speeding the flow of the component tasks constituting the daily work. However, healthcare IT can aid providers in their work only to the extent that providers and IT designers understand *exactly* what the work is to achieve and by what means. Lofty and laudable-sounding goals generally are uninformative for IT design. Explicit, operationally defined goals; work tasks designed to efficiently and effectively achieve the goals;

and clear ideas of what is meant by "efficiently" and "effectively"; these are the prerequisites for evaluative thinking.

Since one's concept of work is molded by one's notion of what is possible, the work of healthcare and IT tools to facilitate it exist in a dynamic, changeable relationship. This relationship resembles the evolutionary dynamic between biological organisms and their complex and ever-changing environment. The concept of a successful organism is meaningless without a specified environmental context. As that environment changes – and indeed it continually changes – so does the evaluative framework for determining what constitutes success.

REFERENCES

Aarts, J., Doorewaard, H., & Berg, M. (2004). Understanding Implementation: The case of a computerized physician order entry system in a large Dutch university medical center. *Journal of the American Medical Informatics Association*, *11*(3), 207–216. doi:10.1197/jamia.M1372

Ash, J. S., Berg, M., & Coiera, E. (2004). Some unintended consequences of information technology in healthcare: The nature of patient care information system-related errors. *Journal of the American Medical Informatics Association*, *11*(2), 104–112. doi:10.1197/jamia.M1471

Blumenthal, D. (1994). The variation phenomenon in 1994. *The New England Journal of Medicine*, *331*(15), 1017–1018. doi:10.1056/NEJM199410133311511

Department of Health. (2002). *Delivering 21st century IT support for the NHS: National specification for integrated care records service*. Retrieved on July 26, 2004, from http://www.dh.gov.uk/assetRoot/04/07/16/76/04071676.pdf

Dick, R. S., Steen, E. B., & Detmer, D. E. (Eds.). (1997). *The computer-based patient record: An essential technology for healthcare* (revised ed.). National Academy Press.

Eddy, D. M. (2005). Evidence-based medicine: A unified approach. *Health Affairs*, *24*(1), 9–17. doi:10.1377/hlthaff.24.1.9

Guerlain, S., Hayes, C., Pritchett, A., & Smith, P. (2001). Exercises/techniques for teaching cognitive systems engineering. In *Proceedings of the Human Factors and Ergonomics Society 45th Annual Meeting*.

Healthcare Information and Management Systems Society. (2006). *A desire for change: Strong leadership required in the EMR-EHR Revolution*. Retrieved on May 23, 2007, from http://www.himss.org/content/files/davies/Davies_WP_Leadership.pdf

Jonassen, D. H. *Technology as cognitive tools: Learners as designers*. Retrieved in 2007, from http://itech1.coe.uga.edu/itforum/paper1/paper1.html

Littlejohns, P., Wyatt, J. C., & Garvician, L. (2003). Evaluating computerised health information systems: Hard lessons still to be learnt. *British Medical Journal*, *326*, 860–863. doi:10.1136/bmj.326.7394.860

Lorenzi, N. M., & Riley, R. T. (2000). Managing change: An overview. *Journal of the American Medical Informatics Association*, *7*(2), 116–124.

Nemeth, C., & Cook, R. (2005). Hiding in plain sight: What Koppel et al. tell us about healthcare IT. *Journal of Biomedical Informatics*, *38*, 262-263. doi:10.1016/j.jbi.2005.05.010

Nemeth, C. P., Cook, R. I., & Woods, D. D. (2004). The messy details: Insights from the study of technical work in healthcare. *IEEE Transactions on Systems, Man, and Cybernetics*, *34*, 689–692. doi:10.1109/TSMCA.2004.836802

Norman, D. A. (1993). *Things that make us smart*. Cambridge, MA: Perseus Books.

Reason, J. (1990). *Human error*. Cambridge, UK: Cambridge University Press.

Resar, R., Rozich, J., & Classen, D. (2003). Methodology and rationale for the measurement of harm with trigger tools. *Quality & Safety in Health Care*, *12*(6), 39–45.

Robertson, B., Elliot, L., & Washington, D. (2007, October 3). Cognitive tools. *Emerging perspectives on learning, teaching, and technology.* Retrieved on December 3, 2007, from http://projects.coe.uga.edu/epltt/index.php?title=Cognitive_Tools

Rogers, E. M. (1995). *Diffusion of innovations, fourth ed*. New York: The Free Press.

Schulman, J. (2004). *Evaluating the processes of neonatal intensive care*. London: BMJ Books.

Schulman, J. (2006). *Managing your patients' data in the neonatal and pediatric ICU: An introduction to databases and statistical analysis*. Oxford, UK: Blackwell.

Schulman, J., Kuperman, G. J., Kharbanda, A., & Kaushal, R. (2007). Discovering how to think about a hospital patient information system by struggling to evaluate it: A committee's journal. *Journal of the American Medical Informatics Association*, *14*(5), 537–541. doi:10.1197/jamia.M2436

Schulman, J., Kuperman, G. J., Kharbanda, A., & Kaushal, R. (2007). Discovering how to think about a hospital patient information system by struggling to evaluate it: A committee's journal. *Journal of the American Medical Informatics Association*, *14*(5), 537–541. doi:10.1197/jamia.M2436

Shortliffe, E. H. (2005). Strategic action in health information technology: Why the obvious has taken so long. *Health Affairs*, *24*(5), 1222–1233. doi:10.1377/hlthaff.24.5.1222

Simon, H. A. (1996). *The sciences of the artificial*. Cambridge, MA: The MIT Press.

Stoop, A., Heathfield, H., de Mul, M., & Berg, M. (2004). Evaluation of patient care information systems: theory and practice. In M. Berg, E. Coiera, H. Heathfield, et al. (Eds.), *Health information management* (pp. 206-229). London: Routledge.

The Center for the Evaluative Clinical Sciences. D. M. S. (1998). *The Dartmouth atlas of healthcare 1998*. Chicago: American Hospital Publishing.

Thompson, T. G., & Brailer, D. J. (2004). *The decade of health information technology: Delivering consumer-centric and information-rich healthcare.* Retrieved on July 23, 2004, from http://www.hhs.gov/onchit/framework/hitframework.pdf

Van Der Meijden, M. J., Tange, H. J., Troost, J., & Hasman, A. (2003). Determinents of success of inpatient clinical information systems: A literature review. *Journal of the American Medical Informatics Association*, *10*(3), 235–243. doi:10.1197/jamia.M1094

Woods, D. D. (1998). Designs are hypotheses about how artifacts shape cognition and collaboration. *Ergonomics*, *41*(2), 168–173. doi:10.1080/001401398187215

Wyatt, J. C. (1995). Hospital information management: the need for clinical leadership. *BMJ (Clinical Research Ed.)*, *311*, 175–178.

Zuboff, S. (1988). *In the age of the smart machine: The future of work and power*. New York: Basic Books.

KEY TERMS AND DEFINITIONS

Cognitive Tool: An artifact to represent and express what one knows; intended to aid human cognitive processing, to extend and facilitate what one could otherwise achieve unaided.

Electronic Information Management Technology (IT): Typically, a database software application (less sophisticated implementations occur in word-processing or spreadsheet software) running on some configuration of computer hardware

Goal, Aim, Purpose: That which one seeks to achieve via a particular work operation; a desired result.

IT Evaluation: The process of determining the degree to which an IT implementation facilitates the work of an individual or organization

Meta-Representation: The representation of the representational system – the explicit map of the portion of reality of interest. Reflection on the chosen map of reality actually tends to occur upon the meta-representation – the mental model of reality.

Patient Information Management System: A data management system that facilitates processing of patient information

Problem Isomorph: A single problem can be stated in various ways, and often therefore can be variously represented. The particular representation, or problem isomorph, can influence the difficulty of solving the problem.

Problem Space: The collection of possible information configurations and actions that may transform them, in order to advance toward a goal; i.e. the circumstances within which the search for the solution to a problem can take place.

Problem Solving: The process of moving from a starting point in the problem space to the goal.

Representational System: A map of the reality over which it is hoped the associated cognitive tool will provide greater mastery. Such a system includes both that which is to be represented and that which does the representing – symbols.

Task: One of a set of actions – specific steps in a process – contributing to achieving a goal.

This work was previously published in Handbook of Research on Advances in Health Informatics and Electronic Healthcare Applications: Global Adoption and Impact of Information Communication Technologies, edited by K. Khoumbati; Y.K. Dwivedi; A. Srivastava; B. Lal, pp. 17-32, copyright 2010 by Medical Information Science Reference (an imprint of IGI Global).

Chapter 1.12

Healthcare Information Systems and the Semantic Web

David Parry
Auckland University of Technology, New Zealand

INTRODUCTION

The World Wide Web (WWW) is a critical source of information for health care. Because of this, systems for allowing increased efficiency and effectiveness of information retrieval and discovery are critical. Increased intelligence in Web pages will allow information sharing and discovery to become vastly more efficient .The semantic Web is an umbrella term for a series of standards and technologies that will support this development.

BACKGROUND

The Web and Healthcare Information Systems

The early development of the Internet, from ARPA developments and the Internet protocol in the 1960s and 1970s to increasing use of e-mail and text-based systems, led to the development of HTTP and HTML in the 1990s (Barry et al., 1997). The Web has become a critical source of information and communication among people in all domains. The world of medicine on the Web, including such concepts as eHealth, have become areas of great academic interest (Pagliari et al., 2005). Thus, the Web and health care are increasingly co-dependent.

Finding the required information in a search of HTML documents is difficult, as HTML is really a formatting language for humans rather than for indexing. Of course, Web-based systems such as search engines or digital libraries are available, but these rely on indexing either as a set of keywords drawn from a limited vocabulary or from sometimes unreliable parsing of the document. Knowing what information a Web page contains, whether it is a medical record, a clinical result, or an academic paper, is still difficult.

DOI: 10.4018/978-1-59904-889-5.ch083

The Semantic Web

Tim Berners-Lee has coined the term “Semantic Web” (Berners-Lee, Hendler, & Lassila, 2001). This term has been enthusiastically adopted and generally includes any work intended to allow the meaning of data contained in Web resources to be made accessible to software agents or humans.

In essence, a semantic Web document is a collection of three parts:

- The document that contains the information, marked up in a suitable way
- A document that contains the rules for interpreting the markup (Namespace)
- A document that links the information with the namespace (i.e., which set of interpretation rules is being used).

There has been a great deal of work under the auspices of W3C to develop standards for the semantic Web, in particular representations using XML. Two of the major efforts are the Web ontology language (OWL) (Smith, Welty, & McGuinness, 2004) and the resource description framework (RDF). In terms of information retrieval, the semantic Web will allow a user to express what they mean to find and find objects that satisfy that request without regard to the language or syntax of the request. The semantic Web implies ways of representing the meaning of documents and constructing queries to discover that meaning. If possible, such a process will be as automatic as possible and incorporate the advances in computing power available to users on the desktop and at the server.

An example may make this system clearer. The example is taken from the W3C example page (http://www.w3.org/2000/10/rdf-tests/)

The original RDF document is:

```
<?xml version=”1.0”?>
<rdf:RDF
xmlns:a=”http://description.org/
schema/”
xmlns:rdf=”http://www.
w3.org/1999/02/22-rdf-syntax-
ns#”
xmlns:oiled=”http://img.cs.man.
ac.uk/oil/oiled#”
xmlns:xsd=”http://www.
w3.org/2001/XMLSchema#”
xmlns:rdfs=”http://www.
w3.org/2000/01/rdf-schema#”
xmlns:daml=”http://www.daml.
org/2001/03/daml+oil#”
xml:base=”file:/C:/
downloads/RDF-Model-Syntax_1.0/
ms_4.1_1.rdf”>
<rdf:Statement>
<rdf:subject
rdf:resource=”http://www.w3.org/
Home/Lassila”/>
<rdf:predicate
rdf:resource=”http://descrip-
tion.org/schema/Creator”/>
<a:attributedTo>Ralph Swick</
a:attributedTo>
<rdf:object>Ora Lassila</
rdf:object>
</rdf:Statement>
</rdf:RDF>
```

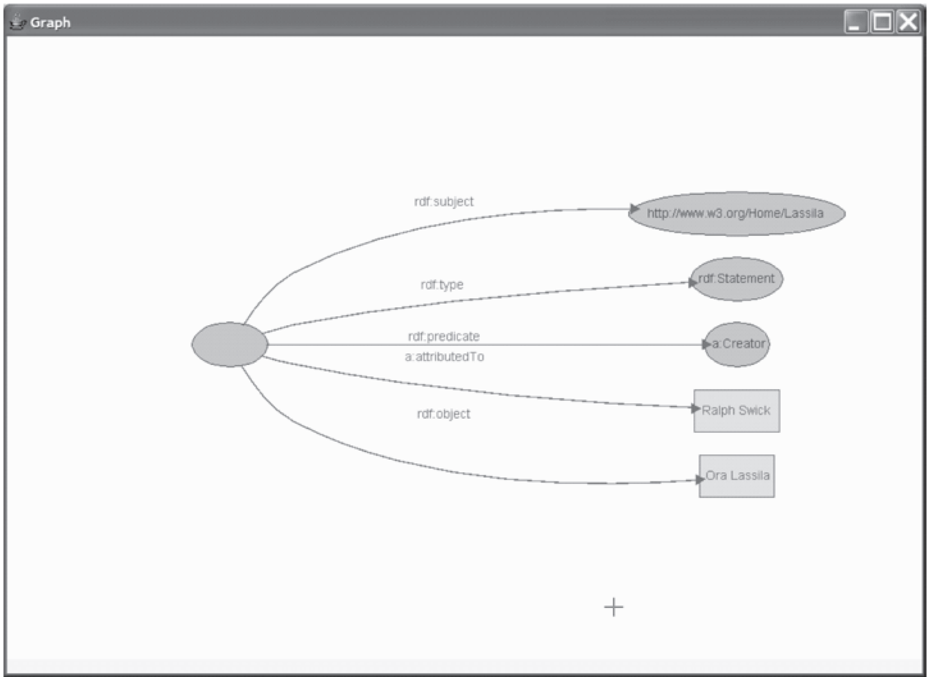
This can be displayed as shown in Figure 1.

This can be expressed in words as “Ralf Swick and Ora Lassila have the attributes of creators of RDF.”

The flexibility of this approach can be seen by the fact that the definitions of what RDF is and what “creator” means can be located in other files. Thus, agreed meanings can be used across multiple data files.

Often it may be useful to think of the meanings of items in documents as related to an ontology and that there is a standard for the expression of ontologies on the WWW. This standard—Ontology Web Language (OWL) (Smith, Welty, & McGuinness, 2004)—allows ontology relations to be coded in

Figure 1. XML document construction



a machine and human readable form within files that can be located on the WWW.

An example of an OWL statement is shown in Table 1 (the example is taken from Smith, Welty, & McGuinness, 2004.

This example shows the definition of an equivalent class—items that satisfy the conditions given in the equivalent class construction are regarded as equivalent. In this particular example, things from Texas are assigned to be “Texas things.” This project is still at a fairly early stage but obviously represents a potentially beneficial approach to standardization that may be useful for the deployment of the fuzzy ontology described later.

Table 1. OWL example

```
<owl:Class rdf:ID=”TexasThings”>
<owl:equivalentClass>
<owl:Restriction>
<owl:onProperty rdf:resource=”#locatedIn” />
<owl:someValuesFrom rdf:resource=”#TexasRegion” />
</owl:Restriction>
</owl:equivalentClass>
</owl:Class>
```

What both these approaches do is allow the page author to identify to agents or humans the intended meaning of various parts of the document. The RDF form does not need the existence of an underlying ontology, but in many cases, an ontology does exist, which makes consistent namespace creation easier. Of course, systems such as HL7 already have what are effectively namespaces, but the semantic Web approach means that the author provides the data, the possible values of the data, and the potential meaning of the data in a format that allows shared meanings. This makes the approach very powerful for semistructured information or approaches where only a subset of the information is needed.

Systems for encoding semantic information do not have to rely on XML or other general-purpose systems. An extremely general-purpose approach to adding semantic information to documents is the WorldNet approach described in Mihalcea and

Mihalcea (2001). In WorldNet, there is a number of keywords, each of which has a large potential set of attributes such as synonyms, hyponyms, related terms, and so forth, which are used for searching. Documents have their own schema that includes information about the position of e-words within the document.

HEALTH INFORMATICS AND THE SEMANTIC WEB

The use of semantically meaningful XML structures is not new in medicine. The entrez database that is used to access PubMed has a standard XML output that allows users and agents such as the entrez e-search tools to identify elements of a document record. Similar systems are available for gene and protein libraries.

The use of Semantic Web technologies for a health database is described in AnhÃ¸j, 2003. In many cases, the use of ontologies has predated the implementation of Semantic Web formulation in the medical domain. In the previous terms, the reference to namespace is implicit, as the namespace is determined by the ontology that is being used. This approach is more powerful in some respects, as extremely complex relations and workflow can be encoded into complex ontologies, but less flexible in that all the documents have to refer back to the same namespace.

Web-based ontologies can be seen as a part of implementing the Semantic Web. The Stamford medical informatics group suggest their language—PROTÉGÉ-2000 (Noy, Sintek, Decker, Crubézy, Ferguson & Musen, 2001)—as a means of representing ontologies on the Web. The central role of ontologies in knowledge management is emphasized by Staab and Maedche (2001).

A number of systems have been designed to allow communication between ontologies; for example, XOL, an ontology exchange language implemented in XML and developed from Ontolingua (Karp, Chaudhri, & Thomere, 2004). The Ontolingua server (Stanford University Knowledge Systems Laboratory, 2001) allows online collaborative editing of ontologies, and the knowledge system laboratory is also the home of a library of ontologies (e.g., the enterprise ontology and others).

The MeSH system also can be easily represented as an ontology, although in this case an object can be allowed to be a member of more than one leaf element at the lowest level. This is because a particular document can be "about" many different and closely related subjects. It is also possible to have the same leaf element incorporated in a number of different branches. This creates problems for some representation systems, and artificial distinctions have to be made between the same terms, depending on from which branch it has come.

A keyword or index term hierarchy can be seen as a particular class of ontology. At the same time, documents can be analyzed in terms of such ontologies. In this case, the attributes used to define a document are themselves divided by navigating the tree that represents possible classifiers. In the information retrieval case, it is highly likely that documents will possess many attributes, some of which may tend to place it in differing parts of the ontology. For example, a page produced by a sufferer's charity about a disease may have attributes such as brevity, low reading difficulty that indicates it would be located in a tree associated with public information, but it may have valuable links to research teams and means of getting funding that would make it suitable for researchers and located in that tree. An XML result from PubMed can be seen as an example of a Semantic Web document, where the namespace is not directly referenced but can be obtained from the publisher.

```
<?xml version="1.0"?>
<!DOCTYPE PubmedArticleSet PUB-
LIC "-//NLM//DTD PubMedArticle,
1st January 2006//EN" "http://
```

```
www.ncbi.nlm.nih.gov/entrez/que-
ry/DTD/pubmed_060101.dtd”>
<PubmedArticleSet>
<PubmedArticle>
<MedlineCitation Owner=”NLM”
Status=”MEDLINE”>
<PMID>15204612</PMID>
<DateCreated>
<Year>2004</Year>
<Month>06</Month>
<Day>18</Day>
```

Not only knowledge sources can be represented in this way. The Electronic Health Record (EHR) can use Semantic Web technologies, for example, by identifying regions that correspond to patient ID, date of birth, or diagnosis.

Current Research Projects in this Area

The National Library of Medicine (http://www.nlm.nih.gov/healthit.html) runs a number of large-scale projects in this area; in particular, the UMLS work mentioned earlier. This forms a basis for a great deal of work. Underlying the concept of a Semantic Web is that of ontology. The protégé research group at Stanford (http://protege.stanford.edu/) is continuing to develop interactive tools and ontology products.

The WWW consortium (W3C) has active programs developing and promoting OWL and RDF (http://www.w3c.org). Research in ontology development includes the use of fuzzy ontologies to better match uncertain classifications (Parry, 2004; Tho, Hui, Fong & Tru Hoang, 2006) and the development of ontologies for specific areas such as the gene ontology machine (http://www.**geneontology**.org). Applications of Semantic Web approaches to health care include drug safety (Stephens, Morales & Quinlan, 2006) and the investigation of e-health quality and reliability (Eysenbach, Lampe, Cross & Brickley, 2000). A particularly strong effort is being made to use semantically enhanced web services in the medical domain in the Artemis project (Asuman et al., 2006).

FUTURE TRENDS

The Bioinformatics community has a number of applications ready for Semantic Web approaches (Wang, Gorlitsky & Almeida, 2005). The wide variety of interfaces to the various databases in this area remains difficult, and a standardized semantic approach seems particularly likely to arrive. The latest release of HL7, version 3 (Dolin et al., 2001) is explicitly based around semantics of documents. Many applications are based around data-sharing via XML documents and Web services, and standards are emerging. Semantic standards—what a particular piece of information means—is intrinsically more complex for more sophisticated information, and it may be that hybrid approaches are used. That is, items such as name, patient number, drug therapy, and so forth are easily standardized, but more abstruse concepts such as prognosis or lesion appearance may not be so easily represented. The Semantic Web architecture will become more attractive for purely internal projects as tools for XML and RDF become more effective.

In business terms, there appears to be a role for brokers and intermediaries between systems. There are potential issues with privacy of medical data in that Semantic Web storage should be more comprehensible than proprietary formats, but health care systems always have had this problem. It seems likely that the open source movement will be particularly adept at adopting this approach, which will lead to increased use of the EHR (Middleton, Hammond, Brennan & Cooper, 2005). In terms of health knowledge and information retrieval, interoperability between systems seems the greatest possible benefit and, in particular, the development of intelligent browsers with agent technology that can vastly increase the power of search by personalizing it and putting it in context.

CONCLUSION

The Semantic Web is based around a number of fairly simple standards, but adoption of those standards in the health care domain is sometimes difficult. It is possible that Web publishers will generally adopt Semantic Web coding standards to allow their documents to be used by increasingly sophisticated agent-based systems. The vision presented in Shadbolt, Hall & Berners-Lee (2006) is attractive and is happening for particular domains. The huge bulk of Web pages that have not been revised for ease of semantic understanding seems to pose a problem. However, HTML coding was seen as difficult in 1996, so as more editors become available and the utility of Semantic Web applications becomes obvious, this may not be a vain hope. Undoubtedly, Semantic Web approaches to information publishing and sharing are likely to be a key aspect of work in health care information in the future.

REFERENCES

AnhÃ¸j, J. (2003). Generic design of Web-based clinical databases. *Journal of Medical Internet Research*, *5*(4), e27. doi:10.2196/jmir.5.4.e27

Asuman, D. (2006). Artemis: Deploying semantically enriched Web services in the healthcare domain. *Information Systems*, *31*(4), 321–339. doi:10.1016/j.is.2005.02.006

Barry, M. L. (1997). The past and future history of the Internet. *Communications of the ACM*, *40*(2), 102–108. doi:10.1145/253671.253741

Berners-Lee, T., Hendler, J., & Lassila, O. (2001, May). The semantic Web. *Scientific American*, 29–37.

Dolin, R. H. (2001). The HL7 clinical document architecture. *Journal of the American Medical Informatics Association*, *8*(6), 552–569.

Eysenbach, G, Y.G., Lampe, K., Cross, P., & Brickley, D. (2000). Quality management, certification and rating of health information on the net with MedCERTAIN: Using a medPICS/RDF/XML metadata structure for implementing eHealth ethics and creating trust globally. *Journal of Medical Internet Research, 2*(suppl2)(e1).

Karp, P., Chaudhri, V., & Thomere, J. (2004). *XOL—Ontology exchange language*. Retrieved September 1, 2002, from http://www.ai.sri.com/pkarp/xol/xol.html

Middleton, B., Hammond, W. E., Brennan, P. F., & Cooper, G. F. (2005). Accelerating U.S. EHR adoption: How to get there from here. Recommendations based on the 2004 ACMI retreat. *Journal of the American Medical Informatics Association*, *12*(1), 13–19. doi:10.1197/jamia.M1669

Mihalcea, R. F., & Mihalcea, S. I. (2001). *Word semantics for information retrieval: Moving one step closer to the semantic Web.* Proceedings of the 13th International Conference on Tools with Artificial Intelligence, Dallas, Texas.

Noy, N., Sintek, M., Decker, S., Crubézy, M., Ferguson, R., & Musen, M. (2001). Creating semantic Web contents with Protégé-2000. *IEEE Intelligent Systems*, (March/April): 60–71. doi:10.1109/5254.920601

Pagliari, C. (2005). What is eHealth (4): A scoping exercise to map the field. *Journal of Medical Internet Research*, *7*(1), e9. doi:10.2196/jmir.7.1.e9

Parry, D. (2004). Fuzzification of a standard ontology to encourage reuse. In *Proceedings of the IEEE International Conference on Information Reuse and Integration (IEEE IRI-2004)*, Las Vegas, NV.

Shadbolt, N., Hall, W., & Berners-Lee, T. (2006). The semantic Web revisited. [see also IEEE Intelligent Systems and Their Applications]. *Intelligent Systems, IEEE*, *21*(3), 96–101. doi:10.1109/MIS.2006.62

Smith, M. K., Welty, C., & McGuinness, D. L. (2004). *OWL Web ontology language guide*. Retrieved March 1, 2004, from http://www.w3.org/TR/2004/REC-owl-guide-20040210/#OntologyMapping

Staab, S., & Maedche, A. (2001). Knowledge portals: Ontologies at work. *AI Magazine*, *22*, 63–85.

Stanford University Knowledge Systems Laboratory. (2001). Ontolingua ontology editor. Retrieved January 3, 2004, from http://www-ksl-svc.stanford.edu:5915/&service=frame-editor

Stephens, S., Morales, A., & Quinlan, M. (2006). Applying semantic Web technologies to drug safety determination. *Intelligent Systems, IEEE*, *21*(1), 82–88. doi:10.1109/MIS.2006.2

Tho, Q. T., Hui, S. C., Fong, A. C. M., & Tru Hoang, C. (2006). Automatic fuzzy ontology generation for semantic Web. *Knowledge and Data Engineering . IEEE Transactions*, *18*(6), 842–856.

Wang, X., Gorlitsky, R., & Almeida, J. S. (2005). From XML to RDF: How semantic Web technologies will change the design of ‘omic’ standards. *Nature Biotechnology*, *23*(9), 1099–1103. doi:10.1038/nbt1139

KEY TERMS

Electronic Health Record: A system of storing information about a patient to assist in diagnosis and treatment.

HL7: A medical message system standard.

MeSH: Medical Subject Headings. Index terms used by NLM.

Ontology: A rigorous and exhaustive organization of some knowledge domain that is usually hierarchical and contains all the relevant entities and their relations.

Semantic: Of or relating to meaning or the study of meaning.

PubMed: Web portal to the National Library of Medicine Bibliographic Database.

W3C: The World Wide Web steering committee.

WWW: The World Wide Web. A system using data and program protocols that allow simple publishing and transfer of information.

XML: Extensible Markup Language. A standard set by W3C for documents that can include description of the meanings of items.

This work was previously published in the Encyclopedia of Healthcare Information Systems, edited by N. Wickramasinghe and E. Geisler, pp. 656-661, copyright 2008 by Medical Information Science Reference (an imprint of IGI Global).

Chapter 1.13

Ontologies in the Health Field

Michel Simonet
Laboratoire TIMC-IMAG, Institut de l'Ingénierie et de l'Information de Santé, France

Radja Messai
Laboratoire TIMC-IMAG, Institut de l'Ingénierie et de l'Information de Santé, France

Gayo Diallo
Laboratoire TIMC-IMAG, Institut de l'Ingénierie et de l'Information de Santé, France

Ana Simonet
Laboratoire TIMC-IMAG, Institut de l'Ingénierie et de l'Information de Santé, France

ABSTRACT

Health data and knowledge had been structured through medical classifications and taxonomies long before ontologies had acquired their pivot status of the Semantic Web. Although there is no consensus on a common definition of an ontology, it is necessary to understand their main features to be able to use them in a pertinent and efficient manner for data mining purposes. This chapter introduces the basic notions about ontologies, presents a survey of their use in medicine and explores some related issues: knowledge bases, terminology, and information retrieval. It also addresses the issues of ontology design, ontology representation, and the possible interaction between data mining and ontologies.

DOI: 10.4018/978-1-60566-218-3.ch002

INTRODUCTION

Ontologies have become a privileged and almost unavoidable means to represent and exploit knowledge and data. This is true in many domains, and particularly in the health field. Health data and knowledge had been structured through medical classifications and taxonomies long before ontologies had acquired their pivot status of the semantic web. In the health field, there are still more than one hundred classifications (e.g., ICD10, MeSH, SNOMED), which makes it very difficult to exploit data coded according to one or the other, or several of these classifications. The UMLS (Unified Medical Language System) initiative tries to provide a unified access to these classifications, in the absence of an ontology of the whole medical domain - still to come.

In order to apprehend the interest of ontologies in data mining, especially in the health domain, it is necessary to have a clear view of what an ontology is. Unfortunately, there is no consensus within the scientific community on a common definition of an ontology, which is somewhat paradoxical, as one of the characteristics of an ontology is to represent a consensus of a community on a given domain. However, one does not need to enter the specialists' debate on ontologies to understand their main characteristics and therefore be able to use them in a pertinent and efficient manner for data mining purposes.

On a first level, one can think of an ontology as a means to name and structure the content of a domain. Among the numerous definitions that have been given, there is some kind of agreement that an ontology represents the concepts of a domain, the relationships between these concepts (IS-A and other relationships), the vocabulary used to designate them, and their definition (informal and/or formal). The IS-A relationship plays a central role, as it provides the (tree-like) skeleton of an ontology. This structure need not be a tree, as a concept may specialize several upper concepts, contrary to a taxonomy. Compared with a thesaurus, an ontology is freed from a particular language: an ontology deals with concepts, independently from the (natural) language that is used to designate them, while a thesaurus deals with terms that are expressed in a particular language. Moreover, a thesaurus does not enable the creation of new relationships between terms, whereas ontologies do.

There is no strict boundary between taxonomies, thesauri and ontologies, and a taxonomy may be considered as a particular case of an ontology. In practice, most ontologies rely on a taxonomic skeleton which is enriched with ontology-specific features. One can also notice that the conceptual schema of a database, expressed in object form, is close to an ontology (a micro-ontology) of the application domain of the database. Therefore, most people dealing with health data have been dealing with ontologies, either explicitly or implicitly – most often implicitly. However, making explicit the notion of ontology has made it possible to formalize and unite various formalisms and practices. The current ontology standard in the web universe, namely OWL[1], might not be the final standard for ontologies, but it has initiated a movement towards the need for an agreement for such a standard.

Ontologies have their roots in Aristotle's categories, and particularly in Porphyry's tree-like representation (3rd century), which laid the foundations for modern ontologies. This tree-like structure is still present in ontologies and in most knowledge representation systems through the IS-A relationship. The attributes in object or frame-based systems and the roles in Description Logics provide the other relationships of a possibly corresponding ontology. However, the introduction of ontologies in the field of Computer Science by Gruber in the 90's was not motivated by philosophical considerations but by the need of a representation in first-order logic of knowledge-based systems in order to facilitate their interoperability (Gruber, 1991). Today's ontologies are still strongly linked to first-order logic, either through Description Logics, which constitute the main stream in the ontology domain, or through conceptual graphs, which also have a strong logic background. Ontologies have also become an unavoidable support to knowledge and data integration.

In order to provide a level of understanding of ontologies that enables the reader to comprehend their interest in data mining, we first present two examples to introduce the basic notions related to ontologies. We then make a short historical presentation of the notion of ontology, with its philosophical background and its introduction in the computer field in the 90's for knowledge sharing purposes. In the following section, we make a survey of classifications and ontologies in the medical and biological fields. We then address some issues related to ontologies: knowledge bases, terminology, information retrieval, and finally ontology building. We conclude by presenting a summary of recent and ongoing work on data mining with ontologies and mention some perspectives.

ONTOLOGY ESSENTIALS, ORIGIN AND DEFINITIONS

The basic notions necessary to approach ontologies are concepts, relations, vocabulary and definitions. We illustrate them through two examples taken from ongoing work involving ontology building and use.

Basic Concepts and Examples

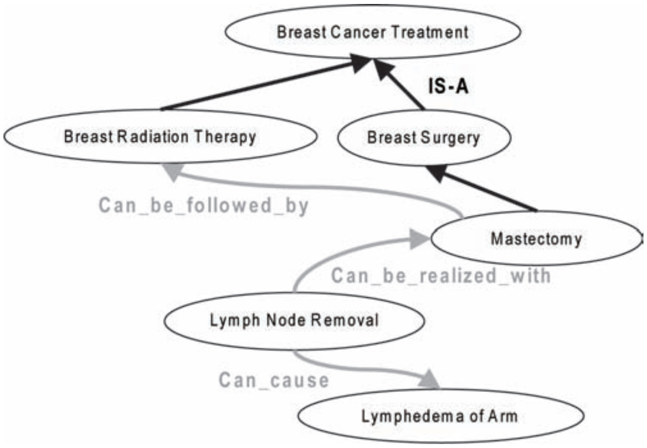
A Concept-Based Terminology in the Field of Breast Cancer

The first example introduces the notions of concept and relationships, and illustrates the terminological aspects of ontologies. Some authors consider that an ontology does not contain any vocabulary, only universals describing "reality" (Smith, 2003). Such universals, anchored in "reality", are different from concepts, which are creations of the human mind. *Absent nipple* is an example of *concept* that is found in medical classifications. According to B. Smith, such a concept is not a universal, as an absent nipple does not exist in reality but is a creation of the human mind. Universals have to be named, but this name is conventional and the various terms used to designate an ontology component (usually called a concept) should be dealt with outside the ontology. Although we understand this view, which implies considering a *terminology* associated with - but not part of - the ontology, throughout this chapter we will adopt the common view of ontologies and consider the vocabulary associated with concepts as part of an ontology.

The problem addressed by the work presented below is that of the language used in medicine by different categories of users, namely health professionals and lay people. Most health professionals recognize that patients and other lay people are not familiar with medical terms. As these terms are used in health-related documents (texts, web sites) it makes it difficult for patients, and more generally for lay people, firstly to find these documents through queries, as their *natural* language is not the language used in the documents themselves, and secondly to understand them. Moreover, much of the health-related scientific literature is in English, which increases the problem of querying the web for some; this is also true for health professionals, who are not always familiar with the English language. One solution to this problem is to create an ontology of the considered domain (ideally the whole medical domain) and to associate with its concepts the terms in the relevant languages, e.g., professional-English, lay-English, professional-French, lay-French. This is the objective of the work undertaken by R. Messai for breast cancer in her PhD work (Messai et al., 2006). The ontology fragment presented in Figure 1 shows an example of a conceptual structure. *BREAST SURGERY*, *MASTECTOMY* and *LYMPH NODE REMOVAL* are concepts. The concept *MASTECTOMY* is linked to the concept *BREAST SURGERY* by the hierarchic relation *IS_A*. This means that the concept *MASTECTOMY* is more specific than the concept *BREAST SURGERY* (conversely, the concept *BREAST SURGERY* is more generic than the concept *MASTECTOMY*). Figure 1 shows three occurrences of pairs of concepts linked by the IS_A relationship:

- BREAST RADIATION THERAPY IS_A BREAST CANCER TREATMENT
- BREAST SURGERY IS_A BREAST CANCER TREATMENT
- MASTECTOMY IS_A BREAST SURGERYand three occurrences of non-IS_A relationships:
- MASTECTOMY *Can_be_realized_ with* LYMPH NODE REMOVAL
- MASTECTOMY *Can_be_followed_by* BREAST RADIATION THERAPY

Figure 1. An example of a conceptual structure in the breast cancer field



- LYMPH NODE REMOVAL *Can_cause* LYMPHEDEMA OF ARM

The IS_A relationship provides the skeleton of the ontology (its taxonomic part), while other relationships provide information about the domain that can be exploited through logical reasoning, for example for information retrieval or question-answering purposes.

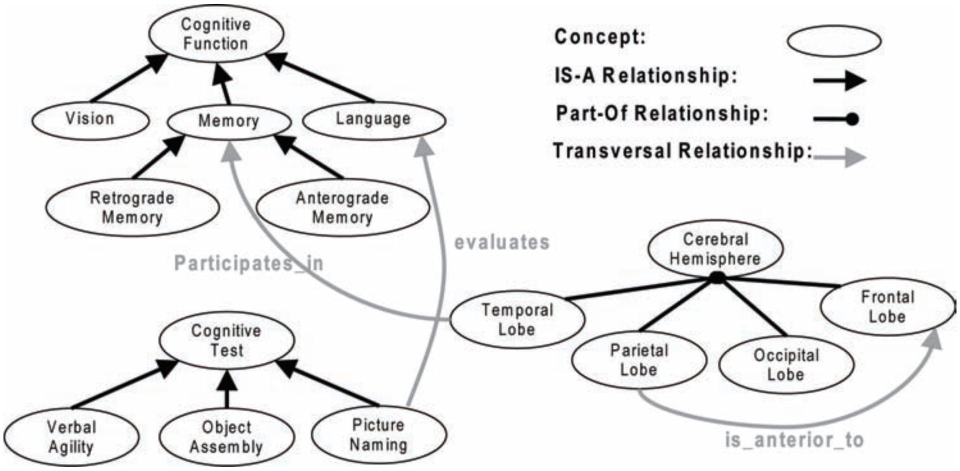
Although the concept names are in english, the concepts themselves are independent from the language, as is the ontology[2]. The name chosen to designate the concept in a given situation among several possible terms is somewhat arbitrary (for a presentation in french, french names would be chosen). Moreover, several terms can be used in the same language to designate a concept, e.G., mastectomy, mammectomy and breast removal, for the concept MASTECTOMY. These terms can be considered as synonyms and any of them could be used to designate the concept MASTECTOMY. However, it is common usage to choose a preferred term among these synonyms, in order to facilitate the communication between the different users of the ontology. In the context of the current project a preferred term has been chosen for each category of users considered: professional-English, lay-English, professional-French and lay-French. Examples of terms associated with the concepts of Figure 1 are given below (the preferred term is underlined).Lymphedema of arm:

- *Lymphedema of arm*, *arm lymphedema*, *edema of arm* (professional-English)
- *Arm swelling* (lay-English)
- *Lymphœdème du bras, œdème lymphatique du bras* (professional-French)
- *Gros bras, gonflement du bras* (lay-French)

One important objective of this ontology is to support multilingual Information Retrieval. It is established that patients' query formulation leads to poor results since most health-related information is available in English and uses a specialized medical terminology. It is likely that they will search for "heart attack" rather than "myocardial infarction", "rash" rather than "exanthema" or "hair loss" rather than "alopecia" (McCray et al., 2003). Therefore, breast cancer terminology for lay people should contain terms specific to the patients' language, such as *"breast pain"* for *"mastodynia"* and *"breast removal"* for "*mastectomy"*, but also medical terms such as *"pyrexia"*, which they can encounter.

Through an ontology with a rich terminology covering English and French, professional and lay languages in the domain of breast cancer,

Figure 2. An example of a conceptual structure in the brain field



lay people will be able to access and understand health-related data and knowledge in the breast cancer field, while using their own words and language. In order that access to web-based medical content be independent from the language and the scientific skill of the user, an ontology associated with a multilingual terminology will be used to index and query documents. Such an Information Retrieval system can also be used by health professionals, as their language has also been employed in the indexing process, through the concept-based indexing approach that is applied (see §4.3).

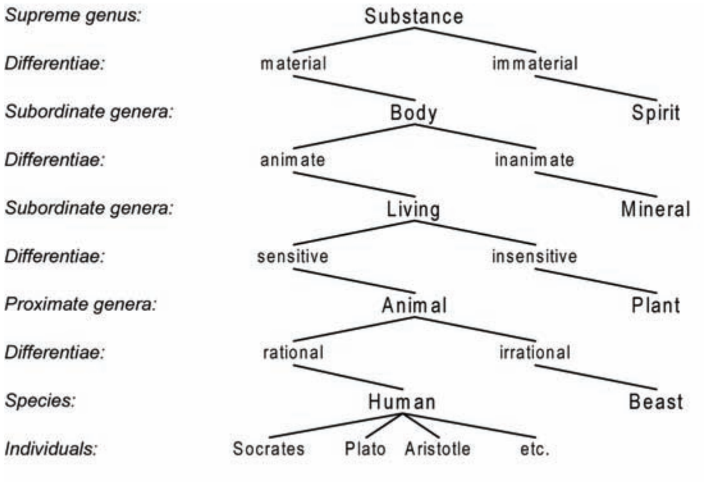
The second example is taken from a former national French project on the mining of brain data (Bonnevay et al., 2003). This project aimed at discovering relationships between brain regions and cognitive functions through the results of cognitive tests performed on patients with brain injuries. To achieve this goal, knowledge about both the anatomical and functional aspects of the brain has been formalised through an anatomical ontology, a functional ontology and an ontology of cognitive tests. The knowledge about the brain domain (a.k.a. anatomo-functional ontology) is expressed through semantic relationships between the concepts of the three ontologies. Generally speaking, a given cognitive function (e.g., *memory, language*) is evaluated by a set of cognitive tests or subtests (e.g., *verbal agility test, picture naming test*). A particular area or region of the brain participates in the execution of a given cognitive function. For example, the *temporal lobe* is involved in *memory*. Figure 2 presents an example taken from the ontology built in this project. It illustrates two basic notions of ontologies: concepts and relationships. It also shows the use of a particular relation, namely *Part_Of*, which play with the *IS-A* relationships a key role in biomedical ontologies such as the Digital Anatomist Foundational Model of Anatomy (FMA) and the Gene (GO) ontology (§3.1). The *Part_Of* relation links an entity and its components, and is intended to be transitive.

This ontology has been used to support the discovery of relationships between the cognitive function and the anatomical regions of the brain in the French national project BC3 (Brain and Health Knowledge Base) (Bonnevay et al., 2003).

Basic Notions

The two previous examples have illustrated the notions of *concepts*, *relations* and *terminology*, which can be considered as the main constituents of an ontology. The IS_A relationship, which is

Figure 3. Porphyry tree[4]



central to ontologies, provides the taxonomic skeleton of the ontology.

In the above examples, definitions were not associated with concepts. As an ontology aims at establishing a consensus within a community on a (general or specific) domain, it is necessary, during ontological engineering, i.e., the design and the building of the ontology, to provide definitions in natural language. Such definitions are often sufficient to reveal dissentions in the understanding of concepts, which often have different meanings in different groups, thus leading the group to look for a consensus.

Associating formal definitions with concepts and relationships requires the use of a formal language. First-order logic is well suited for that purpose, and was indeed used in the first formal work on ontologies, in the KIF/Ontolingua environments (Gruber, 1993). Today, Description Logics (DL), a meaningful subset of First-Order Logic, is the formalism most widely used to support formal ontological work. OWL, the current recommendation of W3C for ontology description, is based on Description Logics. The first and most well known formal work in medicine using DLs is the GALEN system (Rector et al., 1993). It uses a specific DL, namely GRAIL, whose author, I. Horrocks, is one of the designers of the OWL language.

Origins and Definitions

Aristotle's categories may be considered as the first tentative to build an ontology of what exists. It consisted in identifying and naming ten categories[3] into which any existing thing or being can be classified. These categories may seem awkward to us today but it was indeed an original and remarkable work at the time. They were provided as a flat list, but five centuries later, Porphyry (234?-305?) organized them into a tree structure and provided basic principles to differentiate child and parent nodes, as well as nodes at the same level (Figure 3).

These principles consist in identifying sets of characteristics that distinguish two close nodes. This principle is known as the differentia principle and it is the basis of contemporary approaches to ontology construction (Roche, 2003) (Troncy et al., 2002).

The Latin work *ontologia* first appeared in a text in 1613. The word "ontology" itself (in English) first appeared in a text in 1721 in *An Universal Etymological English Dictionary* by

Nathaniel Bailey: *An Account of Being in the Abstract*. It first appeared in a title of a book in 1733 (Notes on the history of ontology http://www.formalontology.it/history.htm). It referred to the philosophical usage of the term. Barry Smith, a philosopher who is now working on ontologies in the biomedical field, gives the following definition: "Ontology as a branch of philosophy is the science of what is, of the kinds and structures of the objects, properties and relations in every area of reality … In simple terms it seeks the classification of entities. Each scientific field will of course have its own preferred ontology, defined by the field's vocabulary and by the canonical formulations of its theories" (Smith, 2003).

The contemporary use of the word "ontology" in computer science and particularly in the semantic web area originates in the work of the Knowledge Systems Laboratory at Stanford in the late 80's to provide a clear and logically defined meaning of knowledge bases, and as a consequence provide a methodology to ensure their sharing and reuse (Gruber, 1991). This resulted in the KIF (Knowledge Interchange Language) language and the Ontolingua language and project (Gruber, 1993).

The first definition referred to in Computer Science comes from the above group: " an ontology defines the basic terms and relations comprising the vocabulary of a topic area as well as the rules for combining terms and relations to define extensions to the vocabulary " (Neches et al., 1991). The most generally referred to definition of an ontology is that given by Grüber: *"an ontology is an explicit specification of a conceptualization"* (Gruber, 1993).

It should be emphasized that there is currently no definition of an ontology that is agreed upon by the computer science community. A fairly complete list of the many other definitions provided since the early 90's, can be found in (Corcho et al., 2003), as well as a survey of methodologies, tools and languages for building ontologies. The question of what is a good or sound ontology remains the subject of an intense debate. Reference authors in this domain are B Smith (http://ontology.buffalo.edu/smith), N Guarino (Guarino et al., 1995) (http://www.loa-cnr.it/guarino.html). In France the work on ontology is centered on terminology (Baneyx et al., 2005), (Roche, 2005).

ONTOLOGIES IN MEDICINE

Medical Classifications

Since Linne's classification of species in 1735, there has been an explosion of the number of classifications in the biomedical field, which poses the problem of reusing data based on different classification systems. With the proliferation of computer tools, this problem has become particularly acute in data mining, where the size of the data set plays an important role; hence, the need to group sets of data from different origins, which is impossible if these data sets use different coding systems. Among the best known and most used we can cite[5]:

- **ICD** (International Statistical Classification of Diseases and Related Health Problems), has been developed by The United Nations World Health Organization (WHO) in Geneva, in collaboration with 10 international centres. It is regularly revised to reflect advances in medicine. The main focus of this classification is *"to promote international comparability in the collection, classification, processing, and presentation of mortality statistics"*[6].
- **SNOMED CT** (Systematized NOmenclature of MEDicine – Clinical Terms) is a clinical terminology. It results from a merging between SNOMED-RT (Reference Terminology) developed by the College of American Pathologists (CAP) and the England and Wales National Health Service's Clinical Terms (a UK-

based terminology for primary care previously known as the Read Codes). It was designed to give a common framework to capture and code information about a patient's history, illness and treatment. A new international organisation, the Health Terminology Standards Development Organisation (IHTSDO, also known as SNOMED SDO) acquired the ownership of SNOMED CT on 26 April 2007 and will be responsible for future maintenance and development.

- **MeSH** (Medical Subject Headings) is a medical Thesaurus used to index, catalogue and retrieve the world's medical literature, by PubMed, the NLM's interface to the MEDLINE database. There are 24,767 descriptors in the 2008 edition of the MeSH thesaurus. In addition to these headings, there are more than 172,000 headings called Supplementary Concept Records (formerly Supplementary Chemical Records) within a separate thesaurus. There are also over 97,000 entry terms that assist in finding the most appropriate MeSH Heading; for example, Vitamin C is an entry term to Ascorbic Acid[7].
- **The FMA** (Foundational Model of Anatomy) is a reference ontology in the field of anatomy. Its main focus is to represent anatomical entities, ranging from biological macromolecules to cells, tissues, organs, organ systems, and major body parts, including the entire body (Rosse, 2003). The different parts of the human body and their relationships are described in such a way that they are understandable to humans and can also be browsed, processed and interpreted by machines. The FMA currently contains around 75,000 anatomical items (concepts) and 120,000 terms.
- **GO**, the Gene Ontology, aims "to describe gene and gene product attributes in any organism". It can be broadly split into two parts. The first is the ontology itself (actually three ontologies), each representing a key concept in Molecular Biology: the molecular function of gene products; their role in multi-step biological processes; and their localization to cellular components. The ontologies are continuously updated, and the new version is made available on a monthly basis. The second part is annotation, the characterization of gene products using terms from the ontology. The members of the GO Consortium submit their data and it is publicly available through the GO website[8].

While most classifications in the biomedical field were designed to answer specific needs, FMA and GO offer a more declarative view of the domain they cover, respectively anatomy and genetics. As a consequence, they are more open to a wide variety of applications.

UMLS[9]

To try to solve the problem of the explosion of biomedical classifications, the National Library of Medicine launched in 1986 the ambitious UMLS program. UMLS stands for Unified Medical Language System and aims at providing a unique entry point for any biomedical item that can be referred to in scientific medical and biological texts or studies. To do so, a so-called meta-thesaurus has been built – and is constantly evolving – in order to cover the whole medical and biological domain. An entry in the meta-thesaurus is a concept with a unique *CUI* (Concept Unique Identifier). The number of concepts in the meta-thesaurus is constantly growing and the 2006 AA release contains 1 276 301 concepts. This size makes it very difficult to manage and it is almost impossible to guarantee the consistency of this set of concepts. The concepts of the meta-thesaurus are linked through the IS_A relationship, which is the main relation, and through other relations such as *Associated_with* and *Occurs_in*. The 2006 version contains 57 different relations. Each UMLS concept is linked to the *same* concept in other classifications. UMLS considers currently 149 classifications. Therefore, it becomes possible, through UMLS, to use data from sources using different classifications, provided that each reference to a data item in a classification is transformed into its corresponding UMLS concept and the UMLS *cui* is used in the global study.

The UMLS program is still active. However, consistency issues are becoming more and more difficult to manage, due to the constantly growing size of the metathesaurus and the poor ontological quality of the UMLS structure. Currently, the OBO initiative appears to be one of the most promising enterprises in the domain of health-related ontologies.

OBO (Open Biology Ontologies)

Data need to be integrated for a better and easier access. One way to achieve data integration is to use ontologies or other terminological resources to annotate data. The absence of a solid theoretical background in the building and the formalization of ontologies have led to a proliferation of ontologies, which itself creates obstacles to integration.

In 2001, Ashburner and Lewis initiated a strategy in order to address the question of: *"how best to represent the proteins, organisms, diseases or drug interactions that are of primary interest in biomedical research"* (Smith et al., 2007) by creating OBO (Open Biology Ontologies), an organization that aims at gathering developers of life-science ontologies. OBO has established the key-principles of sound ontology building and sharing. According to these principles, ontologies must be open and available without any constraint or restriction; they must be scalable and receptive to modification as a result of community debate; they must be orthogonal to other ontologies to facilitate the combination of different ontologies through additional relationships and modular development; they must share the same syntax to facilitate shared software implementation; and they must employ a unique identifier space to enable backward compatibility with legacy annotations as the ontologies evolve.

OBO now holds over 60 ontologies, including the GO and the FMA. It is supported by the NIH Roadmap National Center for Biomedical Ontology (NCBO) through its BioPortal. A group of OBO ontologies developers have initiated the OBO Foundry, a collaborative experiment based on the voluntary acceptance by its participants of an evolving set of principles (available at http://obofoundry.org) that extend those of the original OBO by requiring in addition that ontologies must be developed in a collaborative effort, must use common relations that are unambiguously defined, have to provide procedures for user feedback and for identifying successive versions and have a clearly bounded subject-matter.

RELATED ISSUES

Ontologies and Knowledge Bases

The development of ontologies in Computer Science is anchored in that of Knowledge Bases. In Ross Quillian's PhD thesis (1966 - unpublished), the central theme was "What sort of representational format can permit the *meanings* of words to be stored, so that humanlike use of these meanings is possible? " (Ringland et al., 1987). This sounds today almost as an objective of the Semantic Web, and ontologies appear as an answer to this question. Quillian's answer was Semantic Networks, which made an intensive use of the IS_A relationship, now at the heart of ontologies. However, there was not a clear distinction between concept and instance nodes, and the IS_A relationship could hold between concepts (MALE IS_A HUMAN) as well as between an instance and a concept (John IS_A

HUMAN). This made automatic reasoning complex, and Minsky's frames made a clear distinction between classes and instances (Minsky, 1975). The main reasoning process with frame-based systems was *instance classification*. A frame (class) is characterized by attributes (named *slots*) and by range constraints over these attributes. An instance is classified into a given frame (class), if and only if its own attribute values satisfy the range constraints of the same attribute in this frame. For example, the instance *John* with attribute *Age=40* is classified into the class ADULT as it satisfies the constraint Age>18 associated with this class.

In the same decade, the 70's, rule-based systems were developed independently. Their main function was also *instance classification* although this term was not explicitly used. Instead, their role was described as the process of deriving *conclusions* from initial values called *facts*. The experts who designed the Mycin rules, for example, clearly had in mind an underlying taxonomy, which can be guessed at through the rules (Buchanan et al., 1984). Considering the initial *facts* as the attribute values of an instance, the reasoning process supported by the Mycin set of rules can be understood as the classification of this instance in this implicit taxonomy. This was made explicit in the Centaur system, which was a re-writing of the former rule-based system Puff, replacing some rules by the corresponding taxonomy of classes, while other rules were used to calculate the value of an attribute from other attributes (Aikins, 1983).

Frame systems were much criticized because a hierarchy of frames could contradict the set inclusion property inherent to the IS_A relationship. For example, a class OSTRICH could be defined as a subclass of the class BIRD, with the class BIRD defined with the property *flies=true* and an exception *flies=false* attached to the class OSTRICH. This made sound reasoning with frames impossible and the KL-ONE language was designed to overcome this drawback (Brachman et al., 1985). Although the KL-ONE system was never fully implemented because of the complexity of the logic operations involved, it laid the foundations for Description Logics (initially called Terminological Logics). Description Logics are themselves the most widely used support today to represent formal ontologies, in particular through OWL (Ontology Web Language), which is the standard proposed by the W3C (World Wide Web Consortium) for ontology representation.

The two most important reasoning operations (also called inference) supported by Description Logics are *concept classification* and *instance classification*. Concept classification is the process of identifying the inclusion property between two concepts through their logical definition. For example, given the following two definitions:

- ADULT ≡ PERSON and Age>18
- SENIOR ≡ PERSON and Age>65

Concept classification will establish that SENIOR IS_A ADULT, which can also be read as SENIOR → ADULT, SENIOR *implies* ADULT, ADULT *subsumes*-SENIOR, or SENIOR *is subsumed by* ADULT. *Concept classification* is the discovery of the IS_A relationship (also called *subsumption*) between two concepts from their sole definition.

Instance classification can be seen as a particular case of concept classification and was dealt with in this way in the first DL systems. Given the instance defined by *John≡ PERSON and Age=40*, considering it as a concept (the concept *JOHN* with the single instance *John*) would establish that *JOHN is subsumed by* ADULT. This is instance classification (the classification of the instance *John* into the class ADULT).

However, implementing instance classification through the concept classification process was too expensive, as concept classification is a complex operation, while instance classification can be implemented in a simpler and more efficient manner. Current DL systems distinguish the two operations, as does RACER, one of the most widely used reasoners associated with the implementation of the OWL language in the Protégé environment.

Consistency checking of a set of concepts in a DL is also a side effect of concept classification. If a concept is subsumed by no other concept, either it is a concept at the top of a hierarchy, or its definition is inconsistent (he cannot have a parent concept, due to an inconsistent definition).

Within the Noesis project (www.noesis-eu.org) we have implemented a subset of the MeSH thesaurus in OWL. Although the MeSH thesaurus cannot claim an ontology status, implementing it in OWL and applying the concept classification scheme made possible the discovery of a cycle in the taxonomy of concepts in the first version of the 2007 MeSH. This cycle has been removed in the following version.

One can see the advantages of a formal definition of an ontology, for example through a DL formalism. Non-explicit IS_A relationships between concepts can be discovered automatically, and the whole set of concepts can be checked for consistency. However, implementing an ontology in a formal language can be a difficult task, especially for large ontologies. This was done in the Galen project (Rector et al., 1993) for a subset of the medical field, using the GRAIL DL. The OWL language now offers the possibility of choosing three degrees of complexity in the description of an ontology, by proposing three sublanguages:

- **OWL lite**, which is syntactically simple and adapted to the description of simple hierarchies with simple constraints.
- **OWL DL**, based on Description Logics, which enables automated reasoning and checking for inconsistencies.
- **OWL Full**, which is highly expressive but which cannot guarantee decidability.

Ontology and Terminology

Terminologies focus on *words* and their relationships; where the main relationships are hyperonymy and its inverse, hyponymy. Ontologies focus on *concepts* and their relationships. Concepts are mainly organized through the *subsumption* (or IS_A) relationship, which corresponds to the hyperonymy/hyponymy relationships in terminologies and in thesauri. It organizes concepts by abstracting common characteristics, leading to a hierarchy of concepts corresponding to a taxonomic organization of objects (Roche, 2005). Moreover, ontologies offer the possibility to create new relationships, thus increasing their expressive power.

Ontologies and terminologies are used for the main purpose of providing a shared conceptualization of a specific part of the world to a community of users, aiming to facilitate knowledge communication. Gamper provides four criteria to distinguish the two notions (Gamper et al., 1999):

- **The formal framework of their definition:** The science of Terminology uses the plain text in the natural language to define the meaning of terms. The correct interpretation of the intended meaning depends on the user. Ontologies explicitly specify the conceptual knowledge by the use of a formal language with a clear semantic, which avoids ambiguous interpretation of terms;
- **Computational support:** The available tools differ for the two disciplines: most currently used terminologies provide little or no semantics for both an explicit representation of knowledge and for data maintenance. While for ontologies, through the use of formal representation language, e.g., Description Logics (Nardi and Brachman, 2003), it is possible to check their consistency, and to infer new knowledge.
- **Users:** terminologies are human user-oriented (translators and domain experts are

their primary users). Ontologies are mainly developed for knowledge sharing between agents (human and machines);

- **Natural language usage:** The terminology focuses on knowledge transfer as a linguistic activity, i.e., natural language exploration in order to identify all terms used by people to talk about underlying concepts, whereas ontologies are intended mainly for computational use and can often ignore the importance of naming concepts with "understandable" terms (e.g., UMLS CUI)

In France, the ontology work is much anchored in terminology (Rousselo et al., 2002) (Roche, 2005).

Ontologies and Information Retrieval

Traditional information retrieval systems mostly rely on keyword-based search. They only take into account the co-occurrence of words to represent the documents and the query. However, a relevant document does not always contain the same words as the query. One of the promising solutions to this problem is the use of an external semantic resource in the information retrieval process. Such systems are characterized by the notion of a conceptual space in which documents and queries are represented, in opposition to the word space found in traditional models (Baeza-Yates et al., 99). Since the end of the nineties, ontologies offer this conceptual space upon which these systems depend to retrieve a part of the semantics of both documents and queries.

The identification of concepts in a document (concept mapping) is not an easy task. Moreover, one of the limitations of this approach is that the quality of the search depends on the coverage of the ontology. In order to support concept-based Information Retrieval, an ontology should contain all the terms that can be found in the documents searched for, and also the terms and the expressions used in the queries by people searching these documents.

Using the ontology of breast cancer presented in §2.1.1 to index documents and to interpret queries, any of the terms associated with the concept LYMPHEDEMA OF ARM would be equivalent in a user query. For instance, asking for *lymphedema of arm*, *arm lymphedema*, *edema of arm, arm edema, arm swelling, lymphœdème du bras, œdème lymphatique du bras, gros bras, gonflement du bras* would result in the same set of documents.

In the Noesis project, where objectives included concept-based Information Retrieval and annotation, a significant effort was made for the enrichment of the vocabulary of the concept-based terminology[10] that was used, in order to ensure a good coverage of texts to be indexed by this terminology (Simonet et al., 2006).

Ontology Design

Ontology building is not an easy task and one of the major bottlenecks in developing bio-ontologies is the lack of a unified methodology. Different methodologies have been proposed for different scenarios, but there is no agreed-upon standard methodology for building ontologies, contrary to the database domain, for example, with the Entity-Relationship Model. The building process usually involves domain experts to reflect current knowledge about the concerned domain.

Projects about ontology building started in the early 90's. In 1995, Ushold and King proposed a method to build an ontology from scratch (Ushold et al., 1995), which comprises four steps: identify the purpose, build the ontology by the identification of the key concepts and relationships in the domain of interest, evaluate it, and document it.

Literature scanning for deciding on the basic concepts and relationships to insert in the ontology may be useful to help building an ontology. However, since building an ontology from a huge amount of literature data is a difficult and time-consuming task, a number of tools such as

TextToOnto (Maedche, 2004) and its successor Text2Onto (Cimiano, 2005), TERMINAE (Biebow et al., 1999), the ASIUM system (Faure, 1998), Ontologos (Roche, 2003) OntoLearn (Velardi, 2005) or OntoLT (Buitelaar, 2003) have been developed in order to support the user in constructing ontologies from a given set of (textual) data. The common element to these frameworks is the use of natural language processing for providing features to be used to learn ontological structures. For instance, OntoLT is an ontology learning plug-in for the Protégé ontology editor which basically makes use of the internal structure of noun phrases to derive ontological knowledge from texts. The OntoLearn framework (Velardi et al., 2005) mainly focuses on the problem of word sense disambiguation, i.e., finding the correct sense of a word with respect to a general ontology or lexical database. TextToOnto and Text2Onto are frameworks implementing a variety of algorithms for diverse ontology learning subtasks: relevance measures for term extraction, algorithms for taxonomy construction as well as techniques for learning relations between concepts. Text2Onto also takes into account the fact that the document collection can change and thus avoids starting the whole learning process from scratch every time a change occurs (Cimiano, 2005). TERMINAE is a tool that integrates the design and editing steps. It brings together both Natural Language Processing (NLP) Tools and Knowledge Engineering tools. NLP tools support the extraction of all the occurrences of the different terms, and the definition of the different meanings, called notions, of each term. Knowledge engineering tools associate concepts with terms and insert them into the ontology.

Ontology Representation

Several languages, based on the XML syntax, have been developed for the use of ontologies within the Semantic Web infrastructure. The most representative are RDF/RDFS, the W3C recommendation for metadata representation, OIL, DAML+OIL and now OWL which is the W3C recommendation for ontology representation.

SKOS is an area of work developing specifications and standards to support the use of knowledge organization systems (KOS) such as thesauri, classification schemes, subject heading systems and taxonomies within the framework of the Semantic Web. SKOS provides a standard way to represent knowledge organization systems using RDF, which allows it to be passed between computer applications in an interoperable way. The SKOS specifications are currently published as W3C Working Drafts but they will soon become a W3C recommendation. In the Noesis project, the OWL representation of the MeSH thesaurus also used SKOS elements that were necessary to represent multilingual aspects of the associated vocabulary (e.g., choose a preferred term for each language), which could not be easily achieved in pure OWL.

The Protégé environment is the most used ontology editor. However, its poor user-friendliness has led the OBO group to design their own ontology editor and format, better suited for use by non-IT people.

Although they are currently less in fashion than Description Logics, Conceptual Graphs offer a graphical representation formalism to implement ontologies (Sowa: Building, sharing and merging ontologies, http://www.jfsowa.com/ontology/ontoshar.htm).

DATA MINING AND ONTOLOGIES

The interaction between data mining and ontologies can be considered in two ways:

1. The use of ontologies in data mining processes, either to include domain knowledge in the input information or to represent the results.

2. The use of data mining techniques to build ontologies.

In both cases, it is mainly text mining that is concerned. Text mining aims to extract useful knowledge from textual data or documents (Chen, 2001) (Hearst, 1999). In the biomedical domain, this process is very useful since the huge and rapidly increasing volume of scientific literature makes finding relevant information increasingly difficult. For example, the identification of relationships among different biological entities, e.g., genes, proteins, diseases, drugs and chemicals, etc, is an important concern for biological researchers. While such information can be extracted from different types of biological data (e.g., gene and protein sequences, protein structures), a significant source of such knowledge is the biological textual research literature which is increasingly being made available as large-scale public-domain electronic databases (e.g., the Medline database). Automated extraction of such relationships (e.g., gene A *inhibits* protein B) from textual data can significantly enhance biological research productivity in several ways: by keeping researchers up-to-date with the state-of-the-art in their research domain, by helping them visualize biological pathways, and by generating likely new hypotheses concerning novel interactions, some of which may be good candidates for further biological research and validation (Palakal et al., 2005).

Examples of text mining applications include document classification, document clustering, concept extraction, information extraction and summarization. Using an ontology for document clustering has several advantages: it is possible to cluster documents written in several languages since concepts are *language-independent* and the use of concepts helps reduce the size of data, which, in turn, reduces processing time (Pham et al., 2007). Ontologies also offer a natural support to the extraction of semantic relations between entities. For example, the Genescene system utilizes an ontology-based approach to relation extraction by integrating the Gene Ontology, the Human Genome Nomenclature, and the UMLS (Leroy and Chen, 2005).

Ontologies offer a natural support to data mining in that they provide semantically sound classes to collect and organize data. One important principle behind the use of ontologies to represent the input data in data mining processes is that, by increasing the conceptual level of input data, one can also expect to obtain results at a higher conceptual level. This has been demonstrated in several papers. (Hotho et al., 2003) have shown that using ontologies as filters in term selection, prior to the application of the K-means clustering algorithm, increases the tightness and relative isolation of document clusters as a measure of improvement. Other examples can be found in a new book on data mining with ontologies that presents recent and ongoing research and industrial work in this domain (Nigro et al., 2007).

Text mining is also used in the construction and enrichment of ontologies (Mothe et al., 2007). The statistical analysis of texts of a domain may help exhibit clusters of terms that are candidate concepts for this domain (Karoui et al., 2006), and the discovery of relationships between such clusters of terms can evoke possible relationships between concepts. Although much work is done on the automation of ontology construction (Cimiano et al., 2005), the use of knowledge discovery in texts may help the ontology designer to identify concepts and structure them through IS_A and other relationships, in a semi-automatic way. Ontologos and Terminae are examples of such systems that use linguistic techniques to support the building of ontologies (Roche, 2003) (Biebow et al., 1999).

CONCLUSION

In this chapter, we have provided an overview of ontologies with the objective of helping people involved in Data Mining in the biological field to apprehend the possible contribution of ontologies to their discipline. We did not answer explicitly the question “What is an ontology” and this question is still open to debate. An ontology of ontologies would be needed to organize the various points of view on this question. The same problem arises concerning the term Knowledge Base, and the two notions are strongly related. We have shed some light on some aspects of ontologies that seem important to us. Some of these aspects would justify further developments and we have tried to provide references to major publications in the relevant fields.

Integration aspects are of vital importance in data mining as data from various sources can be used in the input data set. The principle of using an ontology to unify input data from different sources via the concepts of this ontology now appears obvious. However, its implementation with real and heterogeneous databases is not so simple and constitutes the matter of active research and technical work (Lenzerini, 2002). Database integration requires establishing mappings between the schemas of the constituent databases or between these schemas and a global schema built for that purpose and which reflects the conceptual structure of the ontology. Such mappings can be represented as SQL views but recent approaches use Description Logics to implement an ontology-based representation of them (Dejing et al., 2006). We can also note that integrating database schemas is a problem similar to that of integrating different ontologies on the same domain; this problem is known as ontology alignment (Euzenat et al., 2004).

Data mining aims at extracting knowledge from data, thus creating *a posteriori* knowledge, whereas ontologies provide *a priori* knowledge that can be used in the data mining process, as well at its start by providing semantically sound classes to collect and organize data, as at its end to represent the results. One key of the success of ontologies in many domains, including the biomedical field, is that they provide semantics of domain knowledge in a human as well as in a computer-readable form. Data mining techniques can also be used to help building ontologies from texts. Note that some concept-based terminology, e.g., wordnet, which is sometimes (improperly) considered as an ontology, could be used to process the input data by replacing words by low-level concepts of this ontology in the texts to be analyzed. This ontology represents *a priori* knowledge, while the ontology obtained through text mining constitutes *a posteriori* knowledge, and one expects the resulting ontology to provide a description of the domain at a higher conceptual level than the initial one.

We conclude by quoting the editors of a recent book, Data Mining with Ontologies (Nigro et al., 2007) where they recall that: “One of the most important and challenging problems in data mining is the definition of the prior knowledge: this can be originated from the process or the domain. This contextual information may help select the appropriate information, features or techniques, decrease the space of hypothesis, represent the output in a most comprehensible way and improve the whole process. Therefore we need a conceptual model to help represent this knowledge … As a result, ontological foundation is a precondition for efficient automated usage of knowledge discovery information”.

REFERENCES

Aikins, J. S. (1983). Prototypal Knowledge in Expert Systems. *Artificial Intelligence*, *20*(2), 163–210. doi:10.1016/0004-3702(83)90017-6

Baeza-Yates, R. A., & Ribeiro-Neto, B. A. (1999). *Modern Information Retrieval*. ACM Press / Addison-Wesley.

Baneyx, A., Malaisé, V., Charlet, J., Zweigenbaum, P., & Bachimont, B. Synergie entre analyse distributionnelle et patrons lexico-syntaxiques pour la construction d’ontologies différentielles. *In Actes Conférence TIA-2005* (pp. 31-42). Rouen.

Biebow, B., & Szulman, S. (1999). Terminae: A linguistic-based tool for the building of a domain ontology. *In proceedings of the 11th European Workshop, Knowledge Acquisition, Modeling and Management (EKAW' 99)* (pp. 49-66). Dagstuhl Castle, Germany.

Bonnevay, S., & Lamure, M. (2003). Bases de connaissances anatomo-fonctionnelles: application au cerveau et au cœur. [Hermès.]. *Santé et Systémique*, *7*(3), 47–75.

Brachman, R. J., & Schmolze, J. G. (1985). An overview of the KL-ONE knowledge representation system. *Cognitive Science*, *9*(2), 171–216.

Buchanan, B. G., & Shortliffe, E. H. (Eds.). (1984). *Rule-Based Expert Systems: The MYCIN Experiments of the Stanford Heuristic Programming Project.* Reading, MA: Addison-Wesley

Buitelaar, P., Olejnik, D., & Sintek, M. (2003). OntoLT: A protégé plug-in for ontology extraction from text. *In Proceedings of the International Semantic Web Conference (ISWC)*.

Chen, H. (2001). *Knowledge Management Systems: A Text Mining Perspective*. Tucson, AZ: The University of Arizona.

Cimiano, P., & Vorlker, J. (2005). Text2Onto – A Framework for Ontology Learning and Data-driven Change Discovery. In Andres Montoyo, Rafael Munoz, Elisabeth Metais (Ed.), *the 10th International Conference on Applications of Natural Language to Information Systems (NLDB), Lecture Notes in Computer Science. Springer: 3513.* (pp. 227-238). Alicante, Spain.

Corcho, O., Lopez, M. F., & Perez, A. G. (2003). Methodologies, tools and languages for building ontologies. Where is their meeting point? *Data & Knowledge Engineering*, *46*(1), 41–64. doi:10.1016/S0169-023X(02)00195-7

Dejing, D., & Paea, L. (2006). Ontology-based Integration for Relational Databases. *In Proceedings of the 2006 ACM symposium on Applied computing* (pp. 461-466). Dijon, France.

Euzenat, J., Barrasa, J., Bouquet, P., Bo, J. D., et al. (2004). State of the Art on Ontology Alignment. *Knowledge Web, Statistical Research Division, Room 3000-4, Bureau of the Census, Washington, DC, 20233-9100 USA,* deliverable 2.2.3.

Faure, D., & Nedellec, C. (1998). A corpus-based conceptual clustering method for verb frames and ontology. *In Proceedings of the LREC Workshop on Adapting lexical and corpus resources to sublanguages and applications*.

Gamper, J., Nejdl, W., & Wolpers, M. (1999). Combining ontologies and terminologies in information systems. *In Proc. 5th International Congress on Terminology and knowledge Engineering.* Innsbruck, Austria.

Gruber, T. R. (1991). The Role of Common Ontology in Achieving Sharable, Reusable Knowledge Base. In J. Allen, Fikes and E. Sandewall, Eds. *Principles of knowledge representations and reasoning,* Cambridge, MA, Morgan Kaufmann.

Gruber, T. R. (1993). A translation approach to portable ontology specification. *Knowledge Acquisition,* 5(2), Special issue: Current issues in knowledge modeling, 199-220.

Guarino, N., Carrara, M., & Giaretta, P. (1995). Ontologies and knowledge bases: towards a terminological clarification. In N. Mars (Ed.), *Towards Very Large Knowledge Bases, Knowledge Building and Knowledge Sharing* (pp. 25-32). IOS Press, Amsterdam.

Hearst, M. A. (1999). Untangling Text Data Mining. In Proceedings of ACL'99: *the 37th Annual Meeting of the Association for Computational Linguistics* (pp. 20-26). Maryland.

Hotho, A., Staab, S., & Stumme, G. (2003). Ontologies improve text document clustering. *In Proceedings of the 3rd IEEE conference on Data Mining* (pp. 541-544). Melbourne, FL.

Karoui, L., Aufaure, M. A., & Bennacer, N. (2006). Context-based Hierarchical Clustering for the Ontology Learning. *The 2006 IEEE/WIC/ACM International Conference on Web Intelligence (WI-06) jointly with the 2006 IEEE/WIC/ACM International Conference on Data Mining (ICDM-06)* (pp. 420-427). Hong-Kong.

Maedche, A., & Staab, S. (2004). Ontology learning. In S. Staab and R. Studer (Ed.), *Handbook on Ontologies* (pp. 173-189). Springer.

McCray, A. T., & Tse, T. (2003). Understanding search failures in consumer health information systems. *Proc AMIA Symp* (pp. 430-434).

Messai, R., Zeng, Q., Mousseau, M., & Simonet, M. (2006). Building a Bilingual French-English Patient-Oriented Terminology for Breast Cancer. *In proceedings of MedNet 2006, Internet and Medicine.* Toronto, Canada.

Minsky, M. (1975). A Framework for Representing Knowledge. In The Psychology of Computer Vision (Ed.), *P.H. Winston, McGraw-Hill* (pp. 211-277). New York.

Mothe, J., & Hernandez, N. (2007). TtoO: Mining thesaurus and texts to build and update a domain ontology. In H. O. Nigro, S. G. Císaro, and D.Xodo. Idea Group Inc (Ed.), *Data Mining with Ontologies: Implementations, Findings, and Frameworks*.

Nardi, D., & Brachman, R. J. (2003). An introduction to description logics. In F. Baader, D. Calvanese, D.L. McGuinness, D. Nardi, P.F. Patel-Schneider (Ed.), *the Description Logic Handbook* (pp. 5-44). Cambridge University Press.

Neches, R., Fikes, R. E., Finin, T., Gruber, T. R., Senator, T., & Swartout, T. (1991). Enabling technology for knowledge sharing. *AI Magazine*, *12*(3), 36–56.

Nigro, H. O., Gonzalez Cisaro, S. E., & Xodo, D. H. (Eds.). (2007). *Data Mining with ontologies – Implementations, findings and frameworks.* Information Science Reference, IGI Gobal.

Palakal, M., Mukhopadhyay, S., & Stephens, M. (2005). Identification of Biological Relationships from Text Documents. *Book Series: Integrated Series In Information Systems. Book: Medical Informatics*, *8*, 449–489. doi:10.1007/0-387-25739-X_16

Pham, M. H., Bernhard, D., Diallo, G., Messai, R., & Simonet, M. (2007). SOM-based Clustering of Multilingual Documents Using an Ontology. In H. O. Nigro, S. G. Císaro, and D.Xodo. Idea Group Inc (Ed.), *Data Mining with Ontologies: Implementations, Findings, and Frameworks*.

Rector, A. L., & Nowlan, W. A. (1993). The GALEN Project. *Computer Methods and Programs in Biomedicine*, *45*, 75–78. doi:10.1016/0169-2607(94)90020-5

Ringland, G. A., & Duce, D. A. (1987). *Approaches in Knowledge Representation: An Introduction*. John Wiley& Sons.

Roche, C. (2003). *The Differentia Principle: a Cornerstone for Ontology.* Knowledge Management and Philosophy Workshop in WM 2003 Conference, Luzern.

Roche, C. (2005). Terminologie et ontologie. *LAROUSSE – Revue, 157*, 1-11.

Rosse, C., & Mejino, J. L. V. (2003). Reference ontology for bioinformatics: the Foundational Model of Anatomy. *Journal of Biomedical Informatics*, *36*(6), 478–500. doi:10.1016/j.jbi.2003.11.007

Simonet, M., Patriarche, R., Bernhard, D., Diallo, G., Ferriol, S., & Palmer, P. (2006). Multilingual Ontology Enrichment for Semantic Annotation and Retrieval of Medical Information. *MEDNET'2006*, Toronto - Canada.

Smith, B. (2003). Ontology. Chapter in L. Floridi (ed.), *Blackwell Guide to the Philosophy of Computing and Information* (pp. 155-166). Oxford, Blackwell.

Smith, B., Ashburner, M., Rosse, C., Bard, J., Bug, W., & Ceusters, W. (2007). The OBO Foundry: coordinated evolution of ontologies to support biomedical data integration. *Nature Biotechnology*, *25*(11), 1251–1255. doi:10.1038/nbt1346

Troncy, R., & Isaac, A. (2002). DOE: une mise en œuvre d'une méthode de structuration différentielle pour les ontologies. *In Actes 13e journées francophones sur Ingénierie des Connaissances (IC)* (pp. 63-74).

Uschold, M., & Jasper, R. (1999). A Framework for Understanding and Classifying Ontology Applications. *In: Proc.IJCAI99 Workshop on Ontologies and Problem-Solving Methods*. Stockholm.

Uschold, M., & King, M. (1995). *Towards a methodology for building ontologies*. Workshop on Basic Ontological Issues in Knowledge Sharing, held in conduction with IJCAI-95.

Velardi, P., Navigli, R., Cuchiarelli, A., & Neri, F. (2005). Evaluation of Ontolearn, a methodology for automatic population of domain ontologies. In P. Buitelaar, P. Cimiano, and B. Magnini (Eds), *Ontology Learning from Text: Methods, Applications and Evaluation*. IOS Press.

KEY TERMS

Data Mining: Data mining, also referred to as knowledge discovery in databases (KDD), is a process of finding new, interesting, previously unknown, potentially useful, and ultimately understandable patterns from very large volumes of data (Nigro et al., 2007)

Information Retrieval: Information Retrieval (IR) is concerned with the indexing and retrieval of information in documents. Although any kind of document can be indexed and searched for, IR has been first and mainly applied to texts. Active research is currently devoted to content-based indexing of other types of documents such as images, videos and audio content. Automatic indexing of texts relies on a thesaurus. Contemporary IR tends to use ontologies associated with multilingual terminologies in order to make the search less language-dependent (e.g., English documents can be returned for queries posed in French, provided they refer to the same concept).

Knowledge Base: The term "Knowledge Base" was first used in the seventies to designate a set of expert rules to be processed by an "inference engine" along with the " facts " that represent the current situation that the (expert) system is to identify though the chaining of expert rules. In modern systems, starting with frame-based systems, this operation is known as *instance classification*. The most recent KB systems, based upon Description Logics, also consider *concept classification*, which consists in ordering concepts through the subsumption (inclusion) relation.

Medical Classification: Medical classifications provide the terminology of the medical domain (or a part of it). There are more than 100 medical classifications currently in use, most of them being specific of a subdomain (e.g., brain) or oriented towards a specific usage (e.g., MeSH for bibliographical indexing).

Ontology: An ontology is a structured description of a domain under the form of concepts and relations between these concepts. The IS-A relationship provides a taxonomic skeleton while other relations reflect the semantics of the domain. Definitions (either formal or informal) can be associated with concepts, as well as terminological variants, possibly in different languages. Usual definitions are: "An ontology is a specification of conceptualization" (Gruber) and "An ontology describes the concepts and relationships that can exist and formalizes the terminology in a domain" (Gruninger & Lee)

Terminology: Terminology deals with terms definition and usage, in general or in a specific context (e.g., medical terminology). According to authors, the definition of terminology vary from the study of terms to the actual sets of terms of a domain, possibly structured, which brings terminological work near to ontological work. This closeness is illustrated by the neologism "ontoterminology" which has been proposed by C. Roche at the TOTh conference in 2007.

ENDNOTES

[1] The Ontology Web Language: http://www.w3.org/2004/OWL/

[2] This is not strictly true, as there are concepts that exist only in some culture and in a given language. However, in the scientific domain such an approximation is usually considered as valid.

[3] Aristotle's categories: substance, quantity, quality, relation, place, time, position, state, action and affection.

[4] http://faculty.washington.edu/smcohen/433/PorphyryTree.html accessed on April 14th, 2008

[5] http://www.openclinical.org/medicalterminologiesLst.html

[6] Colorado Department of Public Health and Environment. New International Classification of Diseases (ICD-10): the history and impact. Brief. Mar 2001; no.41.

[7] http://www.nlm.nih.gov/pubs/factsheets/mesh.html

[8] http://en.wikipedia.org/wiki/Gene_Ontology

[9] The Unified Medical Language System. http://umlsks.nlm.nih.gov

[10] In the course of the NOESIS project it was improperly called an ontology. Although it was represented in OWL, its structure was strictly that of the MeSH thesaurus.

This work was previously published in Data Mining and Medical Knowledge Management: Cases and Applications, edited by P. Berka, J. Rauch, and D. A. Zighed , pp. 37-56, copyright 2009 by Medical Information Science Reference (an imprint of IGI Global).

Chapter 1.14

Quality of Health Information on the Internet

Kleopatra Alamantariotou
City University London, UK

ABSTRACT

Recent statistics show that the World Wide Web has now grown to over 100 million sites: a phenomenal expansion in only 15 years (Mulligan 2007). It has been estimated that there are 100,000 sites offering health related information (Wilson 2002). As the amount of health information increases, the public find it increasingly difficult to decide what to accept and what to reject (Burgess 2007). Searching for information on the internet is both deceptively easy and the same time frustratingly difficult (Kiley 2002). The challenge for consumers is to find high quality, relevant information as quickly as possible. There has been ongoing debate about the quality of information aimed at patients and the general public and opinions differ on how it can be improved (Stepperd 1999). The purpose of this chapter is to provide a brief overview of the different perspectives on information quality and to review the main criteria for assessing the quality of health information on the internet. Pointers are provided to enable both clinicians and patients find high quality information sources. An understanding of these issues should help health professionals and patients to make effective use of the internet. .

DOI: 10.4018/978-1-60566-002-8.ch031

INTRODUCTION

> *Health information includes information for staying healthy, preventing and managing disease, and making other decisions related to health and health care. It includes information for making decisions about health products and health services. It may be in the form of data, text, audio, and/or video.* (Dzenowagis 2001)

The Internet provides a powerful tool for patients seeking medical information. It offers consumers access to a wealth of health and medical information that can enable them to take responsibility for their own health (Linkous 1999). Information is the communication or reception of knowledge. Such communication occurs in great part through the recording of knowledge (Taylor 2004). Some commentators predict that in the near future the Internet will be an important vehicle for delivering information and medical care. Tom Ferguson coined the term "e Patients" to define those people who were empowered to find medical answers for themselves, rather than rely on any single individual's opinion or interpretation. Virtual children's Hospital based the Internet's first medical Web site since 1993(Risk 2003).

The number of health related Web sites is rising with more 70,000 sites available to patients in 2000. A 2006 survey of 5,007 U.S. adults found that 84% of consumers claimed to have researched a health-related topic online in the past 12 months. (Fox 2006). Another survey reported that eighty percent of American Internet users (some 113 million adults) have searched for information on at least one of seventeen health topics. (Fox 2006). 75% of all adults on line (47% of all adults) use the Internet to look for health information. This amounts to 98 million adults nationwide. (David 2003). On average those who look for health information online do so on average 3.3 times every month(Fox 2006).

Faced with this explosion of online information the main challenge facing today's information consumer is how to find high quality information that meets their personal needs, within an acceptable time frame. But whilst everyone agrees that information quality is an important consideration, the concept of quality is problematic since in medicine there are often gray areas where the evidence-base is poor, making it difficult to determine a gold standard (Lewis 2005) Quality is an inherently subjective assessment, which depends on the type of the information needed, the type of the information searched for, and the particular qualities of the consumer (Wilson 2002). Experts believe that formal methods are needed to describe and assess information quality. Naumann maintains that "quality is the main discriminator of data and data sources on the Web" (Naumann 2001).

The paradox of quality as Robert Pirsing notes is the fact that "even though quality cannot be defined, you know what quality is" (Pirsing 1974). Although the typical consumer may be able to produce and define what quality means to them, each individual's perception of the quality of health information will vary depending upon their current circumstances and quality requirements (Burgess 2007).

A recurrent concern about online health information is that anyone is free to publish. Websites are set up by individuals, patient, charities, activist groups, commercial bodies either selling a product, as well as by health care professionals. The overwhelming majority of these resources are informal, quite often with no clinical input (Potts 2006).

RISKS POSED BY POOR QUALITY INFORMATION

It has never been easier for members of the public to access health information. In the twenty-first century it is taken for granted that patients may browse the Internet for the information about their condition, contact other patients by e-mail, send e-mails to their doctor or use touch screen kiosks in order to get health information (Jones et al 2005). But many believe there is a downside to this development. They fear that while the quantity of information has expanded exponentially, the same is not true for its quality. There is a concern in many professional groups about the potential harm associated with the use of poor quality health information. The quality of health information is of a particular concern because misinformation could be a matter of life and death (McClung 1998, Crocco 2002).

Harm in this context may be defined as adverse events or bad outcomes, either physical or emotional or financial, that occur from acting on materials or information and medication obtained from a Web site. On the other hand Crocco and collegues found only a few cases in the literature of harm associated with poor quality of health information on the Internet. In particular the authors report on a systematic review of peer-reviewed literature, to evaluate the number and characteristics, of reported cases of harm associated with the use of health information obtain on the Internet. (Crocco 2002).

In addition one way to demonstrate the amount of dubious health information online is to carry out a free text search using the phrase 'cancer cure'. The Web sites retrieved from this search contain cure-all remedies, based on scant or no medical evidence. At http://www.1cure4cancer.com for example, visitors are informed that Vitamin B17 kills cancer cells. The site fails to disclose the results of clinical trials into the effectiveness of this treatment. Ekman (2005) has investigated the prevalence and quality of interactive risk sites on the Internet. He found that the number of cancer risk sites increased by 50% between 2001-2002. Ekman's research study found that that the overall quality of the documentation on the cancer risk sites was poor. The majority of the cancer risk sites do not give reliable risks estimates. Similarly Lee et al (2003) found that thirty two percent of bladder cancer information sites contained inaccurate information. One critical problem was outdated data, rather than incurrent information.

Many of those searching for health information are looking for advice not about illness but ways of staying healthy or improving health. Furthermore disease information, material about weight control, and facts about prescription drugs top the lists of interests for health seekers. Many Website dealing with lifestyle choices and health are scams, particularly sites which shortcuts to weight loss and improvements in personal performance. Such sites frequently are devoid of scientific evidence, relying instead on anecdotes where personal experiences are presented as facts without references. Quite often sites with biased information only present one side of the argument. (Kiley 2003).

A longitudinal study (Pandolfini 2002). concluded that the quality of health information on the Internet had improved over the last 5 years. Nonetheless, the author concluded that people should continue to be alert as online information is not always accurate. In the absence of editorial controls, information may be of low quality and potentially harmful (Bower 1996). Poor interpretation of written information on medicines has been shown to lead to anxiety and poor compliancy to therapy. Therefore there is a need for promoting and educating consumer search and appraisal skills when using this information. For instance as Peterson(2003) indicated educating customer to find information on medicines may help them use their medicines in safer and more effective way(Peterson 2003).

There are various Internet sites which monitor health frauds and quackery. These are summarised in Table 1.

Table 1. Wesite monitoring health frauds and quackery

Quackwatch — http://www.quackwatch.com
- A member of Consumer Federation of America
- A nonprofit corporation whose purpose is to combat health-related frauds, myths, fads, fallacies, and misconduct.

National Council Against Health Fraud — http://www.ncahf.org
- A private, non-profit, voluntary health agency that focuses upon health misinformation, fraud and quackery as public health problems (NCAHF 2007).

Health Care Reality Checked and alternative medicine — http://www.hcrc.org
(Kiley 2003).

American Council on Science and Health (ACSH) — http://www.acsh.org
- A consumer education consortium concerned with issues related to food, nutrition, chemicals, pharmaceuticals, lifestyle, the environment and health
- An independent, nonprofit organization (ACSH 2003).

REVIEW OF INITIATIVES TO IMPROVE QUALITY OF HEALTH INFORMATION

The quality of health information on the Internet became a subject of interest to healthcare professionals and consumers groups in the mid-1990s (Gagliardi 2002). This concern is prompted by a desire to prevent of physical, mental, and emotional harm caused by wrong, misleading, inappropriate, false, information to member of the public who use the Internet to seek or receive health information, products, and services (Dzenowagis 2001).

There have been a host of initiatives aimed at establishing criteria for judging the quality of online health information. These have produced policy document, tools to assist the development, implementation and evaluation process and various methods to determine how well Web-sites comply with the standards(in which case they can display a kitemark). The hope is that if developers adhere to the quality criteria, end users will be able to readily identify reputable sites (Ekman 2005). The European Union has also drafted guidelines on quality criteria for health Websites. However, there is no international consensus for how to deal with the quality issue problem (Jadad 1998, Eysenbach 1998).

The organizations who have created guidelines for evaluating health related Websites include

- Health On the Net (HON)
- American Medical Association
- Internet Health Care
- Coalition Hi-Ethics
- MedCertain

None of these guidelines have been systematically applied to a broad set of Web pages and conditions. Furthermore little research has been conducted to empirical assess what a consumer might find while searching on Internet (Berland et al 2002).

In conclusion the emphasis of the responsibility for the future access and quality of health information is placed on the medical informatics leaders who must understand: medicine and information disciplines. Health professionals need to be able to direct patients of good quality health information included health related Websites (Shepperd 1999).

The Judge Health guidelines were developed in partnership between Contact a Family (a UK charity) and the Information Society Research and Consultancy Group at Northumbria University (www.northumbria.ac.uk/isrc).

In addition the Judge project, supported by the Health Foundation developed guidelines in order to judge the quality of health information Web sites. Two sets of guidelines were produced: (i) to help health consumers make informed choice about Web sites.(ii) to assist some support groups to produce good quality Web sites. These were made available via www.judgehealth.org.uk.

The guidelines comprise four sections:

i. How to produce good quality information;
ii. How to design good quality Web sites;
iii. How to market Web sites;
iv. How to help consumers use health information (Barnett 2006).

One of the more successful quality initiatives schemes has been developed by the Geneva based Health On Net Foundation (HON). The initiative is an expression of a self-regulatory mechanism. Self-regulation of the health Internet remains a powerful driver of the pursuit of quality standards for health information on the Internet (Dzenowagis 2001).

The HON code originally consisted of eight broad principles for medical Webmasters. Central to this code is the principle that any medical information must only be given by medically trained and qualified professionals. Where this condition cannot be met there must be clear confirmed that a piece of advice was given from a non-medically qualified individual or organization (HON 2007). To some extend other principles of the code are concerned with how clearly the source of both data and funding for a site can be determined. HON has stepwise taken a more active approach in actually "reviewing" and verifying applications. It is certain that sites displaying a HONcode are not necessary better than those do not comply with these criteria (Lewis 2005).

In 2002 the European commission published a communication called "quality Criteria for Health related Web site" based on a workshop in Brussels . The Quality criteria include Transparency and Honesty, Authority, Privacy and Data protection, Accountability, Responsible Up dating information, Editorial policy and accessibility (E-europe 2002).

According to (e-Europe 2002) quality criteria should address issues of both supplier and user education. In particular one document that simultaneously tell suppliers how to comply with key quality criteria and in order to educate users what to expect from a good health Web site. Needless to say that the quality criteria should address both passive information-giving sites as well as sites that allow for transactions between service or users and information providers.

Moreover the Health Summit Working Group selected defined and evaluated seven major criteria for assessing the health quality information: Credibility, content, disclosure, links, design, interactivity, and Caveats.

Criteria for Evaluating Internet Health Information (Health Summit Working Group H.S.W.G):

- **Credibility:** Includes the source, currency, relevance/utility, and editorial review process for the information. A site should display the name and logo of the institution or organization responsible for the information. Furthermore the date of the original information is based and the date that post on the Web.
- **Content:** Must be accurate and complete, and disclaimer provided. In particular clinical or scientific evidence that supports a position should be clear and understandable. Also a disclaimer describing the purpose and scope authority and currency of the information should be provided.
- **Disclosure:** Web sites is important to provide disclosure including the purpose of the Web site and the profile as result user can understand the intent of the organization or individual . In particular includes informing the user of the purpose of the site, as well as any profiling or collection of information associated with using the site.
- **Links:** Evaluated according to selection, architecture, content, and back linkages. Especially critical to the quality of an Internet Web site are its external resources and links connections to other Web sites that confirm the information that provided .
- **Design:** Encompasses accessibility, logical organization (navigability), and internal search capability. In particular the Web sites must be easy to use. The design including graphics, text and links is important in order to delivery and use of any Web information.
- **Interactivity:** Web sites should include a feedback mechanism for users in order to offer their comment, corrections, and criticisms, and as result raise questions about the information provide. This make the Web site accountable to its user and allowing information exchanged to many individuals.
- **Caveats:** Clarification of whether site function is to market products and services or is a primary information content provider (HSWG 1999).

In addition The eHealth Code of Ethics is developed as a set of guiding principles aimed at health Internet stakeholders worldwide. In January 2000, about 50 experts in providing health information on line attended the "e-health" summit on the ethics providing information on the Internet in Washington. The code of ethics addresses issues of quality, privacy security and confidentiality and commercial behaviour (Eysenbach 2004). The goal of the E-health code of ethics is to ensure that people can confidently and with full understanding of know risks realize the potential of the Internet in managing their own health (Dzenowagis 2001). In conclusion the e-health code of ethics places a border on other organization developing quality standards for Internet health information.

Hi-Ethics Code of Conduct consisted of 14 principles, and was developed by a group of leading for-profit consumer health information Web sites (Lewis 2005). Established on May 2000 current members is 15 companies and current membership fee are 6000 dollars. The rules developed are intended to assure that Internet health services reflect high quality criteria and ethical standards. Also health information is trustworthy and protected. Needless to say that consumers are able to distinguish on line health services that follow the Hi-Ethics principles from those that do not (Hi-Ethics 2007, Dzenowagis 2001). Sustainability of the Hi-Ethics Code of Conduct is Vulnerable to the burdens placed on member companies, citizens and the ability of Hi-Ethics to maintain the currency of the principles. (Dzenowagis 2001). Furthermore AMA code of America Medical Association (Winker 2000). The mission of AMA is to promote the art and science of medicine and the betterment of public health. Guidelines for Medical and health information site on the Internet and Principles Govern AMA Web sites has been established since 2000 by AMA. Providers are Web site of the American Medical Association Medem (www.medem.com) The development of guidelines begin in 1999 where health information on the Web are based on those that govern medical journals, including peer-review process, authorship, sponsorship and the principles of privacy and confidentiality (Dzenowagis 2001, AMA 2007). These are governance tools indended for use by the developers of AMA . Also other organizations have adopted these guidelines for use.

It is certain that all the sets of criteria derive from similar roots. These roots are the principles of privacy, honesty, confidentiality, currency, accuracy, prevalence, consent, disclose and accountability. Quality criteria for patients decision and health information are relevant to patients and health care professionals, health care services and policy makers, all of whom is necessary to be confident about the developing and testing quality tools that undergone before their release (Elwyn 2006). For instance factors affecting the quality of an information source, the issues associated with the accessibility of a resource, the overall design and layout of the information and the ease of using of materials are secondary to the content issues (Intute 2006). At that point that we may be able to understand and examine in more depth the goal of helping patients to have the best quality information in order to take the best health decisions.

Promoting quality criteria for health information means better health. The benefits and outcomes of using health information are many. According to David et al (2003) on line questionnaire produced by the British Life and Internet Project, a total of 93 per cent said that the information had helped in understanding more about an illness or injury and a relatively high 57 per cent of responders said that that the information found was sufficient for them to act upon to improve their health. Moreover a total 26 per cent said that the information found had affected their decision about whether to see a doctor. In conclusion what have we learned from quality of health information on Internet is that consensus is important, collaboration and dissemination are crucial. Furthermore the cost of implementation is too high, also user and provider indifference is real. Moreover citizens education is a difficult and important task. In addition quality criteria are not enough and technology and understanding need to be promoted. As result more research needs to be done on: poor quality and health outcomes, on consumers behaviour, and better international collaboration and dissemination(Risk 2003).

EXAMPLES OF TOOLS FOR ASSESSING THE QUALITY OF CONSUMER HEALTH INFORMATION

Several groups have developed interactive Internet tools to educate consumers. These tools help users to assess the quality themselves(Eysenbach 2004).A further application of the code of good conduct takes the form of a user guidance tool. In particular with a code is demonstrated not by a label, but by a link to a guidance tool which invites the user to check if a site comply the quality criteria. Such tools may be specific to a particular type of information, such as DISCERN **(**http://www.discern.org.uk/**)** where developed to assess the quality of health information on treatment choices (Charnock 1998, Charnock 1999) Areas covered are: bias in the material, a clear statement of aims, references and additional sources of support and information, uncertainty, risks and benefits (including those of opting for no treatment), and treatment options. Moreover DISCERN (http://discern.org.uk) provides a brief questionnaire through which users gain a valid and reliable way of assessing the quality of written information on treatment choices. Similarly NETSCORING which uses a questionnaire of 49 criteria falling into eight categories: credibility, content, links, design, interactivity, quantitative aspects, ethics, and accessibility (e-Europe 2002). In conclusion another user guidance system is QUICK (www.quick.org) where provides children with a step by step guide to assessing health related information on Internet (Eysenbach 2002).

The Health Information Quality Assessment Tool **(hitiWeb.mitretek.org/iq)** — the Health Summit Working Group in North America (hitiWeb.mitretek.org/hswg) is currently developing a reliable and valid appraisal tool for users of health information on the Internet (Mitretek 1999). The main areas currently covered are credibility, content, disclosure, links, design, interactivity, and caveats (information on the function of the site). When looking for health information most Internet users start with a generic search engine. Very few check the source and date of the information they find (Fox 2006).

HEALTH WEBSITES AND SEARCH ENGINES

Health information can be extremely useful, empowering us to make important health decisions. Given the wealthy of information available through the Internet and other sources it is important to be able to assess its quality. This can be difficult because health information is constantly changing.

Web sites should provide clear and conspicuous notice of their information practices. It was thought that the greater the number of sites visited, the greater the like hood of a healthy behavior outcome. This based on an information model that argues that not all sites will present the information in the same way and design. Users benefit from collecting information from a number of sites. In particular they find it easier to collect the information and because jumping from site to site means that users can compare the information and become more knowledgeable (David 2003).

Below we provided some searchable catalogues to good quality health Web sites .

EXAMPLES OF HIGH QUALITY HEALTH WEB SITES

NHS Direct on line (http://www.nhsdirect.nhs.uk**):** The forefront of 24 hour health care delivery telephone and e-health information services during day and night. Provide information and advice about health and based in United Kingdom.

Healthfinder (http://www.healthfinder.gov/**):** Is a gateway consumer health information Web site whose goal is to improve consumer access to selected health information from a government agencies. The developer and sponsor of this site is the office of Disease Prevention and Health Promotion.

In particular is a US government site that provides access to health information from a range of sources, including government agencies and professionals organizations.

HON Health on Net Foundation (http://www.hon.ch/**):** An international not profit organization. It provides a databases of evaluation health materials and also provides the use of the HON Code and help unify the quality of medical and health information available.

MEDLINE PLUS (http://www.nlm.nih.gov/medlineplus**):** Is the National Library of Medicine, and part of National institute of Health. Provides access to a wide range of databases and health related organizations.

Patient UK (http://www.patient.co.uk**):** Designed to direct non-medical people in the United Kingdom to information about health related issue.

Organising Medical Networked Information (OMNI) (http://www.omni.ac.uk**):** OMNI provides access to good quality biomedical and health information Websites worldwide. It has been developed for medical professionals first and it based at the university of Nottingham in United Kingdom.

Provide good quality biomedical and health information by the Internet worldwide.

HealthWeb (http://healthWeb.org): Is a site established by librarians and information professionals from major academic medical institution in the Midwest. The site also provides "user Guides" developed to help consumers use Internet resources more effectively.

National Electronic Library for Health (NeLH) (http://www.nelh.nhs.uk**):** Extend Nhs library service to patient and the public. Provide easy access to health information and to the best current knowledge.

HebsWeb Health education Board of Scotland (http://www.hebs.scot.nhs.uk**):** The Web site for the Health Education Board of Scotland. In particular the site provide access to a wide range of consumer health information resources.

NOAH: New York Online Access to Health (http//:www.noah-health.org/**):** Is a unique collection of state local, and federal health resources for consumers. NOAH'S mission is to provide hifh quality, full term information for consumers, timely and relevant.

National Institutes of Health (http://www.nih.gov/health/consumer**):** Provides access to database of consumer health information published by the US National Institute of Health.

NHS in England (http://www.nhs.uk/**):** Health Web site is based in England, in particular is giving straightforward information presented in words, pictures video and audio about health living.

Best Treatments (http://www.besttreatments.co.uk/**):** In association with BMJ(British Medical Journal clinical evidence is a Web site for patients and doctors. In particular is providing the best research evidence about the treatments for many medical conditions.

Medem (http://medem.com): A new site launched in the fall of 2000, is a project of the leading medical societies in the United States. The site was developed to provide a trust online source for credible, comprehensive, and clinical healthcare information secure and confidential.

National Women's Health Information center (http://www.4women.gov/**):** Is gateway to selected women's health information resources. Its purpose to provide information about prevention, diagnosis and treatment of the illnesses and health conditions that affect them. Is sponsored by the U.S public Health Services office on women's Health.

IPEX (http://www.dipex.org**):** Is a Web site based in Oxford in England. Has a wide variety of personal experience of health and illness. People talking about their experience of illness and health issues.

Diabetes123 (http://www.Diabetes123.com/**):** Is an organization whose mission is give information in online diabetes care, improving quality and reducing the cost of care by increasing the understanding of providing traditional products and services for the treatment of diabetes.

Contact a family (http://www.cafamily.org.uk**):** Is the only United Kingdom wide charity providing advice, information and support to the parents of all disabled children. Also parents can get in contact with other families both on a local and national basis.

StartHere (http://www.starthere.org/bigpage1.htm**):** Offer a variable service to citizens, providing useful information across a broad range of health topics.

EQUIP (Electronic Quality Information for Patients) (http://www.equip.nhs.uk/index.html#top**):** The Web site is based in west Midlands region NHS England and offer a variable links health Web sites. It was created in response to government requirements for improvements in information available to patients.

Health Education Board Scotland (http://www.healthscotland.com/**):** Is a National agency for health improvement from gathering evidence, to planning delivery and evaluation of a range of health topics and life stages.

Clinical Evidence (http://www.clinicalevidence.com**):** Is a new kind of decision support resource. BMJ clinical evidence systematic reviews summarise the current state of knowledge and uncertainty about the prevention and treatment of clinical conditions, based on searches and appraisal of the literature.

PathCAL (http://www.pathcal.ac.uk/**):** Is a set of 129 Web-based tutorials in order to help students understand the basic pathological principles of disease exploiting techniques in learning psychology

National Patient Safety Foundation (NPSF) (http://www.npsf.org/**)**/(www.centreforhig.demon.co.uk**):** Is a central resource in order to facilitated the production and dissemination of high quality patient information for health services users. The trust provides information as part of the health information services and NHS direct include large library information and databases.

Center of Disease Control and prevention(http://www.cdc.gov/**):** An agency of the department of Health and Human services is dedicated to promoting health quality of life by preventing and controlling disease, there are also sections on health topics in the news and health hoaxes (Williamson 2006, Killey 2003, Childs 2003, Shepperd 1999, Fox 2002).

SEARCH ENGINES

According to Fox(2002) A typical health seeker goes on line to see what can find without getting advice about where or how to search from anyone including medical professionals or friends.

You can use some search engines if you can not find what you need from the gateways. Here are some examples of search engines.

- **Google** (http://www.google.co.uk)
- **AlltheWeb** (http://www.alltheWeb.com)
- **Yahoo** (http://www.yahoo.com)
- **MedHunt** (http://www.hon.ch/MedHunt)
- **Mirago** (http://www.mirago.co.uk)
- **Excite** (http://www.Excite.com)
- **Allsearchengines.com** (http://www.Allsearchengines.com)
- **Medstory** (http://www.medstory.com)

LEARNING HOW TO SEARCH

There are free on line tutorials by organizations or libraries. Here are some sites that provide free on line tutorial in order to develop Internet skills:

- The online Netskills Interactive Course (TONIC) Since 1995 Netskills has delivered high quality professional training services to the education public in the UK and beyond (http://www.netskills.ac.uk/onlinecourses/tonic/).
- Resource Discovery Network (RDN) Virtual Training Suite (http://www.rts.rdn.ac.uk) or http://www.intute.ac.uk is a free on line service providing you with access to the very best Web resources for education and research. In particular the service is created by a networked of UK universities and partners. The databases characterized of high quality information.
- Quality information checklist: www.quick.org.uk/menu.htm provides children with a step by step guide to assessing health related information on the Internet.
- DISCERN www.discern.org.uk is a brief questionnaire for users to validate information or treatment choice. (Childs 2003).

CONCLUSION

Health information has been variously described as the foundation for better health. The complexity of the issues surrounding quality of health information in the context of the health Internet has been shown (Dzenowagis 2001).

On demand side, there are different users of information. The usual position searching for information based on quality is to find the best available item that meet patient needs (Burgess 2007). The existence of the pseudo-health segment of information producers and users complicates efforts to introduce quality standards for health information on the Internet. Trustworthy health information from well known source on the Internet needed for the growing user population (Ekman 2005). Qualitative data are needed to design educational and technological innovations to guide consumers to high quality information (Eysenbach 2002).

Since no international consensus for quality criteria exists has as impact the responsibility falls on the medical organizations institutions and societies. It is important that organizations such as medical universities and governmental agencies to provide trustworthy high quality health information on Internet (e-Europe 2002) Experts from around the world will be invited to share their knowledge and experience. The international partnership for health informatics education(IPHIE) dares from 1999 and seeks to maintain, improve and promote medical and health informatics training and education through international collaboration(Murphy 2007).

It is now to be expected that national and regional health authorities, and private medical Web sites owners will implement the quality criteria and to develop information campaigns to educate site developer and citizens about minimum quality standards for health related Web sites.

REFERENCES

ACSH. (2003). American Council on Science and Health. Retrieved 25, June 2007 from, http://www.acsh.org

AMA. (2007). American Medical Association. Retrieved 28, June 2007 from, http://www.ams.assn.org

Barnett, D., Grey, J., & Langrick, C. (2006). Developing a support group Web site use of the judge health guidelines. *Health information on Internet journal, 53*, p3.

BBC. (2003b). Student died after buying Web drugs. *BBC News*. Retrieved 28, June 2007 from http://news.bbc.co.uk/1/hi/england/3130187.stm

BBC. (2004). Millions illiterate about health. *BBC News*. Retrieved 28, June 2007 from http://news.bbc.co.uk/1/hi/health/3530874.stm

Beland, G. K., Ellott. M. N, Moralles, L. S., Algazy JZ, Kravite RL, Broder MS., Kanouse D.E, Munoz J. A., Yang K.,M. C. Glynn E. A. (2002). Health information on Internet. *Accessibility . Quality and Readability In English and Spanish*, *285*(20), 2612–2621.

Bower, H. (1996). Internet sees growth of unverified health claims. *BMJ (Clinical Research Ed.)*, *318*(381).

Burgess, M. S. E., Gray, W. A., & Fiddian, N. J. (2007). Using quality criteria to assist in information searching. International Journal of information quality. Vol 1, No1, pp83-99.

Charnock, D.(1998). *The DISCERN handbook: Quality criteria for consumer health information*. Abingdon: Radcliffe Medical Press.

Charnock, D., Shepperd, S., Gann, B., & Needham, G. (1999). DISCERN — an instrument for judging the quality of consumer health information on treatment choices. *Journal of Epidemiology and Community Health*, *53*, 105–111. doi:10.1136/jech.53.2.105

Childs, S. (2003). *Summary how to search the Internet for health information*. Retrieved 10, June 2007 from www.judgehealth.org.uk/print.htm

Crocco, A. G., Keever, M. V., & Jadad, A. R. (2002). Analysis of cases of Harm Associated with use of health information on the Internet. *Journal of the American Medical Association*, *287*(21), 2869–2871. doi:10.1001/jama.287.21.2869

David, N., Huntington, P., Gunter, B., Russell, C., & Withey, R. (2003). *The British and their use of the Web for Health information and advice: A survey.* Retrieved 28, June 2007 from, http://www.emeraldinsight.com/0001-253X.htm

E-Europe. (2002). Commision of the European communities. Quality criteria for Health related Websites. *Journal of Medical Internet Research*, *4*(3), e15.

Ekman, A., Hall, P., Litton, J. E. (2005). Can we trust cancer information on the Internet? A comparison of interactive cancer risk sites. *Cancer causes and control Journal, 16*, 65-772.

Elwyn, G., O'Conor, A., Stacey, D., Volk, R., Edwards, A., & Coulter, A. (2006). Developing a quality criteria frame work for patients decisions aids: online international Delphi, consensus process. *BMJ (Clinical Research Ed.)*, *333*, 417. doi:10.1136/bmj.38926.629329.AE

Eysenbach, G. (2004). Recent advances Consumer health informatics. Clinical review. *BMJ (Clinical Research Ed.)*, 320.

Eysenbach, G., Diepgen, T. C., & Gray, J. A. M. (1998). Towards quality management of medical information on the Internet. Evaluation labelling and filtering of information. *BMJ (Clinical Research Ed.)*, *317*, 1496–1502.

Eysenbach, G., & Kohler, C. (2002). How do consumers search for and appraise health information on the World Wide Web. *BMJ (Clinical Research Ed.)*, *324*, 573–577. doi:10.1136/bmj.324.7337.573

Fox, S. (2006). *Online health search*. Retrieved 15 of June 2007 from, http://www.pewInternet.org/pdfs/PIP_Online_Health_2006.pdf

Gagliardi, A., & Jadad, A. R. (2002). Examinations of instruments used to rate quality of health information on the Internet. Chronicle of a voyage with an unclear destination. *BMJ (Clinical Research Ed.)*, *324*, 569–573. doi:10.1136/bmj.324.7337.569

General Accounting Office. (1996). *Consumer health informatics-emerging issues*. Washington, DC, Grandinetti, D. A. (1994). Doctors and the Web help your patients surf the Net safety. *Medical Economics*, *77*(5), 186–188.

Hi-Ethics, Inc. (2007). Retrieved 29, June 2007 from http://www.hiethics.com

HON (Health on Net Foundation). (2007). Retrieved 22, June 2007 from http://www.hon.ch/HONcode/Conduct.html

Intute (2006). Intute: Health and life sciences evaluation guidelines. Retrieved 28, June 2007 from http://www.intute.ac.uk/healthandlifesciences/

Jadad, A. R., & Gagliardi, A. (1998). Rating health information on the Internet: navigating to knowledge or to label. *Journal of the American Medical Association*, *279*, 611–614. doi:10.1001/jama.279.8.611

Jones, R., Gann, B., Duman M., Murphy, J.(2005). *Consumer health informatics*. DH V2

Kiley, R. (2003). *Medical information on the Internet. A guide for health Professionals*. Churchill Livinstone.

Kiley, R., & Graham, E. (2002). The patient's Internet handbook. *Royal Society of Medicine*.

Lewis, D., Eysenbach, G., Kukafka, R., Stavri, P. Z., & Jimison, H. B. (2005). *Consumer health informatics. informing consumers and improving health care*. Springer Publications

Linkous, J. (1999). American telemedicine Association Issues Advisory on the use of the medical Web sites. Retrieved from http://www.atmeda.org/news/072899.html

McClung, H. J., Murray, R. D., & Heitlinger, L. A. (1998). The Internet as a source for current patient information. *Padiatrics*, *101*, E2. doi:10.1542/peds.101.6.e2

Mitretek Systems Innovative Technology in the Public Interest (2007). Retrieved 2, June 2007 from hitiWeb.mitretek.org/hswg

Mulligan, Z.(2007) GP specialist e-library. *Health information on Internet. 55*, 5.

Murphy, J. (2007). International perspectives and initiatives. *Health Information and Libraries Journal*, *24*(1), 62–68. doi:10.1111/j.1471-1842.2007.00704.x

Murphy, J. (2007). *Workshop — Consumer Health Information*. City Univercity London

Naumann, F. (2001). From databases to information systems information quality makes the difference. In *Proceedings of Int. Cont on information Quality(ICIQ)*. Boston, MA, USA, (pp 244-260).

NCAHF. (2007) National Council Against Health Fraud. Retrieved 25, June 2007 from http://www.ncahf.org/

Pandolfini, C., & Bonati, M. (2002). Follow up of quality of public oriented health information on the World Wide Web: Systematic re-evaluation. *BMJ (Clinical Research Ed.)*, *32497337*, 82–583.

Peterson, G., Aslani, P., Williams, K. (2003). How do consumers search for and appraise information on Medicines on the Internet? A qualitative study Using focus groups. *J. Med Internet Res* *5*(4), e 33.

Pirsig, R. M. (1974). *Zen and the art of motorcycle maintence*. New York: Bantam Books.

Potts, H. M. M. (2006). Is e-health progressing faster than e-health researchers? *Journal of Medical Internet Research*, *8*(3), e24. doi:10.2196/jmir.8.3.e24

Quackwatch (2007) Retrieved 25, June 2007 from http://www.quackwatch.org/00AboutQuackwatch/mission.html

Risk, A. (2003). Quality of health information on Internet, achievements lessons and the future. *Conference Puebla Mexico Crics VI Birem*. Retrieved 5, July 2007 from http//:www.paho.org/English/PD/IRM/risk.pdf

Risk, A., & Dzenowags, J. (2001). Review of Internet Health information Quality Initiatives. *Journal of Medical Internet Research*, *3*(4), e28. doi:10.2196/jmir.3.4.e28

Shepperd, S., Charnock, D., & Gann, B. (1999). Education and debate. Helping patient access high quality health information. *BMJ (Clinical Research Ed.)*, *319*, 764–766.

Silberg, W. (1997). Assessing, controlling and assuring the quality of medical information on the Internet. *Journal of the American Medical Association*, *277*(15), 1244–1245. doi:10.1001/jama.277.15.1244

Talley, C. R. (1997). Editorial: Trouble on the Internet. *American Journal of Health-System Pharmacy*, 54.

Taylor, A. G. (2003). *The organization of information*. 2nd edition Libraries Unlimited publications.

Williamson, L. (2006). What's new. *Health information on the Internet, 50,* 12.

Wilson, P. (2002). How to find the good and avoid the bad or ugly: A short guide to tools for rating quality of health information on the Internet. *BMJ (Clinical Research Ed.)*, *324*, 598–602. doi:10.1136/bmj.324.7337.598

Winker, M. A., Flanagin, A., & Chi-Lum, B. (2000). Guidelines for medical and health information sites on the Internet. *Journal of the American Medical Association*, *283*, 1600–1666. doi:10.1001/jama.283.12.1600

Wyatt, J. C. (1997). Commentary: Measuring quality and impact of the World Wide Web. *BMJ (Clinical Research Ed.)*, *314*, 1879–1881.

Ziebland, S., Chapple, A., Dumelow, C., Evans, J., Prinjha, S., & Rozmovits, L. (2004). How the Internet affects patient's experience of cancer a qualitative study. *BMJ (Clinical Research Ed.)*, *328*, 364. doi:10.1136/bmj.328.7439.564

KEY TERMS AND DEFINITIONS

Consumer Health Informatics: Consumer health informatics is the branch of medical informatics that analyses consumers' needs for information; studies and implements methods of making information accessible to consumers; and models and integrates consumers' preferences into medical information systems. Consumer informatics stands at the crossroads of other disciplines, such as nursing informatics, public health, health promotion, health education, library science, and communication science, and is perhaps the most challenging and rapidly expanding field in medical informatics; it is paving the way for health care in the information age.

Health Information: Health information is required for a wide variety of purposes, including building knowledge and understanding of health conditions; helping people to decide when they need to seek specialist help; supporting choices in relation to treatment, management or social care options; identifying, choosing and accessing appropriate healthcare providers; and educating patients and the public about public health risks and about primary and secondary prevention.

Internet: The Internet is a world wide, publicly accessible series of interconnected computer networks that transmit data by packet switching using the standard Internet protocol (IP). It is a "network of networks" that consists of millions of smaller domestic, academic, business, and government networks, which together carry various information and services, such as electronic mail, online chat, file transfer, and the interlinked Web pages and other resources of the World Wide Web (WWW).

Quality: Quality is an inherently subjective assessment, which depends on the type of the information needed, the type of the information searched for, and the particular qualities of the consumer. Experts believe that formal methods are needed to describe and assess information quality.

This work was previously published in the Handbook of Research on Distributed Medical Informatics and E-Health, edited by A. Lazakidou and K. Siassiakos, pp. 443-455, copyright 2009 by Medical Information Science Reference (an imprint of IGI Global).

Chapter 1.15

Improving Data Quality in Health Care

Karolyn Kerr
Simpl, New Zealand

Tony Norris
Massey University, New Zealand

INTRODUCTION

The increasingly information intensive nature of health care demands a proactive and strategic approach to data quality to ensure the right information is available to the right person at the right time in the right format. The approach must also encompass the rights of the patient to have their health data protected and used in an ethical way. This article describes the principles to establish good practice and overcome practical barriers that define and control data quality in health data collections and the mechanisms and frameworks that can be developed to achieve and sustain quality. The experience of a national health data quality project in New Zealand is used to illustrate the issues.

DOI: 10.4018/978-1-60566-026-4.ch295

BACKGROUND

Tayi and Ballou (1998) define data as "the raw material for the information age." English (1999) builds on the idea of information as being data in context, with knowledge being information in context, where you know the significance of the information. Translating information into knowledge requires experience and reflection.

Klein and Rossin (1999) note there is no *single* definition of data quality accepted by researchers and those working in the discipline. Data quality takes a consumer-focused view (consumers being people or groups who have experience in using organisational data to make business decisions) that quality data are "data that are fit for use" (Loshin, 2001; Redman, 2001; Wang, Strong, & Guarascio, 1996). Data quality is 'contextual'; the user defines what is good data quality for each proposed use of the data, within its context of use (Pringle, Wilson, & Grol, 2002; Strong, Lee, & Wang, 1997). Therefore:

Data are of high quality if they are fit for their intended uses in operations, decision-making, and planning. Data are fit for use if they are free of defects and possess desired features (Redman, 2001).

Data quality is now emerging as a discipline, with specific research programmes underway within universities, the most significant being that of the Sloan School of Management Information Quality Programme at the Massachusetts Institute of Technology (MIT)[1]. The field is based upon the well-established Quality Discipline, drawing on the work of Deming (1982) and the adaptation of the "*plan-do-check-ac*" cycle (the Deming Cycle). It also draws upon the "*quality is free*" concept of Crosby (1980) arising from the notion that doing things wrong is costly, and imports the ideas behind the Six Sigma approach and Total Quality Management (Juran & Godfrey, 1999) adapted to Total Data Quality Management (TDQM) and the management of information as a product (Wang, Lee, Pipino, & Strong, 1998).

The research programmes are developing ways to combine TDQM with the strategic direction of the organization, aligning the data quality requirements with overall goals. At present, there is little research published in this area, although some organizations do have data quality programmes with some strategic alignment to the business requirements.

Data quality is also becoming an increasingly important issue for health care providers, managers and government departments. The movement towards total quality management in health care to improve patient safety and health care efficiency is demanding high quality information. Further, evidenced based care requires the assimilation of large amounts of relevant and reliable research data available at the point of clinical decision making. Strategic prevention, national consistency of improvement practices, evolving data standards, and targeted improvements with increasing consumer involvement are all moving health care towards a TDQM model of data quality management.

Using the TDQM model, many of the methods developed in other industries can be useful for improving health care data. However, health data differ from data that arise in other fields in several ways. For example, the complex and multidisciplinary nature of medicine means that, unlike other sciences, health care data have no internationally standardized terminologies. This lack of standardization produces many homonyms, where the same term can mean different things depending on context, and synonyms, where there are several ways of expressing the same meaning. Added to these sources of ambiguity is the plethora of healthcare abbreviations which have no agreed format. The required longevity, privacy, and confidentiality concerns associated with health data are also distinguishing characteristics. Combine these inherent features with the need to share and integrate the data across distributed and disparate entities such as the Ministry or Department of Health, regional health boards, hospitals, general practices, and individual specialists, and it is hardly surprising that the improvement of healthcare data quality is multifaceted and more involved than in many other domains.

THE DEVELOPMENT OF A DATA QUALITY EVALUATION FRAMEWORK

A common imperative in the health sector is the need to structure and improve the management of data quality within regional or national health data collections that aggregate patient health data and use the combined data for epidemiological and service planning purposes. Clinicians and managers recognize the need for assessment tools that indicate the level of data quality, identify where the problems are, and who should be accountable. This information can then be used to construct a strategy for quality improvement. This was recently the situation in New Zealand where previous work to develop the Ministry of Health information systems strategic plan, and a current state analysis of data quality, provided further support for the commencement of a programme of data quality improvement.

The starting point for any Data Quality Evaluation Framework (DQEF) in the health sector is the pioneering work of the Canadian Institute for Health Information (CIHI) (2003a, 2003b) The CIHI has developed a comprehensive data quality framework based on a hierarchy of quality attributes ranging from criteria at the base level that are grouped into characteristics, and then further reduced into a small number of high-level dimensions[2]. The CIHI framework is of course developed for Canadian conditions and must be adapted for local circumstances to ensure applicability. This can be done by engaging data custodians and stakeholders in an iterative sequence of focus group, interviews, and discussions that modify the data attributes at each level to reflect existing organizational structures and practice. The iterative process is most readily facilitated by action research using grounded theory (Strauss & Corbin, 1998) to structure the analysis of qualitative data through inductive coding and comparison.

In the New Zealand project, for example, analysis confirmed the utility of the Canadian quality dimensions of accuracy, relevancy, timeliness, usability, and comparability, but found it necessary to add a dimension of privacy and security to ensure that this aspect is explicitly managed to meet New Zealander's expectations for national data collections. The project also revealed that New Zealand's unique patient identifier, the National Health Index (NHI), is a powerful tool for the location of poor quality (e.g., redundant or incorrect) database entries.

The New Zealand project also revealed the advantages of the action research approach. Discussion and feedback, coupled with rigorous analysis, raises awareness of the importance of data quality, an issue which is frequently underrated at all levels by data users and managers. The approach similarly creates a common understanding of terminology and recognition of the importance that quality improvement is an ongoing venture needing continued support and clear lines of accountability. Thus, in developing and applying a data quality evaluation framework, it is important to:

- define the underpinning data quality criteria carefully involving all stakeholders to ensure common understanding and direction;
- consider the critical quality dimensions that reflect how the organization uses data and how data flow throughout the business processes;
- document business processes identifying data sources and their reliability;
- appreciate that the framework requires practical supporting tools, for example, documentation, to make it effective;
- customize the language of user guidelines or manuals with regard to the level and experience of the intended users;
- be aware of the importance of both education and training at all necessary stages and levels – training is essential to affect the culture change that must accompany the realization of the importance of data quality; and
- be aware that application of the framework is an iterative, on-going process – the required outcomes cannot be achieved in a single-pass.

THE DEVELOPMENT OF A DATA QUALITY IMPROVEMENT STRATEGY

Porter (1991) states that the function of a strategy is to integrate the activities of diverse functional departments to ensure consistency within an organization with explicit, reinforcing goals and policies when senior management cannot participate or monitor all decisions directly. It will be apparent from the above discussion that a Data Quality Evaluation Framework will not, by itself, automatically lead to required improvements and that a strategy, as defined by Porter, is critical to its successful implementation. Robson (1997) also notes that a successful strategy "exploits opportunities and fits the circumstances at the time" with a requirement, therefore, to undertake a systematic, skillful, accurate and realistic assessment of the opportunities and to re-evaluate them. The design and execution of a Data Quality Improvement Strategy (DQIS) in health care therefore begins with a current state analysis followed by an assessment of the capability and maturity of the relevant health care organizations to effect the necessary improvements and understand the implications. Benchmarking against international organizations and other business sectors also helps to root the strategy so that it identifies local priorities and exploits current capabilities.

As is typical of many health systems at the present time, an extensive analysis of practices in New Zealand found that data quality management is entirely initiated through "bottom up" processes, in general through information services or information technology teams. Management has not yet taken responsibility, and indeed does not understand their role in the data quality process. Data quality improvement tends to occur when staff become frustrated with their inability to use the data for its intended purpose and there is no one else in the organization responsible for overall data quality management. This bottom up approach introduces silos of data quality improvements that can lead to even more quality issues by increasing discrepancies and producing conflicting reports from the same source. The New Zealand analysis shows that this situation is evident in all types of health sector organizations. It confirms that TDQM and the strategic management of data quality are relatively new phenomena, still rarely found across organizations in either New Zealand or overseas. New Zealand health care is certainly not lagging behind in the management of data quality but its political system, national public sector provision, structured assessment tool, and the NHI suggest that it has the infrastructure and capability to become a world leader in the implementation of a strategic data quality programme based on TDQM principles.

The New Zealand DQIS thus provides the Ministry of Health and the sector with detailed guidelines on how to develop and implement TDQM at all levels of the health sector. Roles and responsibilities are clearly defined, along with data ownership. A series of projects provides the required development for "business as usual" initiatives that institutionalize data quality into every day practice and make use of existing sector knowledge through the development and dissemination of best practice guidelines. For a data quality improvement strategy, it is important therefore to:

- derive and impose standards that facilitate data and information transfer whilst preserving quality;
- re-engineer the business processes to deliver the quality data needed for efficient service planning and the effective practice of integrated patient care;
- identify and disseminate best practice to reduce the development time needed to improve data quality;
- ensure data quality levels are not unnecessarily rigorous to maintain user ownership and workloads at reasonable levels;
- define user accountabilities for data quality and the mechanisms to enforce them; and

- seek to embed the search for data quality in normal working practices and recognize its achievement in appropriate ways such as accreditation.

As these requirements suggest, the strategic management of data quality requires wide ranging skills from practitioners with experience in many different areas. The challenge is, therefore, to encourage these practitioners to develop an interest and ownership in data quality and then to undertake further study to apply their skills to the development of the necessary strategic programmes.

There is considerable theory available in disciplines outside of data quality to support the New Zealand findings that organization wide teams enhance the learning and innovation of those who participate leading to improvements throughout the organization as a whole. Encouraging staff to develop solutions themselves helps to institutionalize data quality in the organization, through the development of emergent strategy. Data quality practitioners are empowered to implement "business as usual" initiatives that they themselves believe work. This emergent strategy is guided by the overarching organizational or national strategy that provides the simple rules that encourage the seeds of innovation and maintain momentum towards the defined vision.

Whilst comparison with data quality initiatives in other sectors is important, the development of a data quality framework and strategy for health care must always recognize the inherent complexity of the "business" of health. Plsek and Greenhalgh (2001) introduce the science of Complex Adaptive Systems (CAS) to help understand and bring about change in the health care environment. A complex system is defined as "a system with many independent agents, each of which can interact with others" (Penchas, 2003), that can behave very sensitively and be influenced by small initial differences (Champagne, 2002). Health care systems are just such systems creating complex adaptive interactions that contain emergent learning and change potential (Penchas, 2003).

In summary, the management and improvement of data quality in health care relies on an action research approach through collaborative groups to understand the relevant issues, an organization wide data quality team to develop the maturity capability of the organization, and an awareness of the inherent complexity of health care that demands multidisciplinary solutions to multidisciplinary problems.

CONCLUSION AND FUTURE DIRECTIONS

The development of a Data Quality Evaluation Framework and a Data Quality Improvement Strategy as described in this article provide clear direction for a holistic and "whole of health sector" way of viewing data quality, enabling organizations to implement local innovations through locally developed strategies and data quality improvement programmes. Simple rules, such as the TDQM process and the data quality dimensions guide the change, leaving room for innovation. With these essential features in place, practitioners can use a range of other devices to embed data quality awareness and accountability in normal practice and facilitate further change.

For example, experience in using the DQEF and the benefits of better data quality information will help to generate appropriate data quality metrics. Suitable metrics are paramount to the success of the DQEF and to provide data suppliers with applicable key performance indicators for expected levels of data quality. The New Zealand research referred to provided an embryonic methodology for metrics development via its ethnicity data collections but the methodology needs further refinement and validation through empirical testing.

Organizationally, data quality practitioners should have a pivotal role in the development and implementation of new systems, including ongoing training of data collection staff on the impact of errors and the downstream uses of the data. Further, the importance of data quality, and the staff who work in this area, needs to be recognized by management teams. Recruitment of staff should include those with the skills of strategic thinking and analysis. Providing such a team with a structured programme of data quality management, with clear roles and responsibilities for the organization to manage their data from a whole of system view, will enable data quality practitioners to concentrate on improvement initiatives.

Other valuable approaches include change management theories such as appreciative enquiry (Fry, 2002), which can help to encourage the utilization of existing organizational knowledge and enact change with a minimum period of diminished performance (Elrod, 2002). The theory of "complex systems of adjustment" (Champagne, 2002; Stacey, 1993) can be instilled in the organization to encourage change through the constant interaction of people throughout the organization. Champagne (2002) notes the similarities between complexity and learning theories. Both see change in a global, integrated way as forming part of the routine life of organizations, with the change process a collective one.

This research that underpins this article was undertaken in New Zealand, but the many similarities between international health care systems and the correspondence in data quality capabilities suggest strongly that the results are generally applicable. This raises the possibility of external benchmarking (Hamel & Prahalad, 1994) between international healthcare organizations to compare performance, develop best practice, and identify key challenges. Even so, the health sector environment has some way to go before reaching second and third generation data quality management as discussed by Redman (2001). Continued research into the prevention of poor quality data through process management could lead to a health sector where all data quality is managed through prevention rather than "find and fix." This may be a difficult, even elusive, goal but its pursuit will bring benefits to all citizens.

REFERENCES

Canadian Institute for Health Information. (2003a). Data Quality Framework. Retrieved October 13, 2005 from http://secure.cihi.ca/cihiweb/dispPage.jsp?cw_page=quality_e

Canadian Institute for Health Information. (2003b). Earning Trust. Key Findings and Proposed Action Plan from the Data Quality Strategies Study. Retrieved October 13, 2005, from http://secure.cihi.ca/cihiweb/en/downloads/DADEarningTrust2003_e.pdf

Champagne, F. (2002). *The Ability to Manage Change in Health Care Organisations*: Commission of the Future of Health Care in Canada.

Crosby, P. (1980). *Quality is Free*. New York: Penguin Group.

Deming, W. E. (1982). *Out of the Crisis*. Cambridge: Massachusetts Institute of Technology.

Elrod, P. D. (2002). The death valley of change. *Journal of Organisational Change*, *15*(3), 273–291. doi:10.1108/09534810210429309

English, L. (1999). *Improving Data Warehouse and Business Information Quality*. New York: John Wiley & Sons.

Fry, R. (2002). Appreciating your past in order to transform the future. Retrieved September 26, 2005, from http://www.clevelandshrm.com/.

Hamel, G., & Prahalad, C. K. (1994). *Competing for the Future. Breakthrough Strategies for Seizing Control of Your Industry and Creating the Markets of Tomorrow*. Boston: Harvard Business School Press.

Juran, J. M., & Godfrey, A. B. (1999). *Juran's Quality Handbook* (5 ed.). New York: McGraw-Hill.

Klein, B., & Rossin, D. F. (1999). Data errors in neural network and linear regression models: An experimental comparison. *Data Quality*, *5*(1), 25.

Loshin, D. (2001). *Enterprise Knowledge Management. The Data Quality Approach*. California: Academic Press.

Penchas, S. (2003). Complexity in health care systems. *Complexus*, *1*, 149–156. doi:10.1159/000077211

Plsek, P., & Greenhalgh, T. (2001). The challenge of complexity in health care. *British Medical Journal*, *232*, 625–628. doi:10.1136/bmj.323.7313.625

Porter, M. (1991). Towards a dynamic theory of strategy. *Strategic Management Journal*, *12*, 95–117. doi:10.1002/smj.4250121008

Pringle, M., Wilson, T., & Grol, R. (2002). Measuring "goodness" in individuals and healthcare systems. *British Medical Journal*, *325*, 704–707. doi:10.1136/bmj.325.7366.704

Redman, T. C. (2001). *Data Quality. The Field Guide.* Boston: Digital Press.

Robson, W. (1997). *Strategic Management and Information Systems* (Second ed.). London: Pitman Publishing.

Stacey, R. D. (1993). *Strategic Management and Organisational Dynamics*. London: Pitman.

Strauss, A., & Corbin, J. (1998). *Basics of Qualitative Research*. Thousand Oaks: Sage Publications.

Strong, D. M., Lee, Y. W., & Wang, R. Y. (1997). Data quality in context. *Communications of the ACM*, *40*(5), 103–110. doi:10.1145/253769.253804

Tayi, G. K., & Ballou, D. P. (1998). Examining data quality. *Communications of the ACM*, *41*(2), 54–57. doi:10.1145/269012.269021

Wang, R. Y., Lee, Y. W., Pipino, L. L., & Strong, D. M. (1998). Manage your information as a product. *Sloan Management Review*, (Summer): 95–105.

Wang, R. Y., Strong, D. M., & Guarascio, L. M. (1996). Beyond accuracy: what data quality means to data consumers. *Journal of Management Information Systems*, *12*(4), 5–33.

KEY TERMS AND DEFINITIONS

Complex Adaptive System: A system with many independent agents, each of which can interact with others.

Data Quality Dimensions: Quality properties or attributes of data; a set of data quality attributes that most data consumers react to in a fairly consistent way.

Data Quality Framework: A tool for the assessment of data quality within an organization; a vehicle that an organization can use to define a model of its data environment, identify relevant data quality attributes, analyse data quality attributes in their current or future context, and provide guidance for data quality improvement.

Data Quality Improvement Strategy: A cluster of decisions centered on organizational data quality goals that determine the data processes to improve, solutions to implement, and people to engage.

Datum: A fact or value assigned to a variable; single observational point that characterises a relationship. Data is the plural noun of datum

Emergent Strategy: A series of actions converges into patterns that become deliberate when the pattern is recognized and legitimized by senior management.

Grounded Theory: A method of extracting meaning and theories from data by systematically and intensively analysing and coding the data, sentence-by-sentence, or phrase-by-phrase.

Total Data Quality Management: An approach that manages data proactively as the outcome of a process, a valuable asset rather than the traditional view of data as an incidental by-product.

ENDNOTES

[1] http://mitiq.mit.edu

[2] Each familiar, high-level, dimension is defined in context by appropriate characteristics that answer "what is/are?" questions such as "what is the level of error?". Underpinning these characteristics are "criteria" that define processes and metrics used to assess the presence of potential data quality issues, for example, "Is the error within acceptable limits?"

This work was previously published in the Encyclopedia of Information Science and Technology, Second Edition, edited by M. Khosrow-Pour, pp. 1877-1881, copyright 2009 by Information Science Reference (an imprint of IGI Global).

Chapter 1.16

Literature Review in Computational Linguistics Issues in the Developing Field of Consumer Informatics:

Finding the Right Information for Consumer's Health Information Need

Ki Jung Lee
Drexel University, USA

ABSTRACT

With the increased use of Internet, a large number of consumers first consult on line resources for their healthcare decisions. The problem of the existing information structure primarily lies in the fact that the vocabulary used in consumer queries is intrinsically different from the vocabulary represented in medical literature. Consequently, the medical information retrieval often provides poor search results. Since consumers make medical decisions based on the search results, building an effective information retrieval system becomes an essential issue. By reviewing the foundational concepts and application components of medical information retrieval, this paper will contribute to a body of research that seeks appropriate answers to a question like "How can we design a medical information retrieval system that can satisfy consumer's information needs?"

DOI: 10.4018/978-1-59904-990-8.ch043

INTRODUCTION

The Internet functions as a family physician as more and more people seek medical information on line and make subsequent healthcare decisions based on the acquired medical information. Consequently, one of the perspectives in biomedical informatics defended by the statistics of (1) significant increase in the prevalence of Internet, (2) increased concern of healthcare among general population, and (3) sheer growth in the number of medical literature available in public concentrates on the use of biomedical information by consumers. Denoted as consumer informatics, this emerging perspective focuses on the consumer's information need, access to the information, and modeling their information need for system integration (Haux, 1997; Lange, 1996; Logana & Tse, 2007; Nelson & Ball, 2004; Soergel, Tse, & Slaughter, 2004; Warner, 1995). However, simple statistics does not secure it as a robust academic discipline since the significance of healthcare information is rather determined by what's in the information and how the information can be used in addition to how users acquire the information. The core problem, in addressing this matter, is the discrepancy between user vocabulary, used by a "lay person", and professional vocabulary used by clinical professionals. While consumers search medical information on the Internet using their everyday terms, medical literature on the Internet is represented in professional terms. Consequently, key words in consumers' queries do not match the medical key words in medical documents (or match the wrong ones). This can cause a significant problem since misinformed healthcare decision is directly related to consumer's health issues. In the field of consumer informatics, therefore, a trend of research has burgeoned in designing the map that can translate (in effect "mapping" one vocabulary to another) consumer vocabulary to professional vocabulary.

The objective of this paper is to discuss concepts of consumer health vocabulary and review research endeavors to reduce the gap between consumer vocabulary and professional vocabulary. Primarily, it aims at examining current methodological approaches to map consumer vocabulary to professional vocabulary, critically reviewing them, and suggesting expanded perspective. With this literature review, researchers in the field of consumer informatics will be able to set a basis for further exploration of healthcare information system design. In addition, concepts and methods regarding vocabulary mapping reviewed here will provide the researchers with critical viewpoints to approach methodological problems and help them identify and gain insights into the system design to reduce discrepancy between consumer information need and medical domain knowledge.

The rest of the paper is structured as follows: Background concept section discusses conceptual background of consumer healthcare vocabulary and how it can be explored and developed to better facilitate links between consumer information needs and medical domain knowledge. In related work section, research studies that contribute to practical solutions of mapping consumer terms to professional terms are reviewed and analyzed. In discussion section, along with critiques for current studies, different perspectives to approach the problem are discussed. The discussion includes a brief review of semantic approach to design consumer vocabulary. Lastly, conclusion section concludes this paper.

BACKGROUND CONCEPT: CONSUMER VOCABULARY

In this section, the concept of consumer health vocabulary is discussed. The definition of consumer health vocabulary, current issues of consumer health vocabulary, and the problems of consumer health vocabulary in regards to information retrieval system are main topics of discussion in this section.

Consumer health vocabulary is a set of terms that is used by the general population when they refer to specific healthcare information needs. In a more practical sense, Zeng and Tse (2006) conceptualize it as a "combination of everyday language, technical terms (with or without knowledge of the underlying concepts), and various explanatory models, all influenced by psychosocial and cultural variations, in discourses about health topics" (p. 24). This definition implies a few major points in understanding the concept of consumer health vocabulary. First, there is a gap between consumer vocabulary and technical vocabulary, not only in lexical collections but also in the conceptualization of the overlapping vocabulary; and second, interpretation of the same term can vary among consumers with different experiences and cultural background.

A series of research studies shows examples of consumer vocabulary issues in particular healthcare situations; Chapman, Abraham, Jenkins, and Fallowfield (2003), in a cancer consultation situation, report that about half the participants in their survey study understood expressions for the "metastatic spread of cancer", e.g., 'seedlings' and 'spots in the liver'. While 63 percent correctly identified that the term 'metastasis' meant that the cancer was spreading, only 52 percent understood that the phrase 'the tumor is progressing' has a negative implication. Lerner and colleagues (2000), in the emergency department situation, describe that patients have limited understanding of medical terms. In their study, the participants were asked to answer whether 6 pairs of terms had the same or different meaning. Individual score was measured based on the number of right answers. The mean number of correct responses was 2.8 (SD = 1.2). Among the incorrect answers, the proportion of patients that did not recognize analogous terms was 79 percent for bleeding versus hemorrhage, 78 percent for broken versus fractured bone, 74 percent for heart attack versus myocardial infarction, and 38 percent for stitches versus sutures. Non-analogous terms were not also correctly recognized; 37 percent for diarrhea versus loose stools, and 10 percent for cast versus splint. Although the situation varied their studies share a common theme of problem addressing that communication between patients and doctors is not well-facilitated due to the language barrier. It is more serious in a situation where a patient does not have a medical professional to interact with, i.e., on line medical search. Making medical decision without proper information can cause a serious danger to patients. Therefore, a system that can virtually aid patients with searching for what they really want is required.

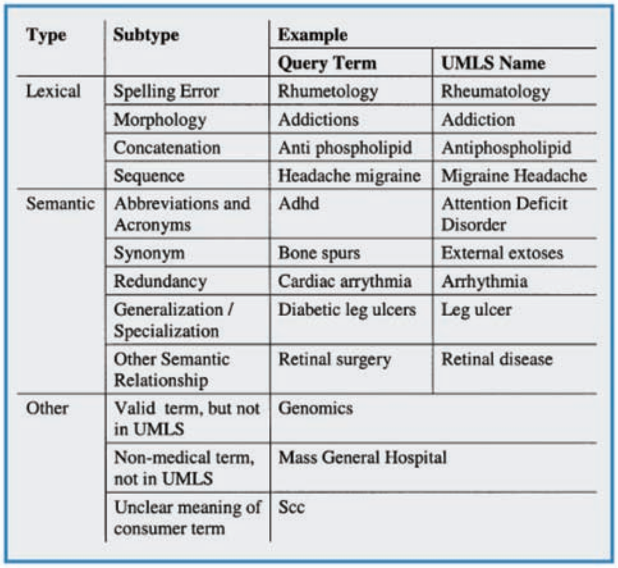
A translation mechanism can be embedded in current medical information retrieval systems so that consumers can search for what they need using their own vocabulary. Since conventional mechanism of best match information retrieval depends intensively on exact matching between user query (i.e., representation of user's information need) and pre-designed information structure of system (i.e., representation of stored texts), mapping consumer vocabulary to professional vocabulary (i.e., system vocabulary) will provide a method to reduce the communication gap. Therefore, the "development of a consumer vocabulary should be based on research that includes consumer information needs and consumers' ways of talking about and expressing those needs" (Lewis, Brennan, McCray, Tuttle, & Bachman, 2001, p. 1530), i.e., representation of consumer needs reflecting cultural context or specification.

RELATED WORK: DESIGNING A COMMUNICATION MAP BETWEEN CONSUMERS AND PROFESSIONALS

A growing number of studies identify that interterritory communication between consumers and healthcare professionals sustain a serious language barrier in terms of understanding terms and concepts. In attempting to overcome the roadblock, researchers design methods to offer links between consumer vocabulary and professional vocabulary. In this section, research studies that contribute to methodological approach of mapping consumer terms to professional terms are reviewed and analyzed.

McCray and colleagues (1999) use UMLS (Unified Medical Language System) Knowledge source server to map user queries put to National Library of Medicine Web site. They report that 41 percent of the 225,164 unique, normalized queries mapped successfully to the UMLS Metathesaurus. Mapped terms were mostly corresponding to

Figure 1. Classification of mismatches between consumer terms and UMLS (Q. T. Zeng et al., 2002)



Type	Subtype	Example	
		Query Term	UMLS Name
Lexical	Spelling Error	Rhumetology	Rheumatology
	Morphology	Addictions	Addiction
	Concatenation	Anti phospholipid	Antiphospholipid
	Sequence	Headache migraine	Migraine Headache
Semantic	Abbreviations and Acronyms	Adhd	Attention Deficit Disorder
	Synonym	Bone spurs	External extoses
	Redundancy	Cardiac arrythmia	Arrhythmia
	Generalization / Specialization	Diabetic leg ulcers	Leg ulcer
	Other Semantic Relationship	Retinal surgery	Retinal disease
Other	Valid term, but not in UMLS	Genomics	
	Non-medical term, not in UMLS	Mass General Hospital	
	Unclear meaning of consumer term	Scc	

concepts of diseases, other types of disorders, and drugs. According to their analysis, term mismatch was caused mainly by user query formulation. In other words, they noticed that user queries are in very specific level that their database may not contain or may only provide indirect information. Moreover, user queries with partial words or abbreviations which are not represented in UMLS were not also efficiently matched. The authors also identify that query length was not sufficient to fully represent consumers' information needs.

Zeng and colleagues (2002) also use UMLS function of conceptual analysis. They collected free text query terms entered into the "clinical interests" section of the Find-a-Doctor function of the Brigham and Women's hospital Web site and free text query terms entered in the MEDLINEplus site. The collected consumer terms were mapped to the UMLS 2000 edition, containing a set of concepts from various vocabularies such as MeSH, ICD-9, and SNOMED. Exact matching method resulted in mapping rate of 49 percent for the unique Find-a-Doctor query terms and 45 percent for the MEDLINEplus unique query terms to UMLS concepts. They identified unmapped terms and classified them into 12 different categories (Figure 1). The categories include spelling error, morphology, concatenation, sequence, abbreviations, synonym, redundancy, generalization, other semantic relationships, valid term not in UMLS, invalid term not in UMLS, and unclear meaning of consumer term. Among them, they also report that, lexical mismatch and conceptual mismatch constituted over 90 percent.

Smith, Stavri, and Chapman (2002) collected features and findings identified in 139 e-mail messages which were submitted to the University of Pittsburgh Cancer Institute's Cancer Information and Referral Service. The e-mail messages were coded and mapped to the 2001 UMLS Metathesaurus. Among 504 unique terms that were identified, 36 percent were exact matches to concepts in the 2001 UMLS Metathesaurus; 35 percent were partial string matches consisting of 24 percent of known synonyms for the metathesaurus concepts and 1 percent was lexical variants. 4 percent of the total terms, were not mapped to the UMLS.

Tse and Soergel (2003) collected 1,936 postings from 12 Web-based health discussion forums for consumer vocabulary corpus. They also collected 208 documents from magazines, newspapers, commercial ads, government publications, and patient pamphlets for mediator corpus. In order to control for various consumer types 14 "lay persons" identified medical expressions from the documents. According to the provided guideline, they selected terms on the basis of their personal experience, knowledge, judgment, and context in the document. The extracted terms were spelling corrected, expanded, normalized, and then mapped to concepts in the 2000-2001 UMLS Metathesaurus using MetaMap and the Knowledge Source Server. Terms that were not mapped automatically were manually mapped to the UMLS with assistance from a physician consultant. Terms were mapped 36 percent for consumer vocabulary, and 43 percent for mediator vocabulary to UMLS.

As reviewed, present technology that enables translation of consumer vocabulary to professional vocabulary is to put existing consumer vocabulary into a formal infrastructure (e.g., UMLS). With this technology consumers will be able to see familiar language and behavior on the system interface level, while requesting complex medical information to satisfy their needs.

DISCUSSION: TOWARDS SEMANTICS

Some studies have examined aspects of controlled medical vocabularies and identified the discrepancy between consumer medical terms and professional medical terms. There are also endeavors to make proper connection between those two groups of terms so that consumers can search for medical information without learning the professional terms. However, it may be also the case that consumers may not be able to distinguish useful information from the search result without proper conceptual understanding. Therefore, in addition to a solid mechanism that can translate consumer terms to professional terms, a repository of semantic definitions and relationships among those definitions is required to help consumers with reliable search. In this section, a need of semantic application for medical information retrieval system is discussed.

Queries formulated by healthcare consumers usually contain multiple concepts resulting in deeper level of information structure in search results. A pivotal point in organizing information from the search result is to understand equivalent or semantically close concept and make subsequent selection. As Lorence and Spink (2004) argue, one-to-one mapping of a term in consumer vocabulary to a term in professional one is likely to be problematic since it does not identify complex relationships among terms, e.g., relationship through specialization hierarchy. As a consequence, consumer, while seeking medical information on line, can be overwhelmed by the cognitive challenges of estimating the semantic distances between a term and various possible meanings of the term. In other words, search results through one-to-one mapping "translator" do not provide contextual cues that can aid satisfy consumer's medical information need, hence enrich the search result.

Biomedical vocabularies and ontology can play a critical role in the process of integrating healthcare information with appropriate semantics. Not only in academics but also in commercial domains, efforts are underway toward integrating biomedical information with proper context of consumer needs. For example, a healthcare application in relation to this area is designed and analyzed, e.g., the Semantic Knowledge Representation Project (National Library of Medicine, n.d.), providing scalable semantic representation of biomedical free text. Internet-based medical search technologies for consumers, in conjunction with their specific level of healthcare inquiries, is evolving to fulfill increasing need to examine the use of language in less strict way with less cultural differences. Therefore, defining and storing semantic relationships among consumer and professional vocabularies can be the next step of system design in medical information retrieval.

CONCLUSION

Designing consumer information retrieval system in the domain of biomedical informatics poses a tremendous challenge in that there are so many variables that have to be counted in the functional logic of such systems. This paper has discussed an overview of consumer informatics, consumer vocabulary mapping, in relation to consumer's medical information search on the Internet. Some studies mentioned in earlier sections examined the mismatch of consumer vocabulary with professional vocabulary while the studies reviewed in later sections have investigated term mapping. Growing opportunities for consumers to gain knowledge about specific health conditions on the Internet offers a significant implication for the design of medical information retrieval system. This paper contended that defining and storing relationships among the consumer and professional terms is required to better facilitate retrieval functions of medical information.

REFERENCES

Chapman, K., Abraham, C., Jenkins, V., & Fallowfield, L. (2003). Lay understanding of terms used in cancer consultations. *Psycho-Oncology*, *12*, 557–566. doi:10.1002/pon.673

Haux, R. (1997). Aims and tasks of medical informatics. *International Journal of Medical Informatics*, *44*, 9–20. doi:10.1016/S1386-5056(97)01254-9

Lange, L. L. (1996). *Representation of everyday clinical nursing language in UMLS and SNOMED.* Paper presented at the AMIA Annual Fall Symposium.

Lerner, E. B., Jehle, D. V. K., Janicke, D. M., & Moscati, R. M. (2000). Medical communication: Do our patients understand? *The American Journal of Emergency Medicine*, *18*(7), 764–766. doi:10.1053/ajem.2000.18040

Lewis, D., Brennan, P. F., McCray, A. T., Tuttle, M., & Bachman, J. (2001). *If we build it, they will come: Standardized consumer vocabularies*. Paper presented at the Medinfo.

Logana, R. A., & Tse, T. (2007). A Multidiscipline Conceptual Framework for Consumer Health Informatics. *Medinfo*, *12*(2), 1169–1173.

Lorence, D. P., & Spink, A. (2004). Semantics and the medical Web: A review of barriers and breakthroughs in effective healthcare query. *Health Information and Libraries Journal*, *21*, 109–116. doi:10.1111/j.1471-1842.2004.00491.x

McCray, A. T., Loane, R. F., Browne, A. C., & Bangalore, A. K. (1999). *Terminology issues in user access to Web-based medical information*. Paper presented at the American Medical Information Association Annual Symposium. National Library of Medicine, U. S. (n.d.). Semantic knowledge representation. Retrieved September 1, 2006, from http://skr.nlm.nih.gov/

Nelson, R., & Ball, M. J. (Eds.). (2004). *Consumer informatics: Applications and strategies in cyber health care*. New York: Springer.

Smith, C. A., Stavri, P. Z., & Chapman, W. W. (2002). *In their own words? A terminological analysis of e-mail to a cancer information service*. Paper presented at the American Medical Informatics Association Annual Symposium.

Soergel, D., Tse, T., & Slaughter, L. (2004). Helping Healthcare Consumers Understand: An "Interpretive Layer" for Finding and Making Sense of Medical Information. *Medinfo*, *11*(2), 931–935.

Tse, T., & Soergel, D. (2003). *Exploring medical expressions used by consumers and the media: An emerging view of consumer health vocabularies*. Paper presented at the American Medical Informatics Association 2003 Annual Symposium.

Warner, H. R. (1995). Medical informatics: A real discipline? *Journal of the American Medical Informatics Association*, *2*(4), 207–214.

Zeng, Q. T., Kogan, S., Ash, N., Greenes, R. A., & Boxwala, A. A. (2002). Characteristics of consumer terminology for health information retrieval. *Methods of Information in Medicine*, *41*, 289–298.

Zeng, Q. T., & Tse, T. (2006). Exploring and developing consumer health vocabularies. *Journal of the American Medical Informatics Association*, *13*, 24–29. doi:10.1197/jamia.M1761

KEY TERMS AND DEFINITIONS

Consumer Informatics: A branch of medical informatics that concerns healthcare consumers' information need, concentrating on their access to medical information through studying methods and models of healthcare consumers' use of information system.

Information Retrieval: A discipline that concerns effective transfer of information between creator of information and user of information. In the system perspective, representation, storage, organization, access, and distribution of information are studied, while, in the user perspective, various information seeking models and how to satisfy users' information need are studied.

Medical Literature Analysis and Retrieval System Online (MEDLINE): A database of literature in life science and medical informatics.

Medical Subject Headings (MeSH): A controlled vocabulary and/or metadata system of medical subjects for the purpose of indexing life science literature.

Ontology: Structural model that represents concepts and relations of the concepts within a domain to reason about objects in the domain.

Unified Medical Language System (UMLS): A controlled medical vocabulary with defined terms and structured mapping amongst the terms.

Vocabulary Mapping: A translation mechanism that links one language to another to promote communication between the users of different languages.

This work was previously published in the Handbook of Research on Text and Web Mining Technologies, edited by M. Song and Y. Wu, pp. 758-765, copyright 2009 by Information Science Reference (an imprint of IGI Global).

Chapter 1.17

Better Knowledge for Better Health Services:

Discovering Guideline Compliance

Stefano De Luca
Evodevo s.r.l., Italy

Enrico Memo
Ca' Foscari University, Italy

ABSTRACT

The expenses in Health Care are an important portion of the overall expenses of every country, so it is very important to determine if the given cares are the right ones. This work is about a methodology, Health Discoverer, and a consequent software, aimed to disease management and to the measure of appropriateness of cares, and in particular is about the data mining techniques used to verify Clinical Practice Guidelines (CPGs) compliance and the discovery of new, better guidelines. The work is based on Quality Records, episode parsing using Ontologies and Hidden Markov Models.

INTRODUCTION

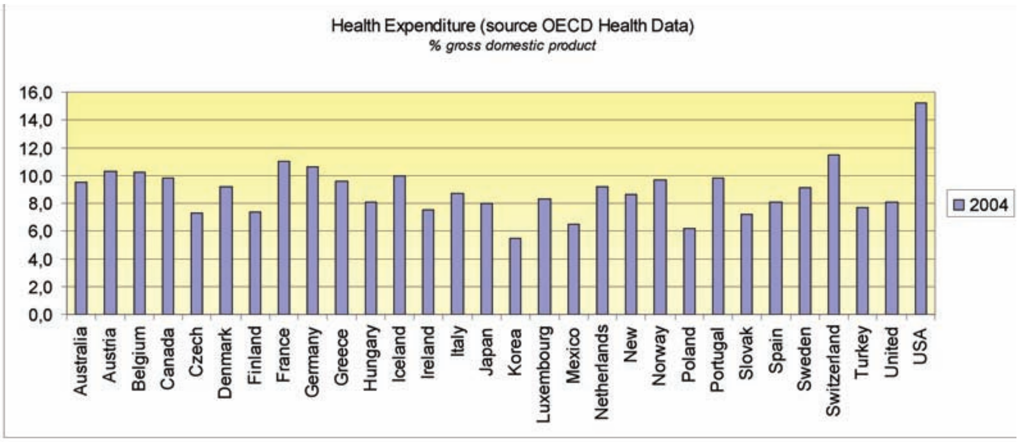
The importance of health and social services is constantly increasing as global societies grow older and the awareness of a proper care is spreading between citizens. Central point of this issue is the increasing cost of maintaining such health and social care systems. As reported by OECD (OECD Health Data 2007), the GDP (Gross Domestic Product) used in the health care varies from 5.5% (Korea) up to 15.5% (USA), in Italy we score a 8.7%. This research used the last complete data, on year 2004. In 2005, 2006 and 2007 this research assisted to a substantial growth, in Italy itexpect a raise from 8.7% up to 9%.

The research's purpose was to reach the definition of a valid and applicable method for inappropriateness reduction in medical praxis. Being sanitary economy a relatively young science, authors were sure that the quest wouldn't be easy and, being the *inappropriateness* recognized as one of the main resource waste causes within health care services, they were also sure that their search wouldn't be a trivial one.

The measure of appropriateness is strongly related to the use of Health Information Technology

DOI: 10.4018/978-1-60566-230-5.ch005

Figure 1 Health Expenditure %GDP



(HIT); use of HIT is seen as a way to increase the general quality of medical care and a way to reduce its cost (Welch et al. 2007); the clinical decision support systems increase guideline adherence in the clinical practice, thus improving health status and improving the financial elements on the long term.

The EPR (Electronic Patient Records, or Electronic Health Records) are the most discussed form of HIT. USA's Institute of Medicine (www.iom.edu) states eight core functionalities describing EPR:

- health information and data storage,
- management of results from laboratory and imagingtests,
- electronic ordering (e.g., prescription drugs and referrals),
- clinical decision support (e.g., guideline reminders),
- interoperability, and
- administrative processes such as billing.

The research intend to start from existing EPR software systems by improving their ability to manage guidelines and to discover important health properties, hidden in the health data.

This chapter describes the process and technologies authors used to approach the inappropriateness, choosing within different instruments the more suitable one, and presents the model developed starting from their consideration.

Because it is very hard to define when a care is appropriate, guidelines usage has been selecedas a metric to measure the appropriateness. The way a care is given mainly depends on the processes defined by medical institution as the correct one, and formalized as medical guidelines. So it is very important to know if the medics are following one of the possible guideline, because if it is so there are strong chances that the given care are appropriate, with greater results for the patient and lower expense for the medical institution (and typically for the government).

In section 2 it'll be discussed the process followed to establish an acceptable (by medics, institutions, government) way to measure care rightness and other, yet established metrics; this section is very important because there is a strong resistance bye medics and medical institution to measure the quality of given cares. Hence in section 3 it'll be proposeda generalized software architecture able to cope with the problems shown in section 2. Section 4 is focused on the clinical guidelines, entering in the core of thispaper, i.e., how to determine if the medics are following them. Section 5 introduces data mining techniques and process (CRISP-DM) when is applied to medical data. Section 6, Guidelines adherence discovery using Markov Chains, describes in detail the new algorithms and tools realized to effectively answer the goal: discovering guideline compliance. Last section 7 draws some conclusion.

THE PROCESS

The study started on 2004 with a project named *Health Mining* (Bei, A., De Luca, S., Ruscitti, G. and Salamon, D., 2005, De Luca S., Memo, E. et al. 2005). The goal of this study was to define a disease management methodology acceptable and approvable by the government levels and by doctors and their structures. Being disease management, and inappropriateness computation in particular, an important element in economic rate of hospitals' work, it was essential to count on a large base to support the methodology, otherwise it'd be easy to experience a reject of the entire process.

National and international instruments recognition represented the first step of followed process. The survey emphasized the following instruments:

- **PRUO:** Protocol for Hospital's Usage Revision and his American version AEP (Appropriateness Evaluation Protocol) are two measure/classification instruments aimed to split the days spent in the hospital in "appropriate" and "inappropriate";
- **Disease Staging:** a classification system for in-patients developed in the USA by prof. Gonnella, from Thomas Jefferson's University of Philadelphia. The classification algorithm evaluates patient's pathological condition and its gravity homogeneously and strictness;
- **AP Pro:** evaluates acute patient's admissions on the basis of discharge forms, it discovers low-complex assistance admissions and minimal severity admissions that, for their characteristics, are suitable for a Day Hospital treatment;
- **LEA:** Essential Assistance Levels are Italian limits established by National Sanitary Service (SSN), defining uniformity for granted cares, based on the constitutional principle that enacts health right for all citizens.

All these instruments, variously used on the Italian territory, missed one of the main characteristics we were searching for: the usefulness of the method for many different user levels.

That's why it has been chosen to proceed with an international comparison, arranging three different expert commissions coming from Sweden, United Kingdom and Germany and asking them which kind of instruments the three different nations were using to cope with inappropriateness at a national and local level. Thanks to this comparison an extremely interesting instrument used by Sweden Health Ministry at a national level since the 80's was discovered: the national quality registers.

National Quality Registers: The Swedish Model

Sweden started more than 15 years ago a specific process trying to answer the following questions: how to enhance quality? How to reduce medical practice variability? How to reduce costs?

The answer has been mainly found in the institution of pathology-specific digital registers. These registers collect data on patients, treatments and subsequent results and outcome. At the present days Sweden can count on over 40 registers and call them "Quality Registers", emphasizing the scope they are built for. National Quality Registers are basically databases collecting:

- Patient personal data
- Diagnosis
- Treatments
- Results

These kinds of data, variously aggregated and statistically analyzed, represent a precious instrument to promote and to monitor the quality enhancing in national health systems.Different registers can all provide the following data:

- Register starting date
- Approximate volume of interventions
- Register's Patient Coverage on Total Patient for a given pathology
- Register's patient inclusion criteria
- Brief list of register's variables
- Feedbacks: data reports and statistical analysis of data
- Results: conclusions emerging from reports and statistics
- Publications
- Contact information for data insertion referent and data transfer criteria

The greatest register value comes from the large amount of homogenous data collected yearly on all the national territory on different pathologies. These data analysis permits the easy, immediate and economic dissemination of new best practices. Registers can also provide a sort of alarm system for defects causing problems to patients, representing a learning and medical decision support system.

Registers are useful if, and only if, each single health unit can monitor provided services' quality in time, comparing reached level with other structures and national average. Many Swedish registers still show great variability moving from region to region: however these kind of instruments can emphasize and disseminate the best performing regional model.

In Sweden Quality Registers are not obligatory, Swedish strategy is to maintain the register participation free and voluntary-based, while maintaining anonymous the data input and publication. In these way non-excellent health units are not discriminated, but fostered in register participation (free and useful for guideline design and best practices individuation).

Registers were born at a local level, but nowadays have been adopted at a national and centralized level. Few, but essential are the register creation and maintenance rules, they must:

- Contain individual data on diagnosis, medical intervention and relative results;
- Preview doctor participation;
- Preview meetings and feedback procedures;
- Facilitate collaboration between health structures;
- Face nationally relevant themes;
- Try to involve private structures;
- Be able to generate relevant and credited information.

In Sweden registers are public and can count on a common system and software, all the data must be inputted immediately and only the complications are lately inserted. Periodically, all data are transmitted from the local database to the national one and yearly each single health unit receives his own report. General data are published yearly and used in national and international meetings.

These were the reason to focus on this instrument, but enriching it at a new level. This process ended his first run with a web based, emphasized version of a quality register based on pacemaker and AICD (Automatic Implantable Cardioverter Defibrillators) implants.Main features of the system were:

- **Web based interface:** no need for installing software on different PC and possibility of older hardware systems utilization;
- **Different user level access:** we previewed Regional, Hospital and single Doctor access to data, each level was characterized by different statistical tools;

Figure 2. Disease Management Process

- **Architecture flexibility:** for an easy application to any disease.

Health Mining project evolved then in a new project, **Health Discoverer**, that enhanced Health Mining with a Service Oriented Architecture, a stronger data mining level and ontology support.

Expected Outcome

The quality register model, based on international standards, lets surgeons to input detailed data regarding patients, symptoms, implants, administered drugs and follow-up. In the original Health Mining, we used CARDS data standard for cardiology audit.

The system offers a large range of statistical analysis on recorded data and previews different user levels: region, hospital and single doctor. The register has been thought to assure regional statistics on the observed medical care and to foster a sharper phenomenon perception; at the hospital level, statistics may be used to compare values with regional averages and to support budget making. Last but not least, the systematic data recording and the statistics availability may be able to cope with medical praxis variability, reducing it.

Process Components

The main process components are the followings:

Disease selection: while Disease Management can be applied to all kind of diseases, the assuption is that it's better to mainly cope with the most interesting illness, in term of social relevance and cost reduction, notwithstanding more managed diseases mean more reuse of medical data and better context for data mining extractions.

Guidelines selection: after a specific disease selection, this step involves the selection of (a set of) field-relevant international guidelines.

Quality records selection and adaptation: given the guidelines, variables referred by inappropriateness studies have been chosen, in order to compose a quality record; the system can use existing international quality records, but they must be localized and adapted to Disease Management purposes.

Business intelligence, Data Mining and rule extraction, new guidelines discovery: after the process phase, the technical ones. Here data are collected and used to calculate statistical groups and process/results variance, to extract rules about the care process and new approach to guidelines or part of them.

Given the task complexity, different tools were used: statistical analysis of deviance is useful to turn off the noise, while Knowledge Discovery in Database (KDD) is critical to extract valuable insights about the best practice or problems in the managed context; so typical business intelligence, statistical tools, specific data mining and rule inference tools were used. **Health Discoverer** adds to this layer an ontological discoverer that enable the model to use logical inference reasoners.

Results evaluation: the last step consists in Evidence Based Medicine usage, exploiting the results to re-plan actions, changing (if necessary) the used guidelines and improving the general process. At this stage the system is ready to re-start the process, with better confidence and control over the way health care can be managed.

All the above phases involve a validation by the scientific committee in order to avoid naïve choices or to avoid confusion between localized improvements and general ones. In this way the system is able to produce a higher quality process, to minimize the possible physicians resistance to the control tool, to design the DM tool in a doctors' positively perceived way.

SOFTWARE ARCHITECTURE

Main goal of Health Discoverer is the collection of all the relevant medical data and their analysis by data mining tools and techniques to discover Clinical Practice Guidelines (CPG) adherence and the reasons resulting in good or bad disease management. In doing so, the interest focuses in sharing knowledge on existing or discovered Guidelines and in the other kinds of knowledge, in particular derived rules, clusters and simpler statistics – including Key Performance Indicators (KPI) as usual in Business Intelligence.

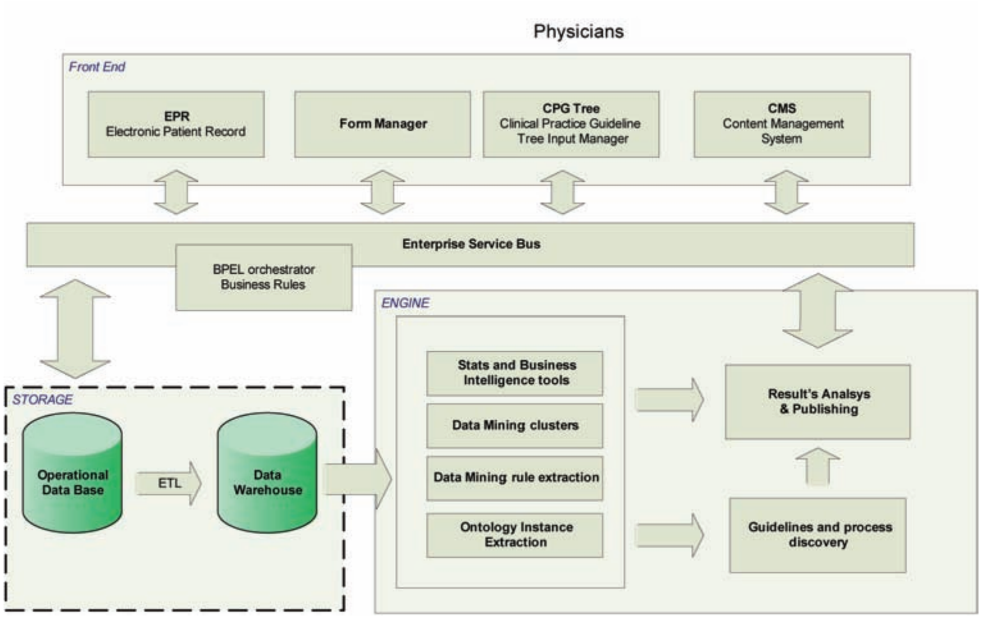
Health Discoverer has three main components: the Input Front-End sub-system, that collects all the information and give users the possibility to input data and view discovered results, the Storage sub-systems, where a Medical Data Warehouse is built, the Engine sub-system, where multiple data mining algorithms and the Guidelines discovery are applied. Health Discoverer is based on a Service Oriented Architecture (SOA), where all components are joined by an Enterprise Service Bus (ESB); the communications are carried out by standard web services and specific medical protocols, as DICOM or HL7 (e.g., for Electronic Patient Record data gathering). The flow of information and services is managed by a standard BPEL engine and a rule engine, both driving the ESB communications.The architecture is based on these macro components:

- **Front end:** is a web based front-end for input patient data and dissemination of the results. It receives data from:
    - **Forms,** generated by a generalized Form Management System which allows to rapidly create a web based way to obtain quality record data;
    - **EPR data stored in HIS system,** usingweb service and HL7/DICOM protocols to pass on EPR, this way supporting the interoperability with other products;
    - **Tree Input Management,** to manage the disease's process tree created by the guidelines, graphically represented in the front-end; the user can select the branch related to the real process of the illness cure and indicate the possible divergence. In this way alternate guidelines can be discovered or, if the guideline does not exists for the chosen illness, it can be anew created.

A **CMS** is used to disseminate results.

- **Storage:** receive the information from the Front End and collected them through an ETL (Extract, Transform and Load); once

Figure 3. Health Discoverer Architecture



in the sub-system, the data will be used to populate a data warehouse, optimized for statistical and data mining purposes.

- **Engine:** core of Health Discoverer, includes the statistical components, the data mining tools, the ontology instance extraction and guideline and process discovery.

Clinical Practice Guidelines (CPGs

Clinical Practice Guidelines (CPGs) are a method for standardization and uniform improvement of the quality of medical care. CPGs describe plans and processes aimed to cure a specific illness.

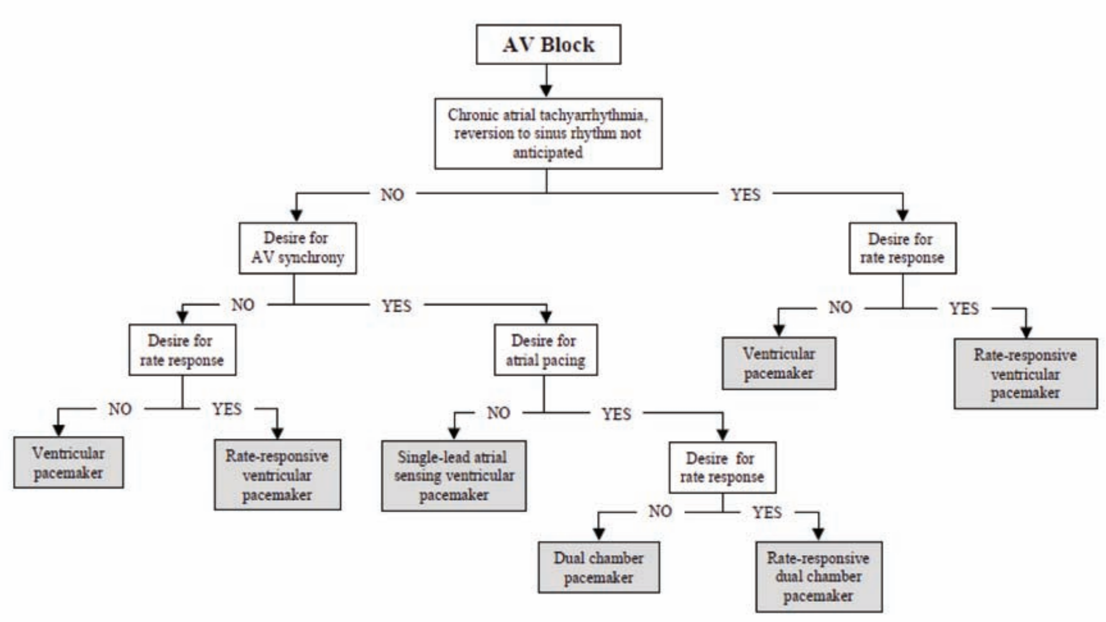
As stated by the International Organization OpenClinical (URL: www.openclinical.org), "Guidelines are designed to support the decision-making processes in patient care. The content of a guideline is based on a systematic review of clinical evidence - the main source for evidence-based care."

According the Institute of Medicine definition, clinical guidelines are "systematically developed statements to assist practitioner and patient decisions about appropriate health care for specific clinical circumstances''.

The guidelines are composed by decision trees, as in *Figure 3*, and descriptive text as "*Under certain circumstances, an implanted pacemaker may be useful for treating patients with recurrent symptomatic ventricular and supraventricu-lartachycardias*". Both the examples are from (ACC/AHA 2002), the ACC/AHA guideline for pacemaker installation.

Guidelines usage is in line with the trend towards evidence-based medicine (EBM) and healthcare, that has ever-greater support, motivated by clinicians, politicians and management concerned about quality, consistency and costs. CPGs are based on standardized medical best practice, and have been shown to be capable of supporting improvements in quality and consistency in healthcare. Many have been developed, though the process is time and resource-consuming. Many have been disseminated, though largely in the relatively difficult to use format of narrative text.

Figure 4. Selection of pacemaker systems for patients with atrioventricular (AV) block (excerpt ACC/ AHA Pacemaker Installation Guideline)



The importance of CPGs is growing, although the relatively low diffusion of EPR limits the impact on the medical practice.

Indeed, CPGs are mostly in textual form, that is impracticable by the EPR and by automatic system able to verify guideline' application. There are several systems aimed to formalize CPGs: Arden, PROforma, USAM, GEM, Helen and GLIF.

Arden Syntax (cf. URL) is a guideline specification standard widely used in Clinical Decision Support Systems; it is based on a procedural language able to encode medical knowledge and logic. Knowledge is defined in *Medical Logic Modules* that use if-then rules to describe the medical process.

PROForma (Fox, Johns & Rahmanzadeh 1998) is aimed to represent clinical knowledge in form of set of tasks; it is a language for modelling clinical processes, along with associated tools and methods for creating clinical decision support, care planning, workflow and other applications. PROforma proposes a standard, computer executable language and interchange format for clinical decisions and processes modeling, and it is used in several commercial DSS, e.g., Arezzo or Cocoon.

The Guideline Elements Model (GEM) is an XML-based guideline document model designed to organize all the life-cycle of guidelines. It is intended to facilitate translation of natural language guideline documents (i.e., the "natural" form of CPGs) into a format that can be automatically processed by machines. GEM is intended to be used throughout the entire guideline lifecycle to model information pertaining to guideline development, dissemination, implementation, and maintenance. GEM is document-centric and want to use the guideline document as a knowledge source to promotes authentic translation of domain knowledge.GLIF is being described just below, 'cause it has been choosedas a standard for this work.

All these standards, and hence the guidelines "formally" described using them, start from the idea that there are persons designing them, and so are unable to encode the knowledge extracted from data mining algorithms (as acknowledged too by Kazemzadeh et al. 2006).

GLIF

The Guideline Interchange Format (GLIF) is a language for structured representation of guidelines, developed to facilitate sharing clinical guidelines.

The GLIF model (Peleg et al. 2000) allows the specification ofa guideline as a flowchart of temporally ordered steps, representing *clinical decision* and *action steps*. Concurrency was modeled using branch and synchronization steps. GLIF's guideline class also can manage authoring information, as the author, the status, the modification date and version, the scope of the guideline, eligibility criteria, and so on.

While developing a guideline, it is important to model not only the knowledge and the task involved in the care giving, but also to manage the guideline maintenance and the instantiation of a CPG in a real clinical environment, e.g., how to get patient data from EPR or to alert medics in case of problems, and, last but not the least, the retrospective assessment of the quality of the application of the guidelines.

The modeling language of GLIF, in particular GLIF3 – its current version, permits to model the actions needed to describe a clinical guideline, using as a low level language a form of XML and an UML-like object oriented structure that permits to have different levels of description, using *classes*. In particular, GLIF3 offers:

- **Action steps:** recommendations for clinical actions to be performed (e.g., prescribe a medicine, order a test, start a treatment).
- **Decision steps:** decision criteria for conditional flowchart traversal (e.g., if-then decisions, as *if patient has high fever then do this*).
- **Branch and synchronization steps:** allow concurrency starting two or more concurrent decision flows, e.g., prescribing a medicine and a laboratory test at the same time. Synchronization reunify different branches in one single flow, e.g., receiving different tests in order to chose the next step.
- **Patient-state step:** characterizes patient's clinical state, the clinical history and diagnoses etc.

Indeed, to extract knowledge from the clinical database and then verify the adherence to the CPGs, GLIF3 has been used to model a flowchart diagram or, better, a finite state automaton with these basic modeling constructs, derived by the GLIF3 steps. This approach is similar to that of Kazemzadeh and Sartipi (2006), although the built automaton is needed to compare with discovered one and not (or at least *not only*), as in cited paper, to incorporate data mining task in a formal guideline.

Using these constructs, a CPG can be represented as a flowchart representation of a temporal sequence of clinical steps. In the following, these steps will be related to *events* to be discovered by the data mining process.

GLIF has three Representation levels: the *Author/viewer*, meant to describe the medical guideline for human understanding; the *Abstract machine*, that can be executed by an interpreter and used to analyze the correctness of guideline application; the *Integration into application environments*, to adapt to specific environments and contexts.

In this work, only the Abstract machine is mainly used, it is defined by logical expressions and actions that refer to defined concepts (medical ontology). The ontology can be formally defined by using the semantic web standards, as RDF and, more interesting, OWL (Web Ontology Language) that supersedes RDF including Description Language constructs and then allowing logical reasoning.

The GLIF standard has been chosen 'cause it is based on ontology, has a clear semantic and it can be based on OWL, that permits to extend the initial knowledge with new rules, although limited by the expressivity of Description Logic (a subset of First Order Logic).

Data Mining in Clinical Context

There is not a shared view of the adequacy of therapy, nor there is sufficient evidence of the right way to manage health care. Hence there is a strong need in having predictive modeling on Disease Management and data mining from the collected clinical work is proposed to start the process. On the other hand, this process needs to be an iterative, human-controlled one to permit the physician the evaluation of automatically generated results (clusters, trends, rules).

To remark the importance of knowledge discovery and modeling, the important Disease Management Association of America (DMAA) has a specific committee named "predictive modeling": "The mission […] is to educate the health care community about analytic tools available for increasing the efficiency and effectiveness of disease management programs." (May, J. (2006), pg. 374).

Data mining is mainly used in the process of guidelines evaluation and new best practice process discovery, although, once the needed data warehouse is complete, it is possible to work on other goals too.

An interesting improvement area is the use of temporal data mining for extraction of long processes and geographical data mining for insights from the hospitals and patients geographical positioning. This is a new frontier of data mining, and there are virtually no works on the health area (except for Rohan. B et al. (2001)).

At last, the goal is to unify the results of the data mining rule extraction with an ontology description of the guidelines; these are formalized by GLIF (GuideLine Interchange Format, for a description see (Kazemzadeh and Sartipi 2006)). The outcome consists in enriching the ontology with logic rules descriptions derived by data mining, so that inference engines, i.e., reasoners, can use them to extend the knowledge discovered by the data mining process.

Definitions

Hand, Mannila& Smyth, in their *Principles of Data Mining*, define Data Mining (DM) as "*the analysis of (often large) observational data sets to find unsuspected relationships and to summarize the data in novel ways that are both understandable and useful to the data owner.*"

In this case, clinical data are used to verify the appropriateness of the given cares, and in particular if these cares are following standard guidelines or, in case the cares are particularly successful, to extract a better guidelines. So, the goal is the building of a Clinical Decision Support System that, by interpreting the patient data using the mined knowledge within the context of the clinical guidelines, will be able to assist the decision makers and the medics to evaluate the current way of giving care and then make better decision about the process and the enforcement of the following standard CPGs.

Applying data mining in health care is not a novelty. However, there are some issues that make DM in this scientific field particular. Medical data sets are typically too large or too sparse. When data from medical machines (e.g., an ECG or a PET) or from an epidemiological study on a country are collected, millions of records, typically low-detailed, may result; for instance, in Italy all the implantations of pacemakers and AICD are registered in a large National records, but the information are limited to the initial diagnosis, personal data and the model of pacemaker installed – really too few information to state care appropriateness. On the other side, if we collect detailed data within a single Hospital, we will have lots of columns, but a small patient populations – in this study more than 300 columns (fields) are filled, but only about a hundred of patients recorded.Both cases require pushing data mining algorithms and processes to their limits (Roddick 2003).

All the most typical data mining techniques were applied to clinical data, in particular the macro areas of classification, clustery analysis and rule discovery. CRISP-DM process manages the application of these algorithms.

KDD Process: CRISP-DM

The KDD process is formalized in an industrial standard, CRISP-DM, that models the life cycle of a data mining project.The steps of CRISP's life cycle, are:

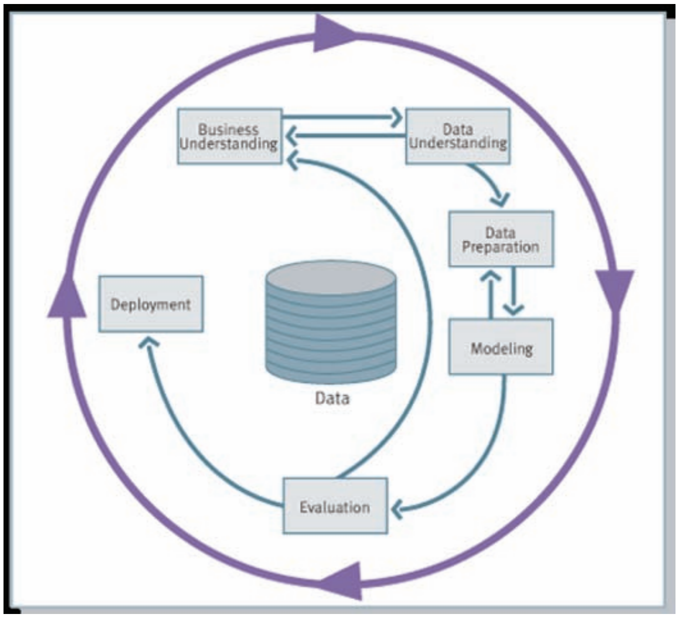
Business Understanding: Understanding the project objectives and requirements from a business perspective, then converting this knowledge into a data mining problem definition and a preliminary plan. The steps in this phase are: Determine the Business Objectives, Determine Data requirements for Business Objectives, Translate Business questions into Data Mining Objective.

Data Understanding: characterize data available for modelling. Provide assessment and verification for data.

Data Preparation: In this phase a set of examples is generated (choose sampling method, consider sample complexity, deal with volume bias issues), the attribute dimensionality is reduced (remove redundant and/or correlating attributes, combine attributes e.g. sum, multiply, difference etc.) attribute value ranges are reduced (group symbolic discrete values, quantify continuous numeric values), data are transformed (de-correlate and normalize values, map time-series data to static representation).

***Modelling*:** In this phase, various modelling techniques are selected and applied and their parameters are calibrated to optimal values. Typically, there are several techniques for the same data mining problem type. Some techniques have specific requirements on the form of data. Therefore, stepping back to the data preparation phase is often necessary.

Figure 5.CRISP-DM life cycle



***Evaluation**:* At this stage in the project a model (or models) appearing to have high quality from a data analysis perspective is built. The model must be evaluated and reviewed to be certain it properly achieves the business objectives. A key objective is to determine if there is some important business issue that has not been sufficiently considered.

Deployment: The knowledge gained will need to be organized and presented in a way that the customer can use it. It often involves applying "live" models within an organization's decision making processes, for example in real-time personalization of Web pages or repeated scoring of marketing databases. It can be as simple as generating a report or as complex as implementing a repeatable data mining process across the enterprise. In many cases it is the customer, not the data analyst, who carries out the deployment steps.

In the following subsection, the main DM techniques in health care are reviewed. An interesting more lengthy source is the paper "Selected techniques for data mining in medicine"(Lavra, 1999).

Classification

In classification the interest is focused in modelling the boundaries between classes (Hand et al. 2001). The act of classification is the training of a function to classify data item into, usually pre-defined, classes. Most popular algorithms in this class are: probabilistic learners as the Naïve Bayesian classifiers, decision tree learner as C4.5, Artificial Neural Networks.

In medicine, an evident use of classification is the partition of the all-patient group in affected and not affected by a disease. This group of algorithms are widely used in medicine, for instance in (Huang et al. 2007) to classify diabetic patients, or (Delen et al. 2005) in predicting breast cancer survivability.

Cluster Analysis

The idea in cluster analysis is to partition data (related to patients, to diseases etc.) to identify groups with a mapping function from a training sample to one of the identified groups. The algorithms in this group usually minimize a distance measure between a new item to be clusterized and the item in the yet classified cluster (e.g., using centroids). Although the goal is the same of classification, usually classification is supervised (i.e., the classification for the training samples is known) while clustering is unsupervised (the algorithms discover *per sé* the groups).

Popular algorithms for clustering are KNN – K-nearest neighbour algorithm, Kohonen maps – or SOM – Self Organizing Maps.

As stated by (Kazemzadeh. and Sartipi 2006), an application of clustering in the clinical care domain might be to perform risk analysis and assess patients' risk factors. (Churilov et al. 2004) have carried out a similar study to assign patients to three disjoint clusters of high, intermediate, and low risk patients.

Association Rules

The goal of association rule mining is the extraction of *if… then…* rules from the data, where *if A then B* will means that items of group A implies items of group B with a certain percentage *confidence*.

Association rules are very general, and can be employed in healthcare for identify patterns in data set; you can say that association rules *explain* the reasons of data, e.g., identify that a disease arises from two composed symptoms. association rules are employed for detecting when medics used a particular type of pacemaker, and then the soundness of the choice can be evaluated.

Each rule of the form $A \rightarrow B$ is characterized by the rule support, i.e., the total number of occurrence of the rule, and the confidence, i.e., the ratio of occurrence where A and B applies to the number of occurrence where only A applies. High confidence will mean that the causal relation between A and B is strong; high support will mean that the given rule that there are many sample of them can be trusted.

Rules are a form of knowledge stating the hidden relations, and so they are very important in clinical data mining. Figure 6 shows some rules extracted with C4.5 algorithm to identify the type of pacemaker medics will use and why.

There are lots of works on this subject; a new interesting one is by (Feng et al., 2006), on rule extraction in traditional Chinese medicine.

Temporal and Spatial Data Mining

Another important point is the need in analysing data within a spatial and temporal framework. This is very important in case of epidemiological studies or syndromic surveillance (cf. URL: www.syndromic.org). This type of surveillance involves collecting and analyzing statistical data on health trends – such as symptoms reported by people seeking care in emergency rooms or other health care settings – or even sales of medicines to early detection of bio terrorism attacks or diffusion of epidemics. Within the context of appropriateness, it is very interesting to discover if there are local differences in managing a specific clinical illness.

Temporal analysis is even more important, given that is important to study the order in which cares are provided. E.g., an important case of inappropriateness arises from two sequential hospital admissions related to the same illness: if the patient was correctly healed in the first admission, there were no raison to admit him again, so it is evident the care from the first admission were faulty.

Usually, in data mining temporal data are flattened in a single row that presents all the data together. This is a oversimplification that can hinder the discover of temporal relationships between cares, and it is inherently hard given the wide degree of freedom in giving care also for the same clinical condition. On the other hands, *real* temporal and spatial mining involves algorithms and processes that are heavy in computation time and not yet so reliable.

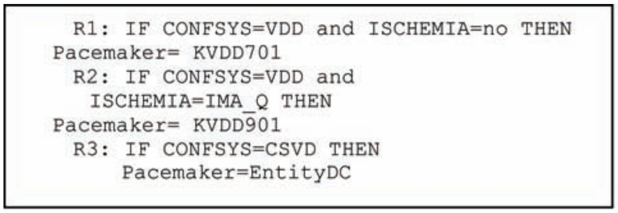
An intermediate way to approach temporal data is the segmentation in discrete *episode events*.Of course, to discover guidelines application,temporal analysisis *needed*, so the choicefallen on episode estimation that permits us to really discover CPGs uses.

Episodes

Episodes are well known in healthcare, and are the base of popular instruments as Diagnosis-Related Group (DRG) or Episode Treatment Groups (ETGs).

Diagnosis-related groups (DRGs) are a classification of hospital case types into groups expected to have similar hospital resource use. Medicare uses this classification to pay for inpatient hospital care. The groupings are based on diagnoses, procedures, age, sex, and the presence of complications or comorbidities. The DRGs may be assigned using

Figure 6. Example of extracted rule



```
  R1: IF CONFSYS=VDD and ISCHEMIA=no THEN
Pacemaker= KVDD701
  R2: IF CONFSYS=VDD and
   ISCHEMIA=IMA_Q THEN
Pacemaker= KVDD901
  R3: IF CONFSYS=CSVD THEN
      Pacemaker=EntityDC
```

different grouper, besides comparisons among different DRG versions should be done with caution since criteria are revised periodically.

Following Williams and Solon (Williams et al., 2002 - Solon et. al., 1967)episodes of care can be defined as "*A block of one or more medical services, received by an individual during a period of relatively continuous contact with one or moreproviders of service, in relation to a particular medical problem or situation*".

Although the definition is very general, it is still useful for defining how to partition the semi-continuous data found in the database. To define a block of cares as a single episode it is necessary to know the specific cares applied to the monitored disease: different diseases can have different way to compute blocks and episodes.

A transformation phase computing episodes from the database is applied. To define an episode a *key element* that identify a clinician (medic, nursery) giving an evaluation or a treatment to a patient is needed; to this key element we can link other elements (as drug prescriptions, tests and so on). In this way a fixed frame window is not used, but the construction of the episode on the relevance of care. This work is based on inpatient cares, so the construction starts from the admission to the hospital and ends with the discharge from the hospital and the subsequent patient recalls – the idea is that the sequence is relative to a complete disease management.

This is coherent with the quality records too, so we have a long sequence of more simpler episodes, each one can be atomic or a simple composition of atomic acts. The episodes are chosen to match the steps in the guidelines.

To have a sound appropriateness instrument, relevant aspects must be included in the episodes, as complications, comorbidities, important treatment as surgery.

Clinical complications: are complications arising during disease treatment that can change significantly the cares; complications can be related to the main disease, and described by the CPG. For instance, after a pacemaker installation can arose a haematoma; complication of a bronchitis can result in a pneumonia.

Comorbidities: it describes the effect of all other diseases or previous medical history (treatment, drugs etc.) an individual patient might have other than the primary disease of interest. For instance, a patient that needs a pacemaker implants *and*have HIV, requires different treatment from a patient without HIV. Comorbidities can impact heavily on the care plans, and it is important to record all the elements that can permit to differentiate patients with or without comorbidities, otherwise data mining will produce incorrect results.

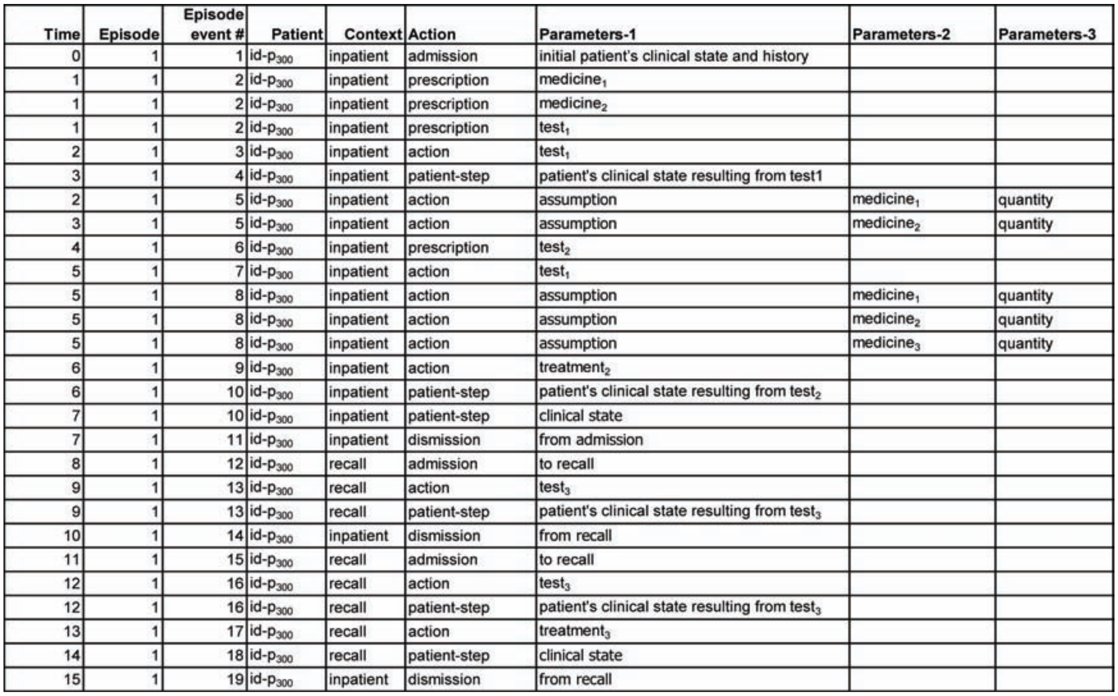
Surgery and other important treatments: in this case, surgery can be considered as a single step in the main guideline, while a specific protocol or guideline are applied to the surgery itself. So the analysis is simplified by managing this sequence of care not a single, complex, one but as the sum of two simpler sequences.

Figure 7 shows a simplified view of the data at the beginning of episode event counting process: each row contains the time when information are recorded, patient id (for privacy reason, his/her name is not used but an id only), the action type, the action parameters.

The data table contains information about a patient (id-p_{300}) admitted to the hospital, the relative given cares and two sequences of recall, the first with only a test and the second with a treatment too.

A tool is applied to this initial table to determine the episodes, *E^2T* or *Episode Extraction Tool*. E^2T uses episode discrimination criteria borrowed by the CPGs and by the medical ontology used as reference. It is useful to note that the column "action" is not present in the initial data, but was derived from the ontology too. This ontology permits to derive that to take a drug or make a test are all "action", while the test results or a screening are "patient-step"; as you can see, the concept "action", "patient-step" and so on come from GLIF3 ontology, extended to suite the needs.

Figure 7. Action records of patient cares



Time	Episode	Episode event #	Patient	Context	Action	Parameters-1	Parameters-2	Parameters-3
0	1	1	id-p_{300}	inpatient	admission	initial patient's clinical state and history		
1	1	2	id-p_{300}	inpatient	prescription	$medicine_1$		
1	1	2	id-p_{300}	inpatient	prescription	$medicine_2$		
1	1	2	id-p_{300}	inpatient	prescription	$test_1$		
2	1	3	id-p_{300}	inpatient	action	$test_1$		
3	1	4	id-p_{300}	inpatient	patient-step	patient's clinical state resulting from test1		
2	1	5	id-p_{300}	inpatient	action	assumption	$medicine_1$	quantity
3	1	5	id-p_{300}	inpatient	action	assumption	$medicine_2$	quantity
4	1	6	id-p_{300}	inpatient	prescription	$test_2$		
5	1	7	id-p_{300}	inpatient	action	$test_1$		
5	1	8	id-p_{300}	inpatient	action	assumption	$medicine_1$	quantity
5	1	8	id-p_{300}	inpatient	action	assumption	$medicine_2$	quantity
5	1	8	id-p_{300}	inpatient	action	assumption	$medicine_3$	quantity
6	1	9	id-p_{300}	inpatient	action	$treatment_2$		
6	1	10	id-p_{300}	inpatient	patient-step	patient's clinical state resulting from $test_2$		
7	1	10	id-p_{300}	inpatient	patient-step	clinical state		
7	1	11	id-p_{300}	inpatient	dismission	from admission		
8	1	12	id-p_{300}	recall	admission	to recall		
9	1	13	id-p_{300}	recall	action	$test_3$		
9	1	13	id-p_{300}	recall	patient-step	patient's clinical state resulting from $test_3$		
10	1	14	id-p_{300}	inpatient	dismission	from recall		
11	1	15	id-p_{300}	recall	admission	to recall		
12	1	16	id-p_{300}	recall	action	$test_3$		
12	1	16	id-p_{300}	recall	patient-step	patient's clinical state resulting from $test_3$		
13	1	17	id-p_{300}	recall	action	$treatment_3$		
14	1	18	id-p_{300}	recall	patient-step	clinical state		
15	1	19	id-p_{300}	inpatient	dismission	from recall		

In the database, we don't find the "branch step" and the "synchronization steps", because there are no explicit data to identify the start of parallel actions (*branch*) and the subsequent unification (*synchronization*); how explained below, this void has impact in the next step.

Once E^2T computed the episodes and its events in the clinical lifetime of a patient, the adherence to the applied therapy to official guidelines can be extracted.

Guidelines Adherence Discovery Using Markov Chains

All the elements needed to compute the guideline adherence by medics are now defined. Indeed we have:

- **databases** with all recorded cares for each patients; these databases are derived by EPR, quality records, doctors' annotations and so on;
- **a data warehouse** that unify all the collected data in homogeneous views (data marts) and permits to analyze data efficiently and with focus the subsequent data mining operations; ETL tools are used to create the data warehouse and in the process inconsistencies are cleaned and reduced and errors in the datacleared;
- **rules and clustering** computed by "traditional" data mining; these results can be used *per se* or as annotation of the discovered CPGs;
- **episodes**, extracted by a parser in accord to events and episode definition; these sequences are specific to each patient cares (in this case, the inpatient cares plus the hospital recalls);
- **formalized clinical practice guidelines**, in GLIF3 format; we can have more than one CPG for each disease, for instance we can have an European, Italian, USA, specific medical association guidelines: these

guidelines are all correct, and a medic can chose one of them or no one, preferring to decide itself.

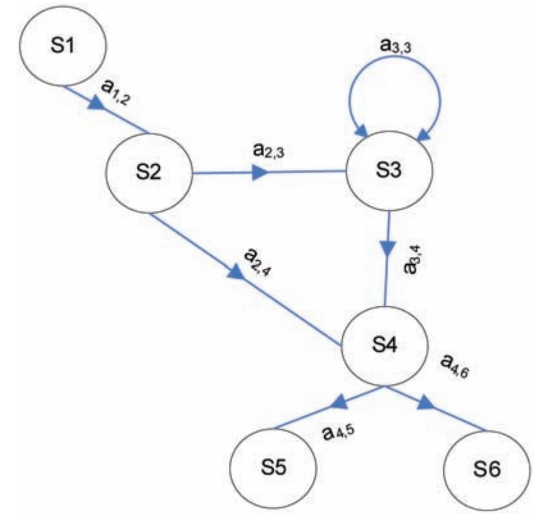
From these key elements, a way to compute the adherence to each possible guideline and, in case is needed, the *real* guideline that the hospital (or the medic) is *really* using.

Hidden Markov Models

As noticed in last paragraph, database shows only the episode events (and hence the episodes), but has no information on the process flow. The moments when clinical personal (medics, nurses and so on) operates a choice is *hidden*: we can watch the observable output of a black box, but we have no (direct) knowledge of how the box operates, i.e. we don't know the *model* of the black box. This is common situation, and there is a strong formalism used to model it: Markov Hidden Models (HMM).

HMM are related to Markov chains. The idea is to have a system that can be modelled any time as being in one of *n* distinct states $s_1, s_2, \ldots, s_n$, as illustrated by Figure 8. The system changes from a state to another according to a set of probabilities associated with each state. The time associated with state changes is denoted as $t = 1, 2, \ldots, m$ and the actual state at time t is denoted as q_t. To have a sound probabilistic description of this system the current state at time t and all the predecessor states are needed; for Markov chains, this probabilistic description is reduced to the current and the predecessor state only (Rabiner 1988, a very good introduction to Markov chains and Hidden Markov Models).

Figure 8



$$P[q_t = S_j \mid q_{t-1} = S_j, q_{t-2} = S_k, \ldots]$$
$$= P[q_t = S_j \mid q_{t-1} = S_i] \tag{1}$$

Only the process in which the right hand side of previous equation is independent of time is considered, and so the probability of the transition a_{ij}, i.e., moving from state s_i to state s_j is:

$$a_{ij} = P[q_t = S_j \mid q_{t-1} = S_i] \tag{2}$$

where

$$a_{ij} \geq 0 \tag{3}$$

and

$$\sum_{j=1}^{N} a_{ij} = 1 \tag{4}$$

Formally, a Markov chain is a triple $\left\langle E, \{p(p_1 = s)\}, A \right\rangle$ where:

- *E={1,2,...,k}* is finite set of states (or events); each state is a symbol generated by the alphabet *S*
- *p* is the set of the initial probabilities;
- *A* is the set of transition probability a_{st} for each *s*, *t* in *E*; as it said, the transition probability a_{st} is $a_{st} = P(p_i = t | p_{i-1} = s)$

More informally, a (first order) Markov chain is a probabilistic automaton where the probability of state change is related only to the previous state. A Markov chain is also an *observable* Markov model, because each state is related to an observable world event (an event of the world being modelled).

Hidden Markov Models deal with the modeling of situation where the world events cannot be observed; this is our case, because the transition is known, i.e., the effects of the state changing, but not the states themselves.

A HMM is a stochastic process determined by the two interdependent mechanisms, an underlying Markov chain having a finite number of states and a set of random functions (the black box). At each time step, the process modelled by the HMM is in a specific state and an observation is given by the random functions related to the current state. The Markov chain that is hidden to the observer changes state in accord to the transition probability from the current state to the next (using the probability matrix that describe each transition from *i* to *j*). The observer sees only the output of the random functions associated with each state and so cannot observer the Markov chain and does not observe its states – indeed, the chain is *hidden* to the observer, while the outputs are known.A formal definition of a HMM, using Rabiner notations is:

1. N is the number of states in the model; although the states are hidden, a certain correspondence between these states and world events can be assumed, in this case states of a CPG;
2. M is the number of distinct observation symbols per state, i.e., the discrete alphabet size; in this case, the types of given cares, the types of tests and so on;
3. A the transition probability matrix $A = \{a_{ij}\}$, where a_{ij} is the transition probability of the underlying Markov chain to move to state j from the (current) state i, as in eq. 2.
4. B the observation symbol probability distribution matrix $B = \{b_j(k)\}$ where $b_j(k)$ is the random function associated with state j and where

$$b_j(k) = P[v_k \text{ at } t \,|\, q_t = S_j]\ 1 \le j \le N \text{ and } 1 \le k \le M \tag{5}$$

5. Initial distribution $\pi = \{\pi_i\}$ where

$$\pi_i = P[q_1\ S_j]\ 1 \le j \le N \tag{6}$$

Hence the elements of an HMM are the model parameters of N, M, A, B, and π.N and M, that are implicit in the dimensions of the matrices A and B, can be removed simplifying the formula. So, a HMM is defined by the notation $\lambda = (A, B, \pi)$.

In conclusion, HMM is used to model the data collected about the CPGs use and discover real practice adherence, using the principles of Evidence Based Medicine: data evidence is exploited to extract knowledge about the appropriateness of (hospital) practice cares and their compliance with one of the CPGs designed by healthcare associations.

Last step to reach the goal is the computation of CPG adherence, as described in the next subsection

Chain Discoverer Tool (CDT)

In the last step in compliance discovering, there are two distinct problems: the first is computing how specific CPG are compliant with the training set, i.e., the collected data marked with episodes and episode events; the second is the discover of the best, possibly new, CPG as determined by the clinical follows up.

There is an important difference in the formalism used in the two problems: the first is a known Markov model, and so known is the underlying Markov chain, i.e., the probabilistic automaton derived by the CPG. Looking at the segment of a hearth CPG in *Figure 3*, it emerges an evidence of a tree that is the base of such automaton: remember, the only observable elements in database are the grey boxes while the branches (e.g., "Deside for rate response") are used by medics but otherwise hidden.

However, if only the compliance must be checked, known sources (from the patient-state step nodes) can be used to verify if the medic followed this particular guideline; e.g., the "chronic a trial tachyarrhythmia" can be verified by the state of the patient, and so the hidden elements are known, and a "simple" Markov chain can be used instead of an HMM.

In the second case, the free search for a good CPG, there is no prepared CPG, and so a full HMM must be used (no CPG, hence no evident Markov chain).

The *Chain Discoverer Tool* (CDT) is used to accomplish both these operations. From the E^{2}T the care data labelled with episodes are discovered, and CDT emits the percentage of compliance with a set of CPGs, and, if requested, the real automaton that describes (probabilistically) the cares given in accord to the database.

Compliance of a Specific CPG

Verification of the degree of compliance with some CPG is a useful tool to verify if a medic and his team are following one of the official guideline; it is important to remember that each disease can have more that a CPG, produced by European medic associations, or American ones or a National associations; hence, while the protocols are mandatory, the guidelines are discretionary. However, for a Clinical Decisional Support System, it is important to know if a medic are using one of the official guidelines or a new (possibly better) guideline.

To compute the distance between a specific care and one of the possible CPGs Laxman's work (Laxman et al. 2005) can be useful, talking about the discover of frequent episodes and learning hidden Markov models. An episode sequence is an ordered tuple of event types, with a time label, for instance:

$$\left\langle (E_1, t_1), (E_2, t_2), \dots, (E_n, t_n) \right\rangle$$

Removing the time label, an episode can b defined as a sequence of events

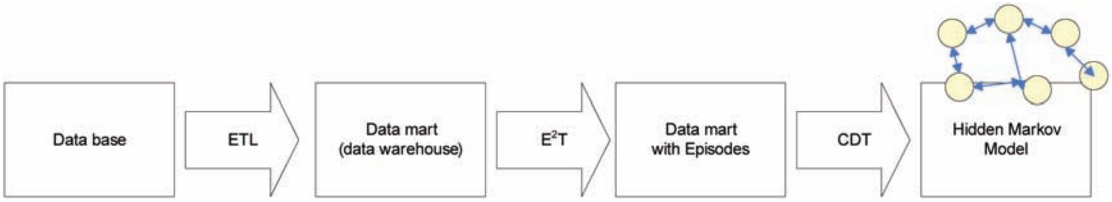
$$E_1 \to E_2 \to \dots \to E_n$$

First step is the counting of non-overlapping episode frequency. Two occurrences of an episode are said to be non-overlapping if no event associated with one appears in between the events associated with the other. The *frequency* of an episode is defined as the maximum number of non-overlapping occurrences of the episode in the event sequence.

The overlapping can happen in clinical data if a patient receive care for two distinct diseases: the two event sequences are overlapping but they belongs to distinct process and CPGs; this differentiation is carried out by the E$_2$T tool.

To determine the adherence to a CPG, the counting of episodes compatible with each CPG must be measured, that is given by algorithm 1:

Figure 9. CPG compliance discovery



```
Algorithm 1 CPGs episode occurrence counting
INPUT: C is the set of candidate episodes, i.e., the training data for a single episode
for all episodes e[i] in C
    for all event A[j] in e[i] do
        for all possible automaton $\alpha_k$
            if A[j] is acceptable by the automaton $\alpha_k$ at step j then increment $freq_{\alpha k}$
OUTPUT: frequencies $freq_{\alpha k}$ for all automata $a_k$ (i.e., all the computed CPGs)
```

This algorithm is a much simplified version of that in (Laxman et al. 2005), because we split the episode counting in the two tools, one step in E^2T and one in CDT.

Discovery of a New CPG

The discovery of a new CPG is equivalent to the discovery of the parameters of a HMM. The parameters that we are looking for are the number N of states, the transition probabilities matrix A – for each a_{ij} and hence the topology of the Markov chain, i.e., starting to a full connected graph, we want to remove the connections a_{ij} where the probability of the transition a_{ij} is 0. The topology of the HMM is defined by the type and the size of the HMM (Kwong et al. 2001). The type of HMM describes the connections between the states in the HMM and the size of HMM is the number of states used in the HMM.

There are several algorithm to compute and optimize the model parameters (the a_{ij}), in particular the Baum-Welch algorithm (Baum 2003), a specialized version of hill climbing. "Optimize" means to discover the most fit parameters compliant with the training set, i.e., the observed data.

This task is a simplified version of the general one. We can estimate the number N of states deriving it from the existing guidelines, and then start from a random probabilities matrix. We used a standard Baum-Welch algorithm although it suffer by sub-optimal optimization (given his hill-climbing derivation). A better, although more complex, solution is to use genetic algorithm that are able to optimize the model parameter *and* the topology at same time; details of such methods are described in (Kwong et al. 2001). We have planned the switch to genetic algorithms in the next version of CDT.

We can derive different HMM from the initial data. We are interested in these cases:

- **The totality of the training sample,** i.e., collected data: this experiment gives us an idea of the real process flow medics are using.
- **Only the training sample with a positive outcomes,** i.e., resulting in a successful disease management and less expensive cares; this is a very important process description, because it can be better than the "official" CPGs.
- **Only the training sample with a negative outcomes,** the inverse of the last case, i.e., resulting in unsuccessful disease management and/or expensive cares; this model is important too, because it gives us hint of how improve the cares.

The data set can be computed using filters as:

- Specific hospital;
- Specific department;
- Specific region etc.

For privacy and legal reason, it is impossible to apply the algorithm to one specific medic/team, although the instrument can be used as an improvement tool by the interested medic (and only from him/her).

CONCLUSIONS AND FUTURE RESEARCH

This research has moved from a Health-Mining project that gave interesting results, especially thanks to wide consensus gained among physicians. The objective was to put the basis for a generic disease management support system, establishing the workflow process and the needed software tools, directly reusable when moving to other diseases. In this sense, Health-Mining was a generalized framework involving not only software elements but also actors (physicians, managers, etc.).

Assuming the process has been correctly developed, actively involving relevant actors, we set-up appropriate instruments to harvest data, copying with frequent and well-known issues related to medical data collection.

Authors were sure that classical statistical analysis of patient records (as in Swedish National Quality Register) would provided us with a large amount of useful information, but they knew that this kind of process is human driven and, being a simple mechanism, would have not been able to discover unknown, probably useful, Guidelines. In fact, thanks to Gödel proof (K. Gödel, 1931), authors know that in a logic-formal system not all the true sentences can be deducted using the given rules. So, they used appropriate languages and algorithms to implement a system free to search for different kind of associations in a given database. Thanks to appropriate interpreters and Clinical Practice Guidelines discoverers they build a system able to focus data mining discovery into understandable and applicable Guidelines, going far beyond the simple statistical analysis of data and avoiding both incompleteness problems and user driven limitations. Concluding, Health Discoverer adds to Health-Mining project new temporal data mining algorithms, ontology extraction capabilities, and a better integration with standard data format for Guidelines.

As future works, authors expect to incorporate this system in the management process of large hospitals. The application to a larger set of illnesses has a direct managerial implication, because the system can act a meter and recommender on a larger audience, and can strengthen the algorithm too, because it will be challenged by more data, and they know how noise, missing data etc. can impact on an algorithm performance.

For the management side, this research has experimented the system (a simpler version) on a real project (pacemaker installation, as reported above), and it got some important results – especially for the extraction rule. Now the researchers want to measure how the system really impacts on the care and cost improvement, and if it is possible to extract better guidelines from the concrete hospital life: it has been theoretically supposed, but a concrete proof will represent a success for the entire theory.

REFERENCES

ACC & AHA. “ACC/AHA/NASPE 2002 Guideline Update for Implantation of Cardiac Pacemakers and Antiarrhythmia Devices”, (2002) American College of Cardiology Foundation and the American Heart Association; 106:2145-2161,

Baum, L. E. (2003, December). Hidden Markov Models and the Baum-Welch Algorithm . *IEEE Information Theory Society Newsletter*, *53*(4), 1–1.

Bei, A., De Luca, S., Ruscitti, G., & Salamon, D. (2005) Health-Mining: a Disease Management Support Service based on Data Mining and Rule Extraction. In *Proceedings of the 2005 IEEE Engineering in Medicine and Biology 27th Annual Conference Shanghai, China,* IEEE.

Churilov, L., Bagirov, A. M., Schwartz, D., Smith, K. A., & Dally, M. (2004) "Improving risk grouping rules for prostate cancer patients with optimization". In *HICSS*, 2004. Data Mining Group, PMML,

De Luca, S., & Memo, E. Santesso. E. et al.(2005) *L'appropriatezza dei ricoveri ospedalieri: analisi e proposte*, (in Italian: *Appropriateness of hospital admissions: analysis and proposals*), 2005 Libreria Editrice Cafoscarina (Venice).

Delen, D., Walker, G., & Kadam, A. (2005) "Predicting breast cancer survivability: a comparison of three data mining methods", in *Artificial Intelligence in Medicine* (2005) 34, pp. 113—127

EMCC (European Monitoring Centre on Change). (2003), *The future of health and social services in Europe*, European Foundation for the Improvement of Living and Working Conditions.

Feng, Y., Wu, Z., Zhou, X., Zhou, Z., & Fan, W. (2006) "Knowledge discovery in traditional Chinese medicine: State of the art and perspectives", in *Artificial Intelligence in Medicine* (2006) 38, pp. 219—236

Field, M., & Lohr, K. (1992) Clinical Practice Guidelines: Directions for a New Program, I.o.M., editor. Committee to Advise the Public Health Service on Clinical Practice Guidelines; 1992.

Forthman, M. T., Dove, H. G., & Wooster, L. D. (2000). Episode Treatment Groups (ETGs): A Patient Classification System for Measuring Outcomes Performance by Episode of Illness . *Topics in Health Information Management*, *21*(2), 51–61.

Fox, J., Johns, N., & Rahmanzadeh, A. (1998). Disseminating medical knowledge: the PROforma approach. *Artificial Intelligence in Medicine*, *14*, 157–181. doi:10.1016/S0933-3657(98)00021-9

Gödel K., *Über formal unentscheidbare Sätze der Principia Mathematica und verwandter Systeme*, Monatshefte für Mathematik und Physik, vol. 38 (1931).

Hand, D. Mannila H. & Smyth, P. (2001), *Principles of Data Mining*, MIT Press, Cambridge, MA, 2001.

Huang, Y., McCullagh, P., Black, N., & Harper, R. (2007) "Feature selection and classification model construction on type 2 diabetic patients' data", in *Artificial Intelligence in Medicine*, Volume 41, Issue 3, November 2007, Pages 251-262

Kazemzadeh, R. S., & Sartipi, K. (2006), Incoporating Data Mining Applications into Clinical Guildelines. In *Proceedings of the 19th IEEE Symposium on Computer-Based Medical Systems (CBMS'06)*, IEEE.

Kwong, S., Chau, C. W., Man, K. F., & Tang, K. S. (2001). "Optimisation of HMM topology and its model parameters by genetic algorithms", Elsevier . *Pattern Recognition*, *34*, 509–522. doi:10.1016/S0031-3203(99)00226-5

Lavrač, N. (1999) "Selected techniques for data mining in medicine", in *Artificial Intelligence in Medicine* Vol. 16 (1999) pp. 3–23

Laxman, S. Sastry, P.S., Unnikrishnan, K.P. (2005) "Discovering Frequent Episodes and Learning Hidden Markov Models: A Formal Connection", in *IEEE Transactions On Knowledge And Data Engineering*, vol. 17, no. 11, November 2005, pp. 1505 – 1517

Mattke, S., Seid, M., & Ma, S. (2007). "Evidence for the Effect of Disease Management: Is $1 Billion a Year a Good Investment?" in *The American Journal . Managed Care (Langhorne, Pa.)*, *13*(12), 670–676.

May, J. (2006). DMAA: Defining Quality in Health Care Coordination. *Disease Management*, *9*(6), 371–375. doi:10.1089/dis.2006.9.371

Mörchen, F. (2006) "Algorithms for time series knowledge mining". In Eliassi-Rad, T., Ungar, L. H., Craven, M., Gunopulos, D. editors, *Proceedings The Twelveth ACM SIGKDD International Conference on Knowledge Discovery and Data Mining*, pages 668–673, 2006.

Mörchen, F. (2007), "Unsupervised pattern mining from symbolic temporal data", in *SIGKDD Explorations* Volume 9, Issue 1, pp. 41 – 55

OECD - Organization for Economic Co-operation and development. (2007), *OECD Health Data 2007 - Frequently Requested Data*,

Peleg, M., Boxwala, A. A., Omolola, O., Zeng, Q., Tu, S. W., Lacson, R., et al. (2000). "GLIF3: The Evolution of a Guideline Representation Format" In Overhage M.J., Ed., *Proceedings of the 2000 AMIA Annual Symposium (Los Angeles, CA, 2000*), Hanley & Belfus, Philadelphia. Proforma,

Rabiner, L. R. (1989, Feb.). A tutorial on hidden Markov models and selected applications in speech recognition . *Proceedings of the IEEE*, *77*(2), 257–286. doi:10.1109/5.18626

Roddick, J. F., Fule, P., & Graco, W. J. (2003) "Exploratory Medical Knowledge Discovery Experiences and Issues", in *ACM SIGKDD Explorations Newsletter*, Volume 5, Issue 1 (July 2003), pp. 94 – 99

Rohan, B., Graham, W., & Hongxing, H. (2001) Feature Selection for Temporal Health Records. In Cheung, D., Williams, G.J. and Li, Q. (Eds.): *PAKDD 2001, LNAI 2035*, pp. 198-209.

Shahar, Y. (2004). Young. O, Shalom, E., Galperin, M., Mayaffit, A., Moskovitch, R., Hessing, A., (2004) "A framework for a distributed, hybrid, multiple-ontology clinical-guideline library, and automated guideline-support tools", Elsevier . *Journal of Biomedical Informatics*, *37*, 325–344. doi:10.1016/j.jbi.2004.07.001

Shahar, Y., Miksch, S., & Johnson, P. (2006) "A task-specific ontology for the application and critiquing of time-oriented clinical guidelines", in *Artificial Intelligence in Medicine*, Springer, Lecture Notes in Computer Science, Volume 1211/1997

Shiffman, R. N., Michel, G., Essaihi, A., & Thornquist, E. (2004), "Bridging the Guideline Implementation Gap: A Systematic, Document-Centered Approach to Guideline Implementation", in *Journal of the American Medical Informatics Association* Volume 11 Number 5 Sep / Oct 2004

Solon, J. A., Feeney, S. H., Jones, S. H., Rigg, R. D., & Sheps, C. G. (1967). Delineating episodes of medical care . *American Journal of Public Health*, *57*, 401–408. doi:10.2105/AJPH.57.3.401

Solon, J. A., Feeney, S. H., Jones, S. H., Rigg, R. D., & Sheps, C. G. (1967). "Delineating episodes of medical care" in *American . Journal of Public Health*, *57*, 401–408. doi:10.2105/AJPH.57.3.401

Tu, S. W., Kahn, M. G., Musen, M. A., Ferguson, J. C., Shortliffe, E. H., & Fagan, L. M. (1989). Episodic Skeletal-Plan Refinement on Temporal Data . *Communications of the ACM*, *32*, 1439–1455. doi:10.1145/76380.76384

Welch, W. P., Bazarko, D., Ritten, K., Burgess, Y., Harmon, R., & Sandy, L. G. (2007, May-June). Electronic Health Records in Four Community Physician Practices: Impact on Quality and Cost of Care . *Journal of the American Medical Informatics Association*, *14*(Issue 3), 320–328. doi:10.1197/jamia.M2125

Williams, G. Baxter. R., Kelman, C., Rainsford, C., He, H., Gu, L., Vickers, D., Hawkins, S., (2002), “Estimating Episodes of Care Using Linked Medical Claims Data”, in R.I. McKay and J. Slaney (Eds.): *AI 2002*, LNAI 2557, Springer, pp. 660–671, 2002.

Won, K.-J., Prügel-Bennett, A., & Krogh, A. (2006, February). Evolving the Structure of Hidden Markov Models . *IEEE Transactions on Evolutionary Computation*, *10*(1), 39–49. doi:10.1109/TEVC.2005.851271

This work was previously published in Social and Political Implications of Data Mining: Knowledge Management in E-Government, edited by MD H. Rahman, pp. 65-87, copyright 2009 by Information Science Reference (an imprint of IGI Global).

Chapter 1.18

A Classification Analysis of the Success of Open Source Health Information Technology Projects

Evangelos Katsamakas
Fordham University, USA

Balaji Janamanchi
Texas A&M International University, USA

Wullianallur Raghupathi
Fordham University, USA

Wei Gao
Fordham University, USA

ABSTRACT

As the number of open source software (OSS) projects in healthcare grows rapidly, researchers are faced with the challenge of understanding and explaining the success of the open source phenomenon. This article proposes a research framework that examines the roles of project sponsorship, license type, development status and technological complements in the success of open source health information technology (HIT) projects and it develops a systematic method for classifying projects based on their success potential. Drawing from economic theory, a novel proposition in the authors' framework suggests that higher project-license restrictiveness will increase OSS adoption, because organizations will be more confident that the OSS project will remain open source in the future. Applying the framework to a sample of open source software projects in healthcare, the authors find that although project sponsorship and license restrictiveness influence

project metrics, they are not significant predictors of project success categorization. On the other hand, development status, operating system and programming language are significant predictors of an OSS project's success categorization. Application implications and future research directions are discussed.

INTRODUCTION

"Rapidly rising healthcare costs and an epidemic of inferior healthcare quality over the past decade" (Brailer, 2005) call for an urgent and aggressive adoption of health information technology (HIT). HIT has the potential to transform the healthcare industry by increasing productivity, reducing errors and costs, facilitating information sharing and improving the quality of healthcare services (Brailer, 2005), effectively transforming the healthcare system. Yet, adoption of HIT has been slow and appears to lag the effective application of IT and related transformations seen in other industries (Goulde & Brown, 2006).

With the renewed urgency to adopt HIT, open source approaches are gaining attention (Goulde & Brown, 2006, Kantor et al, 2003, McDonald et al, 2003, Raghupathi & Gao, 2007). For example, under development in Europe is the open source project Care2X, an application with four components: hospital information system, practice management, a central data server and a health exchange protocol. The software is distributed under the GPL license. Another initiative, OpenEHR, funded primarily by the U.S. Department of Health and Human Services, is an open source application that will support health record exchange and access control services in rural Mendocino County, California. These and other similar initiatives have the potential to create low cost tools for physicians.

On a larger scale, government agencies (the predominant payers of healthcare bills) are looking for open source to meet their primary objectives of lowering costs and enabling connectivity. Canada Health InfoWay, funded by federal and provincial grants, started an open source initiative in 2005 to develop software that hospitals and HIT developers could use to ensure the reliable exchange of patient health records among various entities. The U.S. government already has placed its VistaA integrated hospital software package in the public domain to provide adopters with open source software (Goulde & Brown, 2006).

The most significant open source healthcare application is OpenVista, the open source version of Vista, developed and used by all medical centers of the U.S. department of Veterans Affairs. The Vista software and its EMR module can be purchased for $25.00 or less1, are open source by virtue of the Freedom of Information Act, and are being actively marketed by new vendors. Other open source applications include TORCH, a web-enabled EHR application believed to be usable in single practitioner offices and scalable to multi-site practices. Written in an interpreted language, TORCH is therefore operating system independent. Another clinical medical records type application is tkFP, which was implemented using a number of languages including C, C++, Python and Perl. OSCAR, an application from McMaster University, Canada, comprises several modules including an electronic patient record system, billing, referrals and secure messaging. The system requirements include Linux, Java2 SDK, MySQL and Jakarta Tomcat. GnuMED is yet another EMR built using a cross platform WxPython GUI and the Postgres relational database. FreeMed, on the other hand, uses the popular LAMP (Linux, Apache, MySQL and PHP) platform, to provide web browser-based interface.

These advances suggest that the open source development approach is a viable means to developing HIT applications. Considering these activities, OSS, itself a transformative force in the software industry, may have a significant role in this hoped-for HIT revolution, potentially affecting the development and adoption of HIT and the strategic positioning of HIT vendors. For example, a recent joint venture of Red Hat Inc. and McKesson Corp. is aiming to push IT further into U.S. healthcare through open source software (Babcock & McGee, 2007), thereby intensifying competition between Linux and Microsoft Windows (Economides & Katsamakas, 2006).

And yet while several applications have been reported in the literature (Raghupathi & Gao, 2007), primarily in the bio informatics field, hardly any rigorous studies exist to advance the understanding of OSS development in healthcare. For example, we do not have sufficient insight into the current level and speed of development of OSS in different types of healthcare organizations, and the factors that influence development and adoption.

Therefore, it is important to identify the characteristics and factors that influence software development and adoption in HIT, explain the forces behind them (e.g. sponsorship, licensing, technologies used), evaluate the effect of potential policies, and suggest the targets of such policies. To that end, this article is the first rigorous quantitative study based on objective data. A detailed analysis of open source development is one of the most overlooked aspects of HIT literature. Several HIT applications, including electronic medical record systems, are listed on the SourceForge web site, a good starting point for a comprehensive study of OSS in healthcare.

The rest of the article is organized as follows: section 2 describes the research framework for our study, drawing on work in the OSS and information systems fields. Section 3 describes the methodology and section 4 discusses the results. Finally, section 5 discusses the scope, limitations, conclusions and future research directions of our study.

RESEARCH FRAMEWORK

The primary objective of this research is to classify open source HIT projects into distinct groups based on their success and to explore the antecedents of those groups. Prior research in information systems proposed project metrics and identified antecedents of project success (Crowston & Howison, 2006, Crowston *et al*, 2006, Stewart *et al*, 2006), but there is limited research on classification frameworks that would provide more insight into open source projects (English & Schweik, 2007). For instance, Crowston & Howison (2006) discuss the need to explore the community of developers, leaders, and active users behind OSS to make decisions regarding software viability and suitability for user needs. They suggest looking at sponsorship (as a measure of success). In addition, understanding a project's life cycle and its developers' motivations is a critical basis for the open source community's impact on a project's success. Crowston *et al.* (2007) provide empirical evidence regarding the management practices of OSS teams. Specifically, the authors identify how OSS teams organize their work (focusing in particular on practices for assigning work), how these practices differ from those of conventional software development groups and thus suggest what others might learn from OSS communities.

Crowston *et al.* (2003, 2006) identified measures that could be applied to calculate the success of OSS projects based on a brief review of the literature, a consideration of the OSS development process, and an analysis of the opinions of OSS developers. They suggest that the development of success measures for OSS is important for two reasons. One, such measures would be useful to OSS project managers in assessing their projects. In many cases, third parties sponsor OSS projects so measures would help sponsors estimate a return on their investment. Two, OSS is an increasingly visible and copied method of systems development.

Drawing on prior literature in OSS and information systems we identify the relevant metrics of project success in HIT such as downloads and activity (Crowston *et al*, 2006, Stewart *et* *al*, 2006) and combine them with two extended metrics of success namely, the project rank and participation to create project clusters. Upon the creation of clusters, we explore the antecedents of such clusters. In addition to the effects of project sponsorship and license type, our framework focuses on the effect of such explanatory variables as development status, intended audience and technological factors (database environment, operating system, and programming language) on project success.

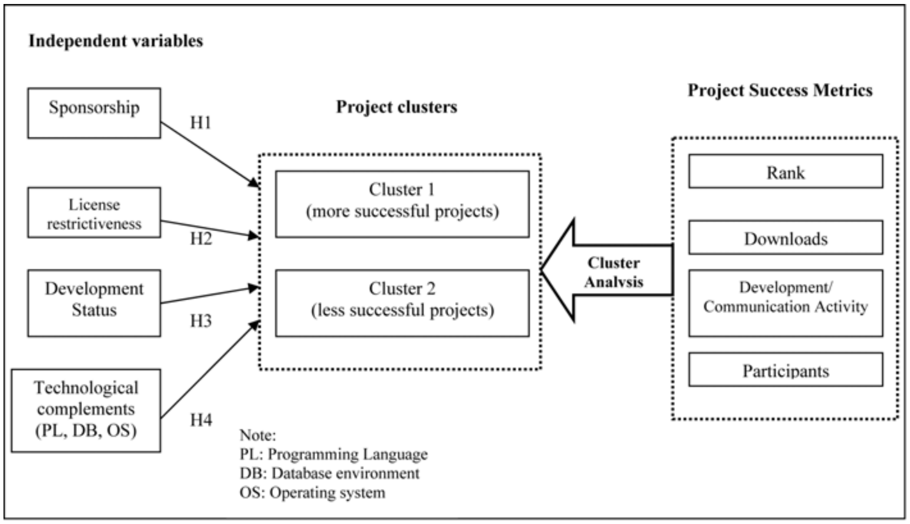
Our research framework is shown in Figure 1. The primary independent variables are *project sponsorship* and *license type.* Other variables considered in the framework are development status and technological variables such as programming language, operating system and database environment. The primary dependent variables are the success measures namely, *activity, downloads, rank, and participants.* Clusters of projects are derived using cluster analysis based on these dependent variables. Once the clusters are identified, we also examine *project sponsorship, license type*, and the other independent variables as antecedents of these clusters. Below we describe the main variables and provide the theoretical justification for the research hypotheses. Our choice of variables is consistent with previous studies on open source project success (e.g. Lerner & Tirole, 2005, Stewart *et al*, 2006). More detailed descriptions can also be found on the Sourceforge website.

DEPENDENT VARIABLES

Project rank**:** As per the SourceForge website, project rank measures the rank of a project within SourceForge database. The measure captures information about traffic, communication and development of each project.[2] Traffic reflects downloads and visits to project page. Development reflects commits to CVS repository and age of last release. Communication reflects tracker, mailing list and discussion forum activity.

- **Downloads:** This metric measures downloads' of a project's code from the project's page, as reported on SourceForge web site. Downloads reflect the popularity of a project to users and is also a proxy of use. Note that downloads are also captured in the *rank* dependent variable.

Figure 1. Research framework



- **Communication and development activity:** It refers to communication activity (tracker, mailing list, and discussion forum activity) and development activity (commits to CVS repository). Note that these are also captured in the *rank* dependent variable. Typically all projects are ranked on a percentile basis; the higher the percentile the greater the activity.
- **Participants:** As reported on SourceForge and in the context of our research framework, the participants metric refers to developers that participate in the project, not the end users. Since we are indirectly capturing the user participation from downloads metric and activity on the project website, focusing on developers' involvement is considered more important here.

Stewart *et al.* (2006) comment that project success in the context of OSS projects is a concept that varies in meaning across projects and stakeholders. Different stakeholders view success differently and are influenced by time, need, use, risk management, and a multitude of other similar context specific variables. Given the nature of OSS projects, where work is performed free of charge by voluntary developers without rigid deadlines or implementation schedules, traditional metrics of "on time and within budget completion" or "revenue generation" are not appropriate to measure the success of these projects. Alternative non-traditional metrics have emerged as indicators of success in OSS projects. These metrics may reflect the perspectives of particular stakeholders or they may have been explored in prior research. For example, (Crowston *et al*, 2003) submits that success or lack thereof is indicated by volume of traffic on the project web site, quantity of code downloads, and the number of people monitoring project activity. The attraction of voluntary developers to join and contribute to an ongoing OSS project, too, is an indicator of OSS project success, as argued by (Stewart *et al*, 2006).

INDEPENDENT VARIABLES

Sponsorship: A project is sponsored when it is initiated and/or actively supported by a healthcare organization or a firm providing health related software. We draw from economic theory in proposing that sponsorship increases a project's likelihood of success. This effect of sponsorship on success may occur because of the provision of resources such as non-volunteer developers, code (Henkel, 2006), or tools. Commitment to a process that is otherwise self-organizing as well as the signaling effect that attracts other developers and users imply that sponsorship should increase the likelihood of project success. Jeppesen & Frederiksen (2006) find that innovative users who contribute to business-hosted communities are either hobbyists or they are responsive to firm recognition. Sponsorship is a categorical variable.

The hypothesis related to sponsorship is as follows:

H1: *Project sponsorship is positively related to higher probability of project being classified into a cluster of more successful projects*

- **License type:** A software license defines the use, modification and distribution rights assigned to users. The invention of GPL (General Public License) by the Free Software Foundation was followed by a large number of open source licenses[3]. The major licenses among them are GPL, LGPL, BSD, MIT and the Mozilla Public License. Compared to closed (proprietary) licenses, GPL provides users with the right to use, modify and redistribute software. There are three main types of licenses (Lerner et al, 2003, Nelson et al, 2002), namely, strong copyleft (highly restrictive, such as GPL); weak copyleft (restrictive, such as LGPL); and non-copyleft (non-restrictive, such as BSD). Highly restrictive licenses are less likely to be usurped by an organization that takes the open source code, modifies it, and then commercializes the result. Prior research (Lerner & Tirole, 2005) examined the choice of open source license and found that restrictive licenses are used for projects targeted to end-users rather than developers, and for projects attractive to consumers, such as games. Earlier research has also argued that projects with restrictive licenses should attract more contributors (Lerner & Tirole, 2005, Stewart *et al*, 2006) but fewer users because of the restrictions and license uncertainty (Stewart *et al*, 2006).

We offer a novel interpretation of the role of licenses in open source development. We propose that a more restrictive license is positively related to higher user downloads. An organization adopting open source at the outset of a project, perceives benefits if it is assured that the project will remain open source in the future. On the other hand, users may perceive that projects with less restrictive licenses will not remain open source in the long run. Stricter licenses are convincing indicators that these projects will not get usurped and will remain open source in the future. Healthcare organizations, the predominant users of health software listed on SourceForge, usually are not interested in commercializing open source code, and for various reasons should find this assurance appealing (for instance, they can avoid commercial vendor lock-in). Projects with higher restrictiveness should also attract developers interested in protecting the openness of their work in the future.

The hypothesis pertaining to license restrictiveness is as follows:

H2: *The higher the license restrictiveness, the greater the probability of the project being classified into a cluster of more successful projects*

- **Development status:** This variable captures the software development status (e.g. pre-planning, alpha, beta, etc.). The development status pinpoints stages of the lifecycle of software development and should affect the success metrics of a project. It stands to reason that the project activity at various stages of development of an OSS project is bound of be varied. Since project success metrics (rank, downloads and activity percentile) all depend heavily on the activity of the project, implicit in our logistics regression of clusters is the hypothesis that development status does have a positive impact on the project classification into successful cluster. Formally, the hypothesis related to project development status is,

H3: *The more advanced the project development status the higher the probability of project classification into a cluster of more successful projects*

- **Technological complements:** We also explore the relationship between each of programming language (PL), operating system (OS), and database environment (DB) and project success measures. The motivation for this comparison is that these technologies are complements to the project output in the sense that output requires a PL and is deployed in a DB/OS environment. Therefore, these technologies are likely to affect the success metrics of a project. For instance, a project targeting a popular OS or DB environment may increase its success potential. Likewise a project using a popular PL in the health domain should attract developers easily as well as organizations that will use this particular PL to customize the OSS. So formally, the hypothesis related to project technological complements is,

H4: *Projects associated with successful technological complements are more likely to be classified into a cluster of more successful projects*

METHODOLOGY

Data Collection

We searched SourceForge for projects using the various keywords pertaining to health, medical, and bioinformatics applications. This search identified 607 projects related to HIT. We then excluded all indirectly related projects, such as those pertaining to pure medical sciences and medical devices. This filter narrowed the field to 258 projects. We excluded 79 of these on the basis of their not being considered typical HIT as per Institute of Medicine classification of HIT applications. An additional 5 projects were deleted because of duplication. The final sample of 174 projects was considered mainstream HIT falling as they did into such categories as health record systems, health office support, and utilities (such as interoperability). In addition, we gathered from the Internet sponsorship information on each project and integrated this data into the SourceForge dataset. A Java program was written to extract data from the web pages of each of the 174 healthcare open source projects. All extracted data were stored in a CSV (Comma Separated Values) text file that could be loaded easily into other applications, such as Excel and SPSS, for further analysis.

Data Preparation and Transformation

The variables in the research framework were coded appropriately to fit our analysis. For example, project licenses were coded as highly restrictive, restrictive and non-restrictive. Three variables that had over 15% missing data were dropped from the dataset and not considered further. SVN Repository Commits (82.7%) SVN Repository Reads (83.2%) and Mailing lists (25.7%) were the three variables that were dropped from the dataset. With regard to other variables, missing values were replaced with "0" or the median of the population (which incidentally was "0").

A large number of variables we studied had "severe positive" skew distributions. To reduce skewness, those variable values were transformed using "Inverse" transformation. Typically, inverse transformation produces values that are ranked in reverse order. It is not difficult to visualize this transformation: 10 becomes 0.1, 100 becomes 0.01, and so on. While 10 is less than 100 (10<100), the resulting 0.1 is greater than 0.01 (0.1>0.01). So we used INVerse REFlect transformation. In other words, we computed the inverse and then reflected by subtracting the inverse value from one ("1"). So an INVREF transformation of 10 results in 0.9 (or 1- 0.1) and INVREF transformation of 100 produces a 0.99 (or 1 - 0.01). The resulting numbers were ranked in the same order as they were originally. This retention of original ranking of transformed variable values made interpretation of subsequent results less confusing. With the INVREF transformation, the severity in the skewness was reduced but not removed altogether. However, the subsequent statistical processes were not overly sensitive to moderate levels of skewness, so the results are meaningful as well as useful.

Descriptive Statistics

Table 1 presents an overview of the project statistics over the past 12 months (the 12-month mean is the value for each metric by project). The mean column represents the grand mean, or the mean of each project's 12-month mean. In a few cases, data was available for fewer than 12 months; they may have been registered within the past year. All the projects were active as of May 2007.

The mean of activity percentile for the projects is 71.84, a positive indicator for the average activity. The average number of developers is 4, but there are projects with as many as 110 developers. It is interesting to note that activity percentiles range from a low of 16.31 to a high

Table 1. Project statistics

Project Activity metrics	Minimum	Maximum	Mean	Std. Deviation
Developers	0	110	4.09	9.267
Activity Percentile (last week)	16.31	99.86	71.8383	22.28214
Forum Messages	.00	3973.00	28.2414	301.15120
Mailing Lists	.00	16.00	.5747	1.69072
Open Bugs	.00	37.00	1.0862	3.94449
Total Bugs	.00	72.00	3.1379	10.88529
Open Support Requests	.00	18.00	.3161	1.52743
Total Support Requests	.00	18.00	.4138	1.76053
Open Patches	.00	3.00	.0287	.27261
Total Patches	.00	3.00	.0402	.29168
Open Feature Requests	.00	23.00	.9425	3.33611
Total Feature Requests	.00	58.00	1.4885	6.06205
Total Pages	14.67	58007.42	1473.55	5609.67
Down loads	.00	10234.25	182.13	859.86
Project Web Hits	0	40825	1580.63	5369.411
Tracker opened	.00	8.75	.15	.83
Tracker closed	0	6	.08	.552
Forum Posts	0	15	.21	1.534
Rank (Mean)	123.92	141852.50	48488.69	33776.82

of 99.86. The total pages in a project ranges from 14.67 to 58,007.

Table 2 presents the descriptive statistics for the main independent and dependent variables. The most common type of license is restrictive, followed by highly restrictive and non-restrictive. The Highly Restrictive and Restrictive licenses do have some overlap, which can be ascertained easily as follows: The mean of Non Restrictive licenses is 0.17, that is, 17% of the projects belong to the Non Restrictive license type. Therefore, 83% (100 - 17) are of the Restrictive type. The means of Highly Restrictive and Restrictive license types add up to 1.12 (0.47 + 0.65) for a total of 112%; therefore, 29% (112 - 83) of the licenses fall under both Highly Restrictive and Restrictive categories.

The prefix DB_ stands for Database Environment, IA_ for Intended Audience, OS_ for Operating System, PL_ for Programming Language, and DS_ for Development Status. To facilitate useful insight and easy interpretation, the dummy variables under each of the categories with these prefixes were first sorted in the order of descending mean values. Then we generated correlations. For example, DB_Unspecified (mean = 0.5805) is listed at the top followed by DB_OS (mean = 0.3448), DB_NOS (mean = 0.0862), and DB_Other (mean = 0.0517) in that order for the Database Environment category. This implies 58% of the projects had not specified the database environment. Additionally, approximately, 34% had employed Open Source (OS) database technologies, while 8% of projects used Non-Open Source database technologies. Approximately 6% of projects employed two or more database technologies concurrently. (Overlapping classifications can be spotted easily when, as in this case, the total of mean values for classifications

Table 2. Descriptive statistics for independent and dependent variables

	Variable (N=174)	Mean	S D
1	Activity Percentile (last week)	71.8383	22.28214
2	Developers_INVREF	0.6423	0.17427
3	Downloads_INVREF	0.5275	0.47923
4	Rank_Mean	48488.6898	33776.823
5	Restrictive	0.65	0.479
6	HighlyRestrictive	0.47	0.501
7	NonRestrictive	0.17	0.379
8	Sponsorship (0 No 1 Yes)	0.37	0.484
9	DB_UNSPECIFIED	0.5805	0.49491
10	DB_OS	0.3448	0.47668
11	DB_NOS	0.0862	0.28148
12	DB_OTHER	0.0517	0.22211
13	IA_ISOR	0.3851	0.48801
14	IA_DEV	0.2759	0.44824
15	IA_UNSPECIFIED	0.1667	0.37375
16	IA_ENDUSERS	0.0862	0.28148
17	IA_GOVNP	0.0345	0.18299
18	IA_AEU	0.023	0.1503
19	IA_EDU	0.023	0.1503
20	IA_CS	0.0057	0.07581
21	OS_Independent	0.3218	0.46853
22	OS_UNSPECIFIED	0.2759	0.44824
23	OS_MIXED	0.1782	0.38375
24	OS_PROPRIETARY	0.0977	0.29777
25	OS_OPENSOURCE	0.0632	0.24406
26	OS_PORTABLE	0.0517	0.22211
27	OS_OSX	0.0057	0.07581
28	OS_IND_WINCE	0.0057	0.07581
29	PL_JAVA	0.4138	0.49393
30	PL_Misc	0.2184	0.41435
31	PL_Unspecified	0.2069	0.40625
32	PL_PHP	0.1724	0.37883
33	PL_C	0.092	0.28979
34	PL_Python	0.069	0.25413
35	PL_CPlusPlus	0.0575	0.23341
36	PL_Perl	0.0575	0.23341
37	PL_PLSQL	0.046	0.21004
38	PL_MUMPS	0.0287	0.16754
39	PL_VB.NET	0.023	0.1503
40	PL_TcL	0.0115	0.1069

continued on following page

Table 2. Continued

	Variable (N=174)	Mean	S D
41	PL_XSL	0.0057	0.07581
42	DS_Unspecified	0.2241	0.41822
43	DS_ProdnStable	0.1667	0.37375
44	DS_Beta	0.1494	0.35754
45	DS_Planning	0.1322	0.33967
46	DS_Multiple	0.1034	0.30542
47	DS_PreAlpha	0.0977	0.29777
48	DS_Alpha	0.0977	0.29777
49	DS_Mature	0.023	0.1503
50	DS_Inactive	0.0057	0.07581

exceeds unity.) Additional insights include the fact that the mean of Sponsorship (0 = No; 1 = Yes) is 0.37, implying 37% of projects had sponsors and the remaining 63% did not. As for the intended audience classification, 38.51% of the projects targeted Industry, Science, Organizations and Research (ISOR), while 27.59% targeted Developers. Because the intended audience categories are mutually exclusive, the sum of their mean adds up to unity. While independent operating systems were preferred by 32.18% of the projects, 41.38% employ Java as the preferred programming language. These observations and others in Table 2 would be of interest to such OSS stakeholders as developers, sponsors, and users.

However, one factor limited our statistical analysis: some projects had missing data or reported none under various dummy variables, currently classified at DB_unspecified, IA_unspecified, OS_unspecifed, PL_unspecified, and DS_unspecifed. If certain data values had been reported for those projects, some of the results could potentially change.

ANALYSIS AND DISCUSSION OF RESULTS

The steps included the following: first, we incorporated select success metrics (see figure 1) as dimensions of cluster analysis to identify the project cluster; and second, we used logistic regression to analyze the antecedents of project participation in each cluster.

Cluster Analysis

Given that our model includes several types of variables including continuous (Downloads, Activity percentile), categorical (Dev_status, License Restrictiveness), and binary (Sponsorship yes/no, other dummy variables), it became necessary to employ two-step clustering unless we could find some transformations to change all of our data into continuous data types. Our solution for this research was to combine cluster analysis and logistic regression. First, we used cluster analysis to group projects into more successful and less successful groups. Then, binary logistic regression was used to understand the impact of attendant independent variables and complementary factors on the increase or decrease in the probability of each project being classified into either of the designated groups.

For the first step, we used two-step clustering to create clusters in SPSS. We let the system create the best number of clusters. Because the focus of clustering is to demarcate projects into successful or otherwise, we specified three criteria:

downloads, rank, and activity percentile for the creation of the clusters. These three dependent variables were chosen primarily because each of them is an alternative measure of project success in different perspectives (Crowston *et al*, 2003, Stewart *et al*, 2006). Dependent variable "developers" is left out of cluster creation process since the prior research didn't conclusively find association with developer participation and project success (Krishnamurthy, 2002). Typically, downloads and activity percentile are positively associated with the success of projects, while rank is negatively associated with the success since lower ranks denote greater success. Table 3 summarizes the cluster distributions for system-picked (two clusters) and user- specified (three clusters).

There is no difference in the first cluster for the system-picked or user-specified cluster creations. It is clear that Cluster 1 (which gives similar results under both processes) is distinct compared to the rest of the data. Consider the following plots of confidence intervals of three key characteristics of clusters that we used as criteria in creating the clusters. Figures 2a, 2b, and 2c show that "downloads" for the first cluster is the main characteristic that differentiates that cluster from the other two in the data set.

The reason for creating two alternate sets of clusters—first a set of two "best clusters" selected by the system and then a set of three "user-requested" clusters—was to compare the sets for developing possible insights. One important discovery was immediately evident: the first cluster remained the same with each approach. This finding suggests the occurrence of a natural cluster on the prescribed dimension viz. the chosen indicators of project success. Descriptive statistics of the best clusters picked by the system are presented in Table 4 below.

The mean values of downloads and activity percentile for cluster 1 at 0.9562 and 83.5743 were higher than those of cluster 2 at .0000 and 57.3941, respectively. Similarly the mean of rank for Cluster 1 at 27742.9737 was substantially lower than the rank of Cluster 2 at 74021.8789 (because the lower ranks indicate higher success). Downloads, Activity Percentile and Rank indicate the predictable behavior because they were used as the basis for defining the clusters in the first place.

It's significant to note that the sponsorship mean for Cluster 1 is a 0.47, indicating that 47% of projects were sponsored. However, only 27% of Cluster 2 projects had sponsors. This finding supports the framing of hypothesis H1. Restrictive and Highly Restrictive license types recorded a higher mean for the Cluster 1 than Cluster 2, supporting the framing of hypothesis H2 that the higher the license restrictiveness the greater the chance a project will be classified as successful. It is interesting to note the mean of Non-restrictive licenses for Cluster 1 is lower than that of Cluster 2, consistent with other findings.

To summarize, Cluster 1 encompasses the most successful open source projects in HIT. These projects are characterized by relatively

Table 3. Cluster distribution

	Best clusters picked by system			**Three cluster request result**		
		N	% of Total		N	% of Total
Clusters	1	96	55.2%	1	96	55.2%
	2	78	44.8%	2	36	20.7%
				3	42	24.1%
		174	100.0%		174	100.0%

Figure 2. (a) Simultaneous 95% confidence intervals for mean value of downloads by the cluster numbers (b) Simultaneous 95% confidence intervals for mean value of project rank by the cluster numbers (c) Simultaneous 95% confidence intervals for mean value of project activity percentile by the cluster numbers

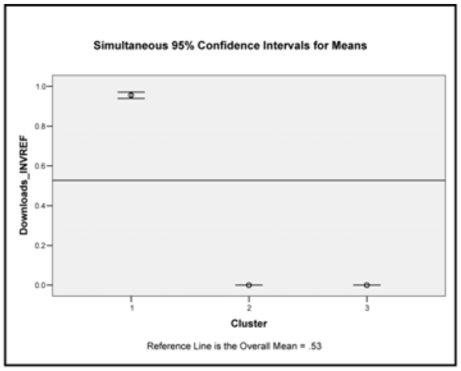


Figure 2a. Simultaneous 95% confidence intervals for mean value of downloads by the cluster numbers

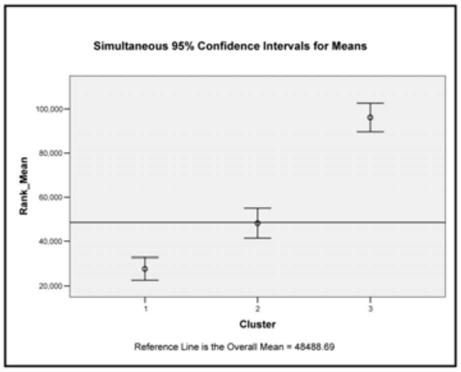


Figure 2b. Simultaneous 95% confidence intervals for mean value of project rank by the cluster numbers

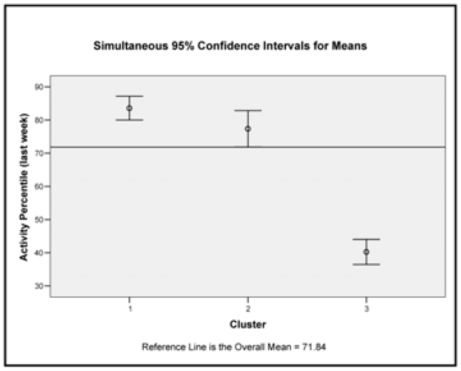


Figure 2c. Simultaneous 95% confidence intervals for mean value of project activity percentile by the cluster numbers

Table 4. Descriptive statistics for key variables of best clusters

BEST CLUSTERS: NUMBER 1				BEST CLUSTERS: NUMBER 2		
	N	Mean	Std. Deviation	N	Mean	Std. Deviation
Downloads_INVREF	96	.9562	.06377	78	.0000	.00000
Rank_Mean	96	27742.9737	20445.14634	78	74021.8789	29164.16388
Activity Percentile (last week)	96	83.5743	14.42206	78	57.3941	21.81324
TotalBugs_INVREF	96	.2728	.38090	78	.0489	.19589
Sponsorship 0 No 1 Yes	96	.47	.502	78	.24	.432
HighlyRestrictive	96	.51	.503	78	.42	.497
Restrictive	96	.74	.441	78	.54	.502
NonRestrictive	96	.16	.365	78	.19	.397
Developers_INVREF	96	.6808	.18848	78	.5948	.14236

(Note:the combination of the means of first three variables, Downloads_INVREF, Rank_mean and Activity Percentile define the centroid of the cluster).

Table 5. Descriptive statistics for key variables of three cluster definition

	Cluster 1: Successful			Cluster 2: Moderately Successful			Cluster 3:Least successful		
	N	Mean	Std. Deviation	N	Mean	Std. Deviation	N	Mean	Std. Deviation
Downloads_INVREF	96	.9562	.06377	36	.0000	.00000	42	.0000	.00000
Rank_Mean	96	27742.9737	20445.14634	36	48198.2929	16237.47063	42	96156.3811	16878.40076
Activity Percentile (last week)	96	83.5743	14.42206	36	77.3694	13.08993	42	40.2724	9.83260
TotalBugs_INVREF	96	.2728	.38090	36	.0646	.22475	42	.0354	.16894
Sponsorship 0 No 1 Yes	96	.47	.502	36	.22	.422	42	.26	.445
HighlyRestrictive	96	.51	.503	36	.44	.504	42	.40	.497
Restrictive	96	.74	.441	36	.58	.500	42	.50	.506
NonRestrictive	96	.16	.365	36	.28	.454	42	.12	.328
Developers_INVREF	96	.6808	.18848	36	.6145	.14858	42	.5779	.13632

(Note: there is no difference in the profile of the first cluster compared to the first cluster under best clusters picked by the system).

high downloads, high rank, and more developers. Cluster 1 projects are also more likely to be sponsored, and they have more restrictive licenses. These observations are consistent with our research framework.

Table 5 presents the descriptive statistics for the three-cluster definition.

The combination of the means of the first three variables in the table defines the centroid of each cluster. The mean of total bugs is higher for successful projects than it is for less successful projects. If one infers that the improvements to projects are based on total bugs reported, then we can surmise that reporting of more bugs indicates higher activity levels and better quality patronage. Sponsorship and license restrictiveness across the three clusters were generally consistent with prior research findings.

Logistic Regression

According to Mertler & Vannatta (2002), "logistic regression has the same basic purpose as discriminant analysis—the classification of individuals into groups." They go on to elaborate that "logistics regression seeks to identify a combination of IVs (independent variables)—which are limited in few, if any, ways—that best predicts membership in a particular group, as measured by a categorical DV (dependent variables)."

One advantage is that no assumption need be made that the predictors are normally distributed, linearly related, or have equal variances within the groups. Accordingly, we do not specifically screen the data for normality, linearity or homoskedasticity in preparation for the logistic regression. Further, since we have used "inverse reflect" transformation on the continuous variables to facilitate other statistical models, and most of the predictors are either categorical or binary, we have effectively avoided the problems with outliers. A preliminary multiple regression was performed to examine multicollinearity among the predictor variables and revealed the tolerance for all variables to be greater than 0.2, the recommended tolerance as per (Field, 2005).

As explained under cluster analysis section, Downloads emerged as the single most dominant factor in the creation of clusters. We left "downloads" out of the binary logistic regressions so that we might understand the impact of other predictors. Since the system picked only two clusters as best clusters, we limit the logistic regression discussion to the two clusters picked by the system. Instead of a single categorical variable "Development Status" (Dev_status) on a scale of 1-7 (denoting Planning, Pre-Alpha, Alpha, etc.), we coded binary 0/1 for each development status stage. Similarly, we coded binary dummy variables for the intended audience and programming language and other categorical variables as discussed above.

A Backward Stepwise Binary Logistic Regression was conducted to determine the independent variables that are significant predictors of the classification of projects into best cluster categories. The regression results indicate that the overall model of 11 predictors and a constant is significant in distinguishing between "successful" and less "successful" projects. (- 2 Log likelihood = 153.774; χ^2 (11) = 85.576; p<.0001). The model correctly classified 81.6% of the cases. Regression coefficients that are significant in the equation that predicts the cluster membership are presented in Table 6 below. Since the Wald statistic is considered to be very conservative and by adopting a liberal significance level (p<.05 or p<.1), nine of the 11 variables are found to be significant contributors to predicting the project category.

Hypotheses Testing

The results obtained from a logistic regression are somewhat different from the other types of regression equations in that, what is predicted in a logistic regression is the probability of a case being classified into a category rather than the value of a DV. The odds ratio or the Exp (B) indicates increase (or decrease if the B value is negative) in odds of being classified in a category when the predictor variable increases by 1. Therefore, the Exp (B), the odd ratio for programming language (PL_CPlusPlus) at 7.736, indicates that for an increase of 1 unit (in this case the flip of 0 to 1 of the dummy variable) there is 7.736 times likelihood of the project being successful for every 1 time of likelihood of project being unsuccessful.

Surprisingly, sponsorship is not indicated at all as a significant predictor of a project success. Therefore, Hypothesis H1 doesn't find support. However, non restrictive license does appear as a

Table 6. Regression coefficient obtained under binary logistic regression

Variable	B	Wald	Df	Sig.	Exp(B)
DS_ProdnStable	1.933	9.645	1	.002	6.912
DS_Planning	-3.403	8.233	1	.004	.033
TotalBugs_INVREF	-2.289	7.739	1	.005	.101
PL_PHP	-1.618	7.535	1	.006	.198
OS_Proprietary	1.334	7.397	1	.007	3.797
DS_Multiple	1.930	5.334	1	.021	6.888
DS_Beta	1.272	4.068	1	.044	3.569
PL_CPlusPlus	2.046	3.157	1	.076	7.736
NonRestrictive	-.939	2.783	1	.095	.391

Dependent variable: Cluster Number (1 or 2)

significant factor having an effect on project classification. Our hypothesis concerning the project licensing was that the higher restrictive licenses lead to project success. To support this hypothesis, one would like to have seen highly restrictive license obtaining a higher Exp (B) than restrictive license and non restrictive license's Exp (B) values respectively. But that was not the case here. So hypothesis H2 also fails to find support.

Three development status levels, including in order Production Stable, Multiple and Beta, have high odds ratios for indicating greater influences of those variables in influencing the probability of the project classification. This evidence provides support for hypothesis H3.

Programming language (PHP, C++), operating system (Proprietary) are predictors of project classification. Providing support for H4, these findings suggest that the success of a project is related to the availability of complementary assets, such as programming skills of developers and operating systems employed by users. Thus, technological factors such as choice of programming language and choice of target operating system strongly influence project success, and should be carefully chosen by project leaders.

Project leaders should carefully analyze and understand the impact of these variables (factors) and their tradeoffs. To summarize, while sponsorship encourages developer participation and higher activity in a project (based on past research findings), it does not guarantee the translation of these positive effects into higher downloads or a higher rank for the project. It is surprising that sponsorship did not influence project success. With regards to license restrictiveness, while it attracts more downloads and consequently results is a higher project rank and higher activity percentile (based on past research findings), we found in Table 6 that license restrictiveness does not guarantee the project classification into the successful projects cluster. This last finding is somewhat inconsistent with the increased downloads and higher activity percentile.

Several inferences can be drawn. While project sponsorship and license restrictiveness had significant influence on project success metrics, they did not directly impact project classification as successful or less than successful. Project development status indeed finds a prominent place in the logistics regression results. This suggests that the stages of development status have significant impact on project classification. Further, it is noted that programming language and operating system also have significant impact on project classification.

CONCLUSION AND FUTURE RESEARCH

This study proposed a research framework that explains open source project success and developed a method of classifying open source HIT projects. That identification of project classes provides useful insights to all OSS stakeholders in terms of project success and the drivers of that success. The study illustrates the usefulness of this approach in the context of HIT projects, while future research can leverage this method to other open source settings. Interestingly, development status, programming language (PHP, C++), and operating system (proprietary) are predictors of project classification. These findings suggest that the success of a project is related to such complementary assets as programming skills of developers and operating systems used by users. Thus, not only legal/social factors (such as license, organizational sponsorship) but also technological factors (such as choice of programming language and target operating system) strongly influence project success. Leaders of future projects should carefully consider the tradeoffs between these variables.

Before we emphasize the contributions, a number of limitations should become explicit. Since data from SourceForge was gathered at a specific time, this study is a snapshot in time. We recognize, too, that not all open source HIT projects are registered with SourceForge; many are registered at Freshmeat and at other related web sites. And many high profile projects maintain their own developer sites. Another limitation is that some projects may have outdated or erroneous data in their listings, not to mention those projects for which there was missing data. We assume that the HIT-related projects found on SourceForge, given the sites popularity and the large number of projects and developers registered there, are representative of the overall open source movement in healthcare.

The study makes a number of important contributions. First, we use cluster analysis to identify groups of successful and unsuccessful projects on SourceForge and find predictors of participation in each group. This systematic approach can benefit future studies that attempt to identify different types of projects in other domains. Second, we develop a theoretical framework that examines the role of technological complements, project sponsorship, development status and license type in the pattern of open source development projects and we test related hypotheses. Drawing from economic theory, a novel proposition in our framework suggests that higher project-license restrictiveness will increase OSS adoption, because organizations will be more confident that the OSS project will remain open source in the future. Third, we demonstrate how open source development may be better understood in the context of a specific domain—healthcare, and we provide insights on the status of open source development in that domain.

Project sponsors, such as firms or organizations, too can benefit from our insights. These findings have the potential to help sponsors identify projects worthy of their time and resource investments, whose success would enhance both brand recognition and market presence. Further, the programming language, database technology, and operating system preferences of developers and users of open source software projects are useful information to IT firms related with these technologies.

Regarding HIT, future research should consider the open source development dynamics (Katsamakas & Georgantzas, 2007) in the HIT context. The impact of OSS on HIT diffusion is another area worth investigating. A time series analysis and longitudinal studies may provide more sophisticated insights into the OSS development process.

Future research might consider a study that compares generic OSS (e.g. projects listed on

SourceForge and Freshmeat) and those developed in-house (e.g. bioinformatics applications). Detailed case studies of important development projects should provide a richer understanding of open source development in healthcare. A related problem to be examined is the adoption of open source software by healthcare organizations. While OSS applications development in health has great potential, the research framework, classification approach and findings presented here may be applied to other industries and organizations. But clearly open source development, especially with regard to healthcare, is a growing field. This is good and timely news given the need for HIT, wherein lies the opportunity to transform an entire industry.

REFERENCES

Babcock, C., & McGee, M. K. (2007). Microsoft Vs. Open Source Moves Into Healthcare. *InformationWeek*, *1128*, 31–32.

Brailer, D. J. (2005). Economic Perspectives on Health Information Technology. *Business Economics (Cleveland, Ohio)*, *40*(3), 6–14. doi:10.2145/20050301

Crowston, K., Annabi, H., & Howison, J. (2003). Defining Open Source Software Project Success. *Proceedings of the 24th International Conference on Information Systems* (pp. 1-14).

Crowston, K., & Howison, J. (2006). Assessing the Health of Open Source Communities. *Computer*, *39*(5), 89–91. doi:10.1109/MC.2006.152

Crowston, K., Howison, J., & Annabi, H. (2006). Information Systems Success in Free and Open Source Software Development: Theory and Measures. *Software Process Improvement and Practice*, *11*(2), 123–148. doi:10.1002/spip.259

Crowston, K., Li, Q., Wei, K. N., Eseryel, U. Y., & Howison, J. (2007). Self-organization of Teams for Free/Libre Open Source Software Development. *Information and Software Technology*, *49*(6), 564–575. doi:10.1016/j.infsof.2007.02.004

Economides, N., & Katsamakas, E. (2006). Two-Sided Competition of Proprietary vs. Open Source Technology Platforms and the Implications for the Software Industry. *Management Science*, *52*(7), 1057–1071. doi:10.1287/mnsc.1060.0549

English, R., & Schweik, C. (2007). Identifying Success and Tragedy of FLOSS Commons: A Preliminary Classification of Sourceforge.net Projects. In *IEEE International Conference on Software Engineering*, Minneapolis, Minnesota.

Field, A. (2005). *Discovering Statistics using SPSS*. Thousand Oaks, CA: Sage Publishing.

Goulde, M., & Brown, E. (2006). *Open Source Software: A Primer for Healthcare Leaders.* Forrester Consulting.

Henkel, J. (2006). Selective Revealing in Open Innovation Processes: The Case of Embedded Linux. *Research Policy*, *35*(7), 953–969. doi:10.1016/j.respol.2006.04.010

Jeppesen, L. B., & Frederiksen, L. (2006). Why Do Users Contribute to Firm-hosted User Communities? The Case of Computer-controlled Music Instruments. *Organization Science*, *17*(1), 45–63. doi:10.1287/orsc.1050.0156

Kantor, G. S., Wilson, W. D., & Midgley, A. (2003). Open-source software and the primary care EMR. *Journal of the American Medical Informatics Association*, 616. doi:10.1197/jamia.M1403

Katsamakas, E., & Georgantzas, N. (2007). Why Most Open Source Development Projects Do Not Succeed? In *Proceedings of IEEE International Conference on Software Engineering*, Minneapolis, Minnesota.

Krishnamurthy, S. Cave or Community? (2002) An empirical examination of 100 mature open source projects. *First Monday*, 7(4). http://www.firstmonday.dk/issues/issue7_6/Krishnamurthy/index.html.

Lerner, J., & Tirole, J. (2002). Some Simple Economics of Open Source. *The Journal of Industrial Economics*, *50*(2), 197–234.

Lerner, J., & Tirole, J. (2005). The Scope of Open Source Licensing. *Journal of Law Economics and Organization*, *21*(1), 20. doi:10.1093/jleo/ewi002

McDonald, C. J., Schadow, G., Barnes, M., Dexter, P., Overhage, J. M., Mamlin, B., & McCoy, J. M. (2003). Open source software in medical informatics-why, how and what. *International Journal of Medical Informatics*, *69*, 175–184. doi:10.1016/S1386-5056(02)00104-1

Mertler, C. A., & Vannatta, R. A. (2002). *Advanced and Multivariate Statistical Methods* (2nd ed.), (p. 313)., Los Angeles, CA: Pyrczak Publishing.

Nelson, M., Sen, R., & Subramaniam, C. (2006). Understanding Open Source Software: A Research Classification Framework. *Communications of the AIS, 17.*

Raghupathi, W., & Gao, W. (2007). An Eclipse-based Development Approach to Health Information Technology. *International Journal of Electronic Healthcare*, *3*(4), 433–452. doi:10.1504/IJEH.2007.015322

Stewart, K. J., Ammeter, A. P., & Maruping, L. M. (2006). Impacts of License Choice and Organizational Sponsorship on User Interest and Development Activity in Open Source Software Projects. *Information Systems Research*, *17*(2), 126–144. doi:10.1287/isre.1060.0082

ENDOTES

[1] Data as of Oct 2007.

[2] For more information see: http://sourceforge.net/forum/forum.php?forum_id=465092

[3] The Open Source Initiative website lists more than 50 approved licenses complying with the open source definition (see http://www.opensource.org/licenses/, accessed August 2, 2006)

This work was previously published in International Journal of Healthcare Information Systems and Informatics, Vol. 4, Issue 4, edited by J. Tan, pp. 19-36, copyright 2009 by IGI Publishing (an imprint of IGI Global).

Chapter 1.19

Cybermedicine, Telemedicine, and Data Protection in the United States

Karin Mika
Cleveland State University, USA

Barbara J. Tyler
Cleveland State University, USA

ABSTRACT

This chapter provides an overview of law relating to online and Internet medical practice, data protection, and consumer information privacy. It provides a comprehensive overview of federal (HIPAA) and state privacy laws, concluding that both those legal resources leave gaps in consumer protection and provide no real penalties for violating the laws. The authors educate the readers to the legal and data protection problems consumers will encounter in purchasing medical and health services on the Internet. Furthermore, the authors recount some actual case studies and follow those with expert advice for those Internet consumers who wish to be not merely informed, but also safe. The authors not only educate the readers to the lack of protection afforded to them but also advocate throughout the chapter that the United States must enact more federal protection for the consumer in order to deter privacy violations and punish criminal, negligent, and wilful violations of personal consumer privacy.

DOI: 10.4018/978-1-60566-012-7.ch018

INTRODUCTION

The practice of medicine is not immune from the information age. The use of the Internet, including e-mail, in medical practice is altering the traditional method of delivering medical care. Millions of Americans now rely upon the Internet as a primary source of medical information or education about their own symptoms, conditions, diagnoses, and treatments. The practice of **telemedicine,** consulting with another physician by using technology, is constantly evolving and expanding into areas never before imagined. Physicians are establishing their own Web sites and some few are now practicing medicine on the Internet.

The progression of the traditional practice of medicine in cyberspace has brought with it many issues related to privacy and **online data protection**. No longer is the **physician-patient relationship** limited to an in-person office consultation that carries with it the legal protections of doctor-patient privilege. Rather, the practice of medicine has evolved to include interactions that might not have ordinarily been considered a **physician-patient relationship**, and these contacts may stretch across both real and virtual boundaries. In fact, the interactions are, at times, both real and virtual, and the consumer-patient is now in a situation where it is difficult to identify exactly who is the party on the other end.

This chapter will provide an overview of the law relating to **cybermedicine,** medicine practiced without traditional in-person contact, and **telemedicine,** in terms of data protection and other legal complications related to licensing and a conflict of state laws. The chapter will examine the laws applicable to Web sites where medical diagnosis or the purchase of medical services (including prescriptions) is available. The chapter will discuss how the new methodology of acquiring medical care is at odds with traditional notions of state regulation and how current laws, both federal and state, leave many gaps related to any consumer protections or potential causes of action when privacy is compromised.

This chapter will proceed with an overview of the federal **Health Insurance Portability and Accountability Act of 1996** (**HIPAA**), an act promulgated to ensure privacy of health information as well as access to health care. It will review **HIPAA**'s application to medical practice conducted on the Internet. It will, in brief, discuss the plethora of sites available over which American citizens may purchase prescription drugs without a prescription from a licensed United States physician or merely through an overseas Web site with no physician to monitor the transaction. We then will examine current federal laws which are not set up to regulate these international transactions. The chapter will explore potential legal complications with **personal data** and privacy issues related to purchasing medical treatment or services on the Internet and describe what, if any legal recourse consumers might have when the outcome of an Internet medical transaction turns out to be undesirable. The chapter will posit some expert advice for consumers regarding using websites for medical purposes as well as protecting their own privacy. Lastly, this chapter advocates a federal law more punitive that **HIPAA;** one that regulates and protects patient information, medical transactions, and interactions on the Internet and deters violations of **patient privacy** by mandating significant fines and imprisonment for negligent or criminal and willful violations of that privacy.

THE TRADITIONAL PRACTICE OF MEDICINE IN THE UNITED STATES

Physician's State Licensure

The study and practice of medicine is core to mankind's need to extend and preserve life. The evolution of medical practice over the centuries from prehistoric times has involved the study of the human body and its mechanisms, disease processes, surgery, and natural herbal and manufactured drugs, to the present time, with its focus on modern genetic testing and techniques. While modern medicine and medical education had its genesis in the 19th century, the 20th century has made incomparable strides in clinical practice, immunology, and pharmacology.

Practicing medicine is not regarded by the law as an inherent right of an individual. Rather, it is regarded as a privilege that is granted by the people in a state acting through their elected representatives. Because it is considered a privilege to practice medicine, each state protects health care consumers by licensing and regulating physicians. As a report to Congress stated, "The purpose of licensing health care professionals is to protect the public from incompetent or impaired practitioners" (Telemedical Report to Congress, 1996). Licensure authority defines who has the legal responsibility to grant health professionals the permission to practice their profession. Physicians, dentists, registered nurses, and pharmacists are subject to mandatory licensing in all 50 states. Many other types of health care professionals are also licensed in most states. The federal government licenses some individual health care providers, for example, those professionals who manufacture, distribute, prescribe, and dispense controlled substances must be registered with the Drug Enforcement Administration (Miller, 2006).

Historically, under the Tenth Amendment to the United States Constitution, states have the authority to regulate activities that affect the health, safety, and welfare of the citizens within their borders, including the practice of medicine. The United States Supreme Court has recognized that states have a "compelling interest in the practice of professions within their boundaries" (Goldfarb v. Virginia State Bar, 1975).

In response to this amendment, each state has created a Medical Practice Act that defines the proper practice of medicine and mandates the duties of the state medical board to regulate medical practice. Every state and United States territory has a medical board. The primary means through which the state medical boards promote sound medical practice and keep consumers safe is through licensing and regulating of physicians.

The federal government plays little role in setting standards for the medical field except to the extent that the Food and Drug Administration is responsible for determining what prescription drugs are available, and setting safety standards for drugs and packaging. Retail pharmacies are highly regulated. All states require pharmacies have a license. Some states regulate hospital pharmacies through hospital licensing, exempting those pharmacies from the pharmacy licensing system. Pharmacy regulations often require staffing requirements as well that limit the hiring of those who are unlicensed. Standards of practice can be found in many places such as state statutes, agency regulations, and county or municipal ordinances.

Pharmacists fall into the category of coverage by state law as well. All states require licensing of pharmacists. The National Association of Boards of Pharmacy (NABP) is the independent group that assists member boards and jurisdictions in developing, implementing, and enforcing uniform standards. This group provides an Electronic Licensure Transfer Program (ELTP) listing all 50 states, the District of Columbia, Puerto Rico, and the Virgin Islands and the requirements for licensed pharmacists to transfer an existing license from one state or jurisdiction to another, as well as the fee for processing the preliminary application (NABP Web site, 2007). The federal government, under the Drug Enforcement Administration, licenses professionals who manufacture, prescribe, dispense, or distribute controlled substances.

Board Certification

Traditional **medical licensing** has changed in recent years to require more education for those physicians or specialists who wish to acquire **board certification** beyond the traditional state medical license. A seachange has occurred in the medical sciences as a direct result of exponential advances in electronics, chemistry, physics, computer sciences, engineering, and clinical medicine. Medical practice today requires so much knowledge, it is virtually impossible for any physician to become an expert in every field. Thus, many current clinical practices require advanced, specifically focused knowledge and extra years of training and education in specific fields of study.

According to the American Board of Medical Specialties (ABMS), there are more than 130 medical specialties and subspecialties. There are 24 member boards listed as members of the ABMS. If a physician is **board certified** it means that the physician has not merely completed medical school and holds a valid state license but has also completed an appropriate residency from 3 to 7 years and been examined using the criteria informing the physician's specific field.

As medicine and its practice become infinitely more complicated to practice, the licensure system within the United States discourages interstate practice (Johnson, 2006). There are some exceptions to requiring an actual physician's state license in each state: one such exception is the consulting exception. Physicians may practice medicine in another state by acting in consultation with a state-licensed referring physician. Even this exception varies from state to state and this exception preceded the advent of the practice of **telemedicine**. To remedy this discouraging of interstate practice, specialists who complete residencies should be considered for federal licensing. This licensing would allow the best and brightest to practice within the United States in all jurisdictions, regardless of state boundaries and not be hindered by local restrictions on consulting and practice.

Establishing the Physician-Patient Relationship

Whether express or implied, the traditional **physician-patient relationship** is contractual in nature and grounded in the premise that the physician is a learned individual, skilled and experienced in subjects about which the patient knows little or nothing but things that are of vital interest to the patient since they determine his health (Miller, 2006; Kohlman, 2006). This relationship is a fiduciary one, requiring the highest ethical obligation from the treating physician. Generally, the relationship may be created from an express or implied agreement. It is an express agreement when actual written forms are signed, the patient agreeing to pay for services in exchange for the performance of a specific service from the physician. In most cases, however, the agreement is implied. The patient finds a physician or is referred, makes an appointment, and travels to the physician's office. When the physician accepts the patient or undertakes to treat him, and the patient accepts the services, the relationship is created. Generally, a physician or other independent practitioner has the right to accept or decline to establish a professional relationship with any person (Miller, 2006).

Even though the existence of a **physician-patient relationship** usually depends upon whether a physician has examined, diagnosed, and treated a patient, the relationship must first be consensual for the purposes of **doctor-patient** privity. The relationship is considered consensual when the patient knowingly seeks the services of the physician and the physician knowingly accepts treatment of the patient (Kohlman, 2006). Certainly, such a relationship exists when a patient makes an appointment with and sees a practitioner in her office. In addition, physicians and surgeons on a hospital staff enter into a **physician-patient relationship** with every patient that they treat in the hospital, whether the patient has been admitted for emergency treatment or is even conscious or able to consent. Once the relationship is established, it is a fiduciary relationship in which mutual trust and confidence are absolutely essential. The practitioner incurs a duty of due care to the patient that is always measured by a professional standard for rendering professional services—one that is usually monitored by the state in which the physician is licensed (Johnson, 2006).

Informed Consent

In general, consent for most treatment must be an **informed consent**. This type of consent means that the treating provider is required to give the patient or decision maker several elements of information before the decision on treatment is made. As the American Medical Association states so eloquently on its Web site: "Informed consent is more than simply getting a patient to sign a written consent form. It is a process of communication between a patient and physician that results in the patient's authorization or agreement to undergo a specific medical intervention" (AMA, 2007). To establish a cause of action based upon lack of **informed consent**, the patient must prove that a practitioner failed to disclose to the patient the various alternatives and the reasonably foreseeable risks and benefits involved which a reasonable medical practitioner under similar circumstances would have disclosed (AMA, 2007). The ethical obligation to communicate certain information to the patient exists in statutes and case law all 50 states.

In 2007, Medicare and Medicaid circulated new interpretive guidelines contained in the Code of the Federal Regulations that significantly expanded the scope and documentation of **informed consent** that must be obtained by hospitals prior to performing surgical procedures. For example, the new Medicare/Medicaid guidelines require that patients be informed if a practitioner, other than the primary surgeon, would perform important parts of the procedure, even when the person is performing under the supervision of the primary surgeon. Additionally, where surgery is concerned, the consent form must specify the "specific significant surgical tasks" that would be conducted by surgeons other than the primary surgeon (42 C.F.R. § 482.51). This requirement gives more transparency to the long-held ability of an experienced surgeon to allow a resident who is learning to gain experience in doing surgical procedures by requiring the patient be informed of that fact in advance.

Liability-Battery and Negligence

Because of the way in which the traditional medical relationship is established, the liability imposed for breaches of duty can be contractual in nature or based on tort law. Tort liability is civil in nature, not criminal, and is imposed by the common law and some statutes for injuries caused by breaches of duty not based on the contract. Tort liability is almost always based on fault, whether the fault be intentional, reckless, or negligent. The most frequent type of liability for health care professionals and institutions is the negligent tort. The five elements required to establish negligence or malpractice are the following: (1) a duty, that means what should have been done; (2) a breach of duty, or a deviation from the required standards of care; (3) injury to a party; (4) causation, that means an injury directly and legally caused by the deviation from what should have been done. To determine negligence, it is foremost important to be informed regarding the duty required by the practitioner in the jurisdiction.

Once the existence of a duty is established, the scope of the duty must be determined. This scope is often referred to as the *standard of care*. The standard of care for individual health care professionals is what a reasonably prudent health care professional engaged in a similar practice would have done under the circumstances (Miller, 2006). Thus, the standard of care may differ for one who is an internist, a pediatrician, an obstetrician, or a thoracic surgeon based upon each physician's special education and training. **Board certified** and trained specialists would owe a higher duty of care because of their advanced education, training and skill.

When there is no **informed consent** or authorization for a procedure, the physician or other practitioner can be liable for battery even if the procedure is properly performed, beneficial, and has no negative consequences for the patient. The touching of the patient alone leads to the liability (*Fox v. Smith*, 1992; *Bommardy v. Superior Court*, 1990). Early court cases provided that giving the patient incorrect or incomplete information about a procedure or treatment could invalidate the consent and make the practitioner liable for a battery (*Bang v. Miller*, 1958; *Moser v. Stallings*, 1986). The majority of jurisdictions now rule that failure to disclose or to fully inform the patient is a separate cause of action from a battery.

Jurisdiction, Venue, and Conflict of Laws

In the practice of traditional medicine, there has been little question as to where a particular cause of action might be brought against a medical practitioner or when that action might be brought. The traditional patient/physician privilege has existed on a personal level with a patient physically seeing a physician. That physician may not practice medicine unless licensed in that particular state. Thus, were there to be a cause of action brought against the physician, the action would be brought in the state where the relationship existed, and the laws of that state regarding proving a cause of action would be applied. The state would necessarily provide a statute of limitations for bringing a malpractice or other legal action against the physician.

There would be exceptions, however, if the individual seeking medical attention was not from a particular state but sought expertise medical help or particularized treatment. Nonetheless, in a traditional **physician-patient relationship** in which each party is physically present during the treatment phase, the theory of where the lawsuit is brought and what laws are applied remains essentially the same. If a patient seeks treatment in a state in which she is not domiciled, that patient is still seeking treatment from a physician who must adhere to the licensing requirements and standards of the second state. Thus, it would be those laws that would apply should the patient be injured in the course of medical treatment or determine to bring a cause of action at a later date. No federal laws would apply, except to the extent that a patient might possibly be bringing an action based on an inappropriate action taken by the FDA related to a controlled substance or other type of drug (McGrath, 2005).

THE INTEGRATION OF FEDERAL LAW INTO THE TRADITIONAL PRACTICE OF MEDICINE: HIPAA

The landscape of state domination of the medical profession changed somewhat with the enactment, in 1996, of the federal Health Insurance Portability and Accountability Act commonly referred to as "**HIPAA**." The enactment of **HIPAA** has also had implications concerning the burgeoning business of providing medical advice and treatment electronically.

HIPAA was originally enacted to provide for the "portability" of health care coverage for workers who had lost jobs or were changing jobs (Metz, 2004). Ideally, **HIPAA** sought to implement a more unified system of medical information storage such that medical information could be easily transmitted electronically (Chiang & Starren, 2002).

Because **HIPAA** contemplated the use of a unified electronic storage system, there was a demand that there be provisions enacted that would ensure the privacy of electronically transmitted material. Thus, included within **HIPAA** are protections covering the privacy of an individual's medical records. The privacy provisions of **HIPAA** are intended to allow a patient to limit who will have access to medical records and further provides a limitation on the internal use of sharing information for purposes of diagnosis in that it restricts the disclosure of health information to the "minimum amount necessary" required for the intended purpose (Schmidt, 2000).

HIPAA specifically covers health information "oral or recorded in any form or element that:

a. Is created or received by a health care provider, health plan, public health authority, employer, life insurer, school or university, or health care clearing house; and
b. Relates to the past, present, or future, physical or mental health condition of an individual; the provision of health care towards an individual; or the past, present, or future payment for the provision of health care to an individual. *(Health Insurance Portability and Accountability Act of 1996)*

HIPAA essentially applies to three specific health entities: health care providers (such as doctors and hospitals), health care plans, and health care clearing houses, which include such entities as third party billing services that may be hired to "code" certain medical procedures for insurance companies (Public Welfare. 45 C.F.R. § 160.102). **HIPAA** also applies to "employers, insurance companies, and public agencies that deliver social security or welfare benefits" to the extent that they work with or necessarily disseminate information related to an employee's medical records (§§ 160,164). **HIPAA** applies to all individual health information that is "maintained or transmitted" and includes "health claims, health plan eligibility, enrollment and disenrollment, payments for care and health plan premiums, claim status, first injury reports, coordination of benefits, and related transactions" (Metz, 20004). Thus, the purpose of **HIPAA**, to provide health care portability for the patient while protecting privacy concerns, has broad and far-reaching consequences and regulations affecting the practitioner, the health care institution, and the insuring entity.

In addition to **HIPAA**, federal privacy law also has been enacted to protect the confidentiality of information concerning patients who are referred or treated for alcoholism and drug abuse (42 U.S.C. § 290dd-2). The rules apply to any specialized programs to treat substance abuse in any facility that receives federal funds, including Medicare and Medicaid.

State Law and HIPAA

The United States Constitution provides that federal law is the "supreme law of the land." Ordinarily, that clause would be interpreted to mean that when the federal legislature has passed a law on a particular issue, that federal law would take precedence over state laws on similar issues. Indeed, the enactment of **HIPAA** "mandated" that all state-licensed medical entities and professionals be "**HIPAA** compliant" within a certain period of time regardless of any state laws on the issue (Privacy Rights Clearing House, 2003).

However, the Supreme Court has determined that when there are both federal laws and state laws covering the same issues, federal laws will not supersede a state law if the state law provides more "protections" than the federal law. It is said that a federal law may provide a "floor" for the rights of an individual while a state may provide a "ceiling" (Kramer, 2007). As applied to **HIPAA**, an individual is certain to enjoy the privacy protections set out in the federal statute, but may enjoy *more* privacy protections if his/her home state has enacted additional privacy requirements for medical practitioners. Examples of state laws that provide greater privacy protection than **HIPAA** are those state laws regulating the release of a patient's mental health information and HIV/AIDS test results **(**Miller, 2006). In cases in which the state protections are greater, the state law trumps any federal law.

Civil Liability for Violations of HIPAA

Currently, **HIPAA** has no civil liability provisions for any violations of the statute. Thus, an individual who has been harmed in some way by a practitioner or entity that fails to protect them has no legal recourse for damages under the federal law. The law does provide criminal consequences in the form of fines and jail time. **HIPAA** provides that a "person who knowingly… uses or causes to be used a unique health identifier [e.g., names, addresses, social security numbers], . . .obtains individually identifiable health information relating to an individual," or "discloses individually identifiable health information to another person" may:

1. Be fined not more than $50,000, imprisoned not more than 1 year, or both;
2. If the offense is committed under false pretenses, be fined not more than $100,000, imprisoned not more than 5 years, or both; and
3. If the offense is committed with intent to sell, transfer, or use individually identifiable health information for commercial advantage, personal gain, or malicious harm, be fined not more than $250,000, imprisoned not more than 10 years, or both. (45 C.F.R. § 160.102)

HIPAA appears to specifically limit enforcement actions may be brought by only the respective states or the secretary of health and human services (42 U.S.C. § 300gg-22(a); *O'Donnell v. Blue Cross Blue Shield of Wyo.*, 2001). Thus, reporting a **HIPAA** violation might be the best that an individual harmed by the release of data can do. However, some plaintiffs have attempted to bring indirect causes of action for a **HIPAA** violation by bringing a common law invasion of privacy action against the offending party. In fact, **HIPAA** does not always pre-empt state litigation practices (Beck & Hermann, 2007). Moreover, some states specifically allow causes of action for the dissemination of private medical information (*Pettus v. Cole*, 1996).

TELEMEDICINE, CYBERMEDICINE, AND INFORMATIONAL WEB SITES

The Basics

When determining the complications related to medical practice and privacy on the Internet, it is important to understand the distinction between the types of medical Web sites that one might encounter, and the medical interactions that one might have. Like the traditional "in person" patient/physician relationship, some "virtual" interactions between patients and physicians are between known individuals who might actually "see" each other, although far removed from each other geographically (Harrington, 1999). In other interactions, however, the person logging into a website might have no idea who is on the other end, or even if the person on the other end is a physician. Thus, these relationships make the definitions of "patient" and "physician" hazy when attempting to discern the application of any existing privacy laws to Internet or telemedical transactions (Lewis, 2004).

Telemedicine

Telemedicine is defined as the "use of telecommunications technology to provide health care services to patients who are distant from a physician or other health care provider" (Granade & Sanders, 1996). Generally, a consultant is used to medically diagnose a patient's condition via two-way interactive television, remote sensing equipment, and computers. Such medical practice has advantages, not only for improving access to medical specialties, but for primary care for patients and cost reduction (Johnson, 2006). For example, in rural Arkansas, a pregnant patient with a family history of spina bifida, a congenital abnormality of the spine, living in a rural area whose obstetrician has just performed a prenatal ultrasound, can have her test transmitted to a specialist in maternal-fetal medicine in a large medical center who can review the test and opine the fetus is developing normally and immediately reassure the patient (Johnson, 2006). The benefits of using technology of the rich to diagnose and treat the poor has substantially increased the opportunities of those who would not otherwise receive health care and allowed them to receive specialized treatment (Tyler, 1998). Moreover, the availability of **telemedicine** has enabled the sharing of both information and expertise which has enhanced the development of the medical profession in general.

Cybermedicine

A. Patient Treatment

An offspring of the information and technology revolution, **cybermedicine** is the embodiment of a discipline that applies the Internet to medicine. The field uses global networking technologies to educate, innovate and communicate in ways that enhance and promote medical practice, rapidly transforming medicine into a different discipline. In many respects, **cybermedicine** is broadly defined as the practice of medicine without the necessity of any physical in-person consultation or examination (Scott, 2001).

Cybermedicine is a relatively new phenomenon that has been around for less than 15 years. On Friday, October 4, 1996, the news announced the first virtual real live doctor's office on the World-Wide-Web had opened (Cyberdocs Today, 1996). On this site, for a reasonable fee of $65, a patient could enter her name and vital statistics, her medical problem, send the service her symptoms, provide credit card information, and within a few minutes—without ever being examined—receive treatment and possibly a prescription. This first site located in Massachusetts, required that the patients either be physically in the state of Massachusetts or traveling abroad in a foreign country. These two location safeguards, allowed the site creators to circumvent the problem of state licensing laws for liability purposes (Tyler, 1998). If the patient was traveling in a foreign country, the patient who needed a medication refill could have one sent by fax machine to a local overseas pharmacy within a few hours. The reach of **cybermedicine** has since extended beyond the boundaries of a home state.

B. Prescription Drug Purchasing

An "offshoot" of the **cybermedicine** industry is a new generation of Web sites that provide prescription drug delivery to consumers. Estimates of the number of **Internet pharmacies** operating in the United States have reached as high as 1400 (Gregg, 2007). In 1 year, one article estimates that 135% more Web sites have offered controlled substances such as Xanax, Vicodin, and Ritalin. Investigators found 394 Web sites advertising controlled prescription drugs and 7% of the sites, or about 187, offered to sell the controlled drugs. The vast majority of those Web sites offered to sell the drugs *without a prescription* (DeNoon, 2007).

While most **Internet pharmacies** are legitimate businesses that offer customers an attractive and convenient option to purchase affordable medicine in accordance with state and federal law, these new **online pharmacies** present many problems for drug companies, consumers, and physicians. Consumers find it very attractive to order from the privacy of their own homes and find that such pharmacies offer privacy and convenience for them based upon medical consultation with a physician.

In some instances, the "privacy" aspects making many sites attractive are problematic in and of themselves. Individuals can often order drugs by a brief description of symptoms—symptoms that they may or may not have (FDA FAQ's, 2007). In addition, because the Internet guarantees near anonymity, there is no way for the "Web site" to tell that the person ordering on line is the person actually on the other end of the transaction. Although this type of scenario raises the specter of fraud, it raises other issues related to privacy.

The truth is that anyone who owns a credit card and a computer can order controlled substances or any other drugs online. Pharmacies that do not require a faxed or mailed prescription from a licensed physician present serious concerns for not only privacy but life itself. Drugs offering help for erectile dysfunction, Viagra, Cialis, and Levitra, rank among the top 10 drugs bought online. Other drugs in the top 10 sought after online are Propecia, for baldness, as well as drugs for acid reflux, cholesterol, and bone density (Lade, 2007). Anonymity seems to be the deciding factor in ordering such drugs online. Legitimate pharmacies functioning online can be problematic for privacy concerns. An FDA advisory was issued in spring 2007 after examining foreign drug purchases and finding drugs with potentially dangerous side effects were easily ordered online, without a prescription. Two deadly examples of resulting problems with online ordering of drugs follow.

C. A Suicide Case

In what is believed to be the first lawsuit of its kind, the parents of John McKay have sued an Internet site, a Colorado physician, and a pharmacy in Mississippi in federal court in California for wrongful death and negligence in the suicide of their son (Ostrov, 2007). John McKay was a Stanford University freshman and debating champion who used a credit card to order 90 tablets of the anti-depressant Prozac (generically called fluoxetine) from an **online pharmacy**. The pharmacy McKay used does not require a faxed or mailed prescription from a licensed physician. Instead, the prescription site asks only that the patients fill out an online questionnaire about their health history. McKay noted on his application that he had moderate depression, had taken the drug before, and was not suicidal. The doctor who wrote the prescription had a restricted **medical license** and was not allowed to prescribe drugs.

Less than 7 weeks after ordering Prozac, John McKay killed himself. He was 19 years old. Articles reveal that neither the web prescribing doctor nor the **online pharmacy** accepted any responsibility for McKay's death (Ostrov, 2007; Lade, 2007). California law requires that prescriptions must be written by a licensed California physician after a physical examination of the patient (Ostrov). Prozac and similar antidepressants carry the FDA's strongest warning that notes the link between taking the drug and suicide in children and adolescents. The warning urges physicians to closely monitor young patients on these drugs especially at the start of treatments.

Expert Advice in Light of McKay

- Parents must monitor the Internet use of children and young adults.
- Parents should check the family mail for suspicious packages.
- Parents should keep credit cards and any documents with credit card numbers away from children.
- Parents should make certain young people who are treated for depression are consistently monitored by a physician.

D. An Overdose Case

Christopher Smith made over $24 million dollars selling prescription painkillers illegally through his **Internet pharmacy** before he was indicted (Unze, 2007). Minneapolis court documents show that Smith sold prescription painkillers to Justin Pearson at least 12 times in 2004-05. Justin accidentally overdosed on Christmas Day, 2006. Two other individuals listed in the government's filing bought drugs from Smith and committed suicide or died of medical complications from prolonged controlled substance abuse within 18 months of purchasing drugs on the Web site. Smith was convicted of conspiracy to sell drugs illegally, misbranding drugs, and money laundering. He was sentenced to 30 years in federal prison August 1, 2007 (Unze). Pearson's family members petitioned the state legislature to change the law on **Internet pharmacies**. Minnesota law now prohibits doctors from writing prescriptions for Minnesota clients based solely upon an online questionnaire.

Expert Advice for Finding Safe Internet Pharmacies Online

- Use a pharmacy in the United States, not Canada or Europe.
- A safe pharmacy has a phone number and address listed.
- A safe pharmacy is one that is licensed by a government agency or certified by a reliable organization. (The National Board of Pharmacy has a Web site verifying U.S. pharmacies have met state and federal regulations. See www.vipps.info).
- A safe pharmacy has a clear privacy policy. Read it. Make certain it is easy to understand and explicitly states it will not share your personal information with others unless you agree.
- Always have a prescription from a physician or health care professional who has examined you.
- Make certain a licensed pharmacist is available to answer any questions you have.
- Price comparisons can be found at Pharmacy Checker, a company that certifies online pharmacies. See www.pharmacychecker.com.

INFORMATIONAL AND SELF-HELP SITES

A third category of electronically available medical Web sites are those that are purely for information, or provide forums for discussing medical problems. Web sites proliferate that are available for educating the public about everything imaginable in health care from routine procedures to rare diseases. Because of the availability of these sites, patients can now read excellent articles and research dealing with a rare disease that they, or a family member, may suffer from. There are many stories regarding individuals who diagnosed their own or others' illnesses by using the Internet.

Hospitals as prestigious as the Mayo and Cleveland Clinic also routinely set up Web sites that not only provide information about the hospital, but provide information on disease processes and give health care consumers preoperative and postoperative instructions. In addition, these Web sites often provide links to articles about particular diseases, or even have informational charts concerning drug interactions. Sites such as WebMD allow individuals to look up symptoms or ask medical questions of certain practitioners in an effort to get feedback on a particular ailment. Finally, listservs and chatrooms provide individuals the opportunity to share information about particular medical ailments or seek advice or support from others dealing with the same problems. As an example, ACOR.org provides those afflicted with various cancers to share information with an international contingency about their conditions.

PRIVACY CONCERNS RELATED TO ELECTRONIC SITES IN GENERAL

Since the inception of the Internet and the ability to enter personal information into a Web site, there have been problems with ensuring that **personal data** remains secure. Today, there are burgeoning problems with credit card fraud and **identity theft** in the best of circumstances. Connecting to a virtual site in which information must travel along millions of shared lines compounds the problem, even in situations where an individual believes she is entering into a transaction onto a trusted site. Even if a company takes the opportunity to employ encryption methodology (such as Verisign), the opportunity for data stealing remains in situations where hackers lurk. It is impossible to say with certainty that any electronic transaction will remain completely private (Mencik, 1999).

Unfortunately or fortunately, depending upon personal point of view, there is no overarching regulation of the Internet. The Internet is not a place, nor is it contained within a certain jurisdictional boundary. Those setting up Web sites do not have to sign up with a central authority or conform to certain rules and regulations. There is no central place to register domain names and no periodic reporting that must be done to maintain a Web site.

Some regulation of business on the Internet has begun. There are some laws that govern some types of Internet business and/or transactions; however, most of these laws draw upon principles that are more appropriately applied to land-based businesses and not cyberspace entities. For instance, the Federal Trade Commission is charged with enforcing various consumer protection laws such as preventing false advertising and deceptive trade practices (Granfield, 2000). Both state and federal law enforcement agencies are charged with preventing fraud occurring over the Internet, and there are various statutes, both state and federal, that deal with preventing the dissemination of spam (Controlling the Assault of Non-Solicited Pornography and Marketing Act of 2003).

Nonetheless, no law now in existence is able to prevent the stealing of **personal data**, and few laws can protect individuals whose **personal data** is used unknowingly by a Web site for uses such as targeted advertising. The only way for individuals to protect themselves to the highest degree possible is to be aware of the privacy policies of the Web site with which they are dealing. Financial data should be logged only into trusted Web sites that have **encryption** methodology in place, and **personal data** (such as names and addresses) should be shared only on websites that have a similar **encryption** data or on those that have privacies policies with which the individual agrees. Most consumers should be aware that the Internet makes it very easy to share data with other businesses, and that most businesses would prefer to engage in quick, targeted advertising. Any registration with any type of Web site may make the consumer part of a larger database that will not only result in unwanted email solicitations, but will make the consumer more susceptible to scam advertising.

Consumers should be aware that Web sites, even those related directly to the medical profession, have different types of privacy policies. Some highlights from these privacy policies are included in Table 1.

When accessing any Web site where personal information is disclosed, consumers who have any privacy concerns at all should be aware of the privacy policies related to the Websites. As the examples indicate, not all information that might be thought to be private or even protected by **HIPAA** is necessarily private. For instance, there are many pharmaceutical Web sites that are not United States Web sites and not subject to United States laws. Although many of these websites have "American" sounding names, the consumer should be aware that when logging in, entering data, and ordering, that information entered might not be as private as the consumer thought.

In addition, many Web sites contain somewhat of a "caveat emptor" proviso indicating to the consumer that if there are any links accessed from the first website, the consumer should understand that the privacy policies of the first Web site do not apply. Further, various Web sites disclose that private data may be accessed by a company doing business with the first party and that the company is required by federal law to enter into contracts ensuring the privacy of data. However, most Web sites are vague about what data is protected and do not provide the consumer access to the actual contract and listing of data that is being disclosed and how it will be protected.

Finally, various Web sites provide for the disclosure of data in certain instances—such as, in numerous pharmacy sites, disclosure to a friend or family member who is the caretaker of

Table 1.

Web Md	**There is a lengthy privacy policy that includes information about what cookies are collected. The policy also provides that personally identifiable information will not be disclosed except 1) to meet legal requirements and 2) when there is a threat requiring disclosure. The site informs the consumer that the consumer will be informed of "material changes" to the policy and provides that complaints may be lodged with TRUSTe privacy watchdog**
American Academy of Family Physicians (AAFP)	A shorter privacy policy discloses use of cookies and states that member information may be provided to "constituent" chapters. The policy also provides that some information may be disclosed for purposes of targeted sales. There is a disclaimer providing that some information may be disclosed when legally required. The site also "forewarns" the consumer that it cannot be held responsible for the actions of third parties whom have links within the site.
Merck.com	Merck provides that consumers may elect a level of privacy protection. The policy states that, "Personal information about you will be accessible to Merck, including its subsidiaries, divisions, and groups worldwide, and to individuals and organizations that use personal information solely for and at the direction of Merck," and further provides that information will be disclosed only to those "working on its behalf."
American Heart Association	Policy gives consumer ability to "opt out" of disclosure, but also provides that "aggregate information" is sometimes disclosed for research purposes. There may be disclosure as "required by law."
Revolutionhealth	Policy provides that the information provided by the consumer may be used to acquire information about other people in your demographic area for targeted advertising. The policy states that information may be disclosed for legal reasons, or when a "threat" is involved (e.g., national security). The site has a disclaimer that if third party sites are accessed, the privacy policies of the third party sites should be reviewed. Consumers have an opportunity to "opt out" of particular disclosures.
MedRx-One (No prescription necessary site)	Non U.S. company; one line privacy policy: "medrx-one pledges that the information you enter will not be shared with any parties not directly involved with the ordering or delivery process without your expressed consent (except for fraud cases) and that any e-mails you receive from medrx-one will be related to your order." The terms of use indicate that "local laws" (i.e., country of origin) will apply to any legal issues.
CVS	Provides state specific privacy policies in addition to an extensive privacy policies that mirrors the **HIPAA** regulations. Provides that information may be disclosed to "business associates" provided an appropriate contract exists that safeguards privacy. Sets out that information may be disclosed in some instances to an individual (friend or family member) involved in your care, "if we can reasonably infer that you agree."
Walmart	Walmart's privacy policy provides, "We may use or disclose your PHI for prescription refill reminders, to tell you about health-related products or services, or to recommend possible treatment alternatives that may be of interest to you," and, "We may disclose your PHI to a family member or friend who is involved in your medical care or payment for your care, provided you agree to this disclosure, or we give you an opportunity to object to the disclosure. If you are unavailable or are unable to object, we will use our best judgment to decide whether this disclosure is in your best interests."

the individual seeking a prescription. Although this proviso may make it more convenient for a caretaker to access information about meds for an individual unable to access the data herself, there is also a potential for abuse. In many situations, an individual has sought out the Internet for purposes of enhanced privacy for the very reason that she does not want family members to be aware of certain health information. Without any verification procedures in place, many individuals may have their medical privacy compromised even though a website is legitimate, well-respected, and has various privacy protection procedures in place that a consumer believes are absolute.

Although there is sometimes recourse when there has been an alleged breach of privacy occurring by way of an Internet transaction, this recourse may be limited in scope. As previously discussed, various federal entities are responsible for ensuring the enforcement of some laws; however, the

Internet provides opportunities for businesses to both form and disappear overnight making it not only impossible to find the target of the investigation, but to determine what would be the appropriate jurisdiction to handle any complaint. Furthermore, although there are various actions that might be brought against Web site companies that do business in the United States and technically exist in the United States, there is virtually no recourse available against website companies that exist outside the boundaries of the United States. These sites may not have even minimal privacy protections for consumers. Certainly, the speed with which Web sites may be formed and disbanded will serve to hinder any sanctions or penalties that may be geared toward the enforcement of privacy rights.

Finally, the varying privacy policies in place on Web sites make it difficult for consumers to even know what their rights are, or what rights were violated. Although most legitimate companies dealing with medical data have privacy safeguards in place, there are various “loopholes” that consumers must be aware of whenever transacting business on the Internet. These include releases for targeted marketing in some instances, disclosure to third party companies with which the original company does business, disclosure to caretakers, and disclosures for law enforcement purposes (and when “threats” are involved).

CONCERNS RELATED TO THE DISCLOSURE OF MEDICAL INFORMATION

A. Patient Rights and State Remedies

Medical information is often the most private and intimate information about an individual. Health information privacy is based upon two principles: 1) the patient should be entitled to know what is contained in her own record; and 2) the patient should be able to control who has access to that information. States, individually, have long been the principle regulators of health information. While physicians have always been obliged under their ethical obligations and the Hippocratic Oath to protect health care information, other secondary users in the health chain such as insurers, the government, and employers have, in the past, not always had the obligation to keep information confidential when storing or transmitting it. Only recently, the federal government has promulgated, through **HIPAA**, the Federal Health Privacy Rule to even out and establish a floor of privacy protection to all citizens.

While all states have constitutions that may give rise to a right of privacy, explicit guarantees of privacy in state constitutions are rare. Applying privacy protections to health information has occurred in piecemeal fashion with little consistency from entity to entity and state to state. Thus, the right of privacy in state law provisions is a patchwork varying from legislative protection to only common law provisions.

While every state has a statute restricting the use and disclosure of medical information, few states have taken a broad or uniform approach. Rather, the protection afforded to the information tends either to be specific to a certain condition or fails to cover much of the information collected. Most states have some type of statutory provider-patient privilege that affords to the consumer limited protection of one’s health information. But states vary widely in the scope of the provisions that are enacted restricting the use of medical information (Pritts, 2002).

Most states allow health care providers to use and disclose patient identifying information for treatment, payment, peer review, and research purposes. For any use or disclosure of information, not specified by state statute, the patient’s written permission is required. Patients should be informed regarding the information divulging practices of their health care providers. They are entitled to receive and review their medical records. In addition, the security of their medical information should be protected from unauthorized use or disclosure.

To be effective, the state privacy statutes must provide remedies and penalties for violating them. Thus, if personal health care records are not provided to a patient, there must be a sanction for failure to do so. In addition, if health care providers can divulge information with impunity, there is no real benefit to consumers.

States run the gamut in the remedies in their statutory provisions to protect the health consumer. Some states have expressly granted rights to patients to bring suit for equitable relief and attorney fees. Other states hold a violator liable for actual and punitive damages (Pritts, 2002). If a person can show the privacy violation was made with knowledge or was made intentionally, many states allow for criminal penalties including fines and imprisonment.

B. Need for Remedies & Uniformity

The problem remains that there is no uniform comprehensive state approach to violations of health care consumer privacy. Most states have allowed only some elements of fair and uniform disclosure into their codes. Many have no remedy for violations. California has crafted some of the most privacy-oriented consumer protection laws in the nation (Cal. Civ. Code 56-56.37). California's code affords patients by law rights to most of the major holders of health information. And the code restricts disclosures by health care providers, HMOs, and even employers. The California code also gives patients the right sue to enforce their rights. Yet, even California's law is lacking because there is no provision to require notice of the health care providers' practices and policies to patients. Individual states have a long way to go to offer real solutions to the problem of privacy.

FEDERAL PRIVACY PROTECTIONS

Applicability of HIPAA to Cybermedicine and Telemedicine

With the recent issuance of federal government regulations governing the use and disclosure of health information by the Department of Health and Human Services, the role and importance of state government remedies has changed. While **HIPAA** is the first federal health privacy law, it does not pre-empt stronger state laws. So state law can offer greater protection than **HIPAA** provides especially with remedies for abuse (Pritts, 2002).

Unlike many laws that do not contemplate the incorporation of technology into every day life, **HIPAA** was originally enacted for the specific purpose of integrating the use of computer technology in the dissemination of information. Thus, after the enactment of **HIPAA**, traditional forms of communication were added to coverage so that there would be no loopholes regarding the dissemination of information through such avenues of communication as oral and written communications. As a result, the application of **HIPAA** appears to be broad-based covering traditional forms and both cyber and **telemedicine**, at least in large measure (Wachter, 2001).

For example, **HIPAA**'s "Privacy Rule" is broad-based in its application and protects individualized medical information transmitted "in any form or medium." It extends to all patients whose information is collected. The Rule imposes responsibilities on all employees and volunteers and requires health care institutions to receive contractual assurances that business associates that will be handling individualized medical information will keep that data private (pp. 1-4).

Also required, **HIPAA** mandates that those dealing with providing health care provide a Notice of Privacy Practices that will set out how the organization will protect health-related information and specify a patient's rights including:

- How to gain access to the patient's health records.
- How to request corrections to errors in a patient's health records (or voice a disagreement with a medical conclusion).
- How to determine where medical information has been disclosed.
- How to request additional confidentiality for particular health information.
- How to keep information confidential by providing alternate contact numbers such that information will not be given to members of a household.
- How to complain about a breach of privacy protocol.
- How to contact the U.S. Department of Health and Human Services to follow up about a complaint regarding a breach of privacy protocol (University of Miami School of Medicine, 2005).

Additionally, the Privacy Rule requires supplemental authorization if a health care provider intends to disseminate any private information for the purpose of research, some types of marketing, or fundraising. Information related to psychotherapy is also considered overly sensitive, and **HIPAA** requires supplemental authorization for the dissemination of this type of information. There are, however, some types of medical information that are not considered completely private. This information may be disclosed in limited circumstances without there being a **HIPAA** release. These categories include:

- Information related to public health issues.
- Information related to abuse or domestic violence situations.
- Information related to law enforcement, or some judicial proceedings.
- Information that might prevent an imminent threat to public safety.
- Specialized information as required by particular state or federal statutes.

In addition, not all forms of communication of medical information fall into the category of marketing. For instance, it is not considered marketing for a covered entity to use personal information to tailor a health-related communication to that individual, when the communication is:

- Part of a provider's treatment of the patient and for the purpose of furthering that treatment, such as the recommendation of a particular medication.
- Made in the course of managing the treatment, such as reminders of appointments (Privacy Rights Clearinghouse).

In many instances, individual state laws will govern what must be disclosed regardless of the fact that **HIPAA** is a federal statute. And one author has argued that states should not rely solely on the Federal Health and Privacy Rule to protect citizens, but that they should "at a bare minimum . . . mirror the federal protections, thereby allowing enforcement to occur at the state level" (Pritts, 2002). Thus, states are encouraged to enact legislation spelling out health consumers' rights and remedies. In addition, those states that have already enacted comprehensive health privacy rules should reevaluate their statutes so they fill in gaps that may exist. For example, use of health information for marketing purposes is often ignored in state laws, while some states have enacted more stringent standards than the federal law (Boyer, 2004).

Whereas **HIPAA**'s Privacy Rule protects against the disclosure of certain information, **HIPAA**'s Security Rule sets out regulations related to the electronic transmission of data and thus imposes security requirements on the electronic systems themselves. Moreover, the Rule imposes these restrictions on the "covered entities" of health care providers, health plans, and health care clearinghouses. Neither in-person nor hand-written communications are covered by the Security Rule, but do fall under the Privacy

Rule which covers "any mode" of communication (University of Miami Medical School; 45 C.F.R § 164.302, 45 CFR § 164.306).

Given that **telemedicine** stems from a traditional doctor-patient relationship in which consultations are theoretically done remotely, technically, the criteria related to HIPAA would apply to those practicing **telemedicine**. However, there would be some complications related to **HIPAA** and privacy in general depending on what type of **telemedicine** relationship is established.

In a situation where a patient sees her own physician and there is a consultation that is done while her physician is in the room, there is the opportunity for the original physician to ensure that the consultant is bound, in writing, by the prescriptions of **HIPAA** and that the patient is informed of her rights under **HIPAA** should there be such a consultation. If, however, there is a remote consultation being done without the involvement of an initial more primary care physician, there is less of an opportunity to verify privacy rights, especially if there is some immediacy to the teleconference.

Although it is unlikely, and currently uncommon for an individual to log on to a Web site and visually present an injury for diagnosis, it is likely that this type of doctor/patient interaction will increase in the future. With such an immediate relationship, there might be little opportunity for the patient to be told of the website's privacy practices, and there would unlikely be any opportunity to review and sign appropriate forms.

Thus, although any type of **telemedicine** practitioner would be bound by HIPAA, the patients would be well-advised to know the policies of the particular practitioner before going ahead with a consultation. In the case where a primary care physician would be involved in a **telemedicine** conference, the patient would be well-advised to know what privacy policies have been established between the two entities.

The practice of **cybermedicine** is similar to **telemedicine** and, for the most part, those who practice **cybermedicine** are bound by HIPAA as are those involved with **telemedicine**. However, **cybermedicine** may present more opportunities for compromising privacy because there are various forms of what might be considered the practice of **cybermedicine** that are not subject to the **HIPAA** regulations (Lewis, 2004).

Cybermedicine is often associated with prescription drugs, and, true enough, pharmacists and pharmacies are subject to the regulations of **HIPAA** as are the parent companies that might be engaged in the pharmaceutical business (such as Rite Aid or CVS). However, **cybermedicine** is also associated with such Web sites as "Ask a Physician," "Self-Help," or "General Advice" Web sites. Even in the case of "Asking a Physician," one might not establish a doctor/patient relationship necessary to bind the doctor in question to **HIPAA** as a health care provider.

Although many individuals might ordinarily believe that information is confidential because there is a person's medical condition being discussed, that is not the case (Nath, 2006). Many people routinely log into Web sites to find out information concerning symptoms, or request information about a particular drug. Some sites require information such that a response might go to an email address, or may even require information such as an address. Because these sites are not health care providers, there is no prohibition that would prevent continuous emailings, or postal mailings that a person may not want about a condition that a person may not want others to know about. Because there is no health care provider relationship, there is nothing prohibiting any of these sites from selling information to other entities.

There are numerous privacy concerns that may develop by virtue of the fact that lines blur as the electronic trail becomes more extensive. In an ordinary situation, a health care provider deals with secretaries who may deal with insurance companies, who may deal with other insurance companies, who may deal with outsourcing of billing and/or data processing, who may ultimately deal with collection agencies for unpaid bills. Although each of these entities would technically be bound to keep data private under an initial business entity and employee agreement, the more people involved, the more difficult it is to control who has what data.

Where **telemedicine** and **cybermedicine** are concerned, the trail goes out even farther. In **telemedicine** situations, there may be staff in a room unseen by a patient having nothing to do with the procedure or medical consultation (such janitors, computer technicians, or camera operators). For both **telemedicine** and **cybermedicine**, there are Web designers and engineers who may have access to information in databases within the Web site. None of these ancillary workers are generally bound to keep health information private.

When the Web site itself is set up to work as a place where health care is provided, there is a good argument that these technical employees are bound by **HIPAA** as employees dealing with health treatment information; however, that characterization is debatable if dealing with a third party Web administrator (i.e., an independent contractor), or when the Web administrators are part of a larger conglomerate, such as when a retailer (e.g., Walmart) has a site where prescriptions may be filled. There is also some uncertainty as to what is the status of a third-party owner of a website when that owner is not in the health care field but rather has purchased the website for investment purposes, or even when the Web site itself is a subsidiary of a health care company (Nath, 2006).

In all instances involving use of the Internet for medical care, the consumer must not assume that whatever **personal data** is being handled will be kept confidential. If the consumer is attempting to protect private data, that consumer must be aware of the policies of the entity from wherever any type of medical information is shared.

Problems with Privacy Liability

While **HIPAA** pre-empts any state law that provides less protection than it does, state laws that provide greater or equal protections than **HIPAA** remain in effect. Certainly, **HIPAA** privacy rules allow providers to share private information as long as it is used for allowable purposes such as billing and treatment. Most states have placed significantly more limitations on the scope of courts to order release of personal health information. Several areas of personal medical information, including mental health and HIV/AIDS cases also are protected by state statutes that restrict disclosure of such information.

There is a common law cause of action that consumers may have based upon the **physician-patient relationship** and privacy (Miller, 2006). Two examples of such actions include:

1. A New York court legally enjoined a psychoanalyst from circulation a book in which detailed information concerning a patient was written (*Doe v. Roe*, 1977).
2. The Oregon Supreme Court ruled that a physician was liable for revealing his patient's identity to the patient's natural child who had been adopted (*Humphers v. Inter. Bank*, 1985). This breach was held to be a breach of professional responsibility.

Thus, state law may statutorily and at common law offer greater privacy protection than does **HIPAA** privacy rules.

PRIVACY CONCERNS FOR THE FUTURE

The future of medicine and healthcare necessarily must contain a prediction for the increased utilization of computer information and the Internet. Any such discussion will contain the exponential increase in the use of national and international markets with more chances for individual privacy to be compromised. There is an increasing focus on computerized medical records. The Veterans Administration has adopted computerized record keeping (*Schmidt v. Dept. of Veterans Affairs*, 2003). An executive order in 2004 established the Office of Health Information Technology. Thus, the federal government is moving forward in its efforts to use technology in health record keeping.

The advantages for such record keeping systems are better patient care information and fewer iatrogenic illnesses, drug interactions, and prescribing mistakes. The disadvantage is the security risk. Each day, the newspaper contains stories of computer records being stolen or compromised. The **HIPAA** privacy rules do pertain to all computerized records and e-mail. Records and communications of this sort must be protected with **encryption** and other security steps. Computerized records have been accidentally posted on the Internet (Pillar, 2001).

E-mail communications should be handled with the same discretion that other methods of communication are treated. E-mails can be requested in discovery and may be used in civil and criminal actions: e-mails tend to exist in cyberspace forever. Stories abound regarding health care information emails that have accidentally been sent to hundreds of the wrong recipients (Salganik, 2000). The law relating to computers, e-mails, and the Internet is still developing.

Individuals deserve privacy in their dealings with physicians, health maintenance organizations, billing agencies, pharmacies, and other entities. The remedies, both civil and criminal, offered to consumers for breaches of privacy are piecemeal at this time and consist largely of common law actions or those statutorily provided by each state.

The federal **HIPAA** law articulates the minimum protection that may be afforded to individuals. There is no uniform consistent statutory scheme to protect individual privacy of medical information nationally. Each state is free to create its own legislation. It is important to minimize the accidental release of private information. The law is continually developing in the area of privacy, the Internet, e-mails, and computer-stored information. New legal issues emerge each day that need attention in this ever expanding area. Federal law must be enacted to deal with Internet privacy violations uniformly and provide deterrents for violating the law with significant fines and criminal penalties for the full range of patients' privacy violations from merely negligent to that purposeful criminal violation of patients' privacy. Web sites that provide drugs to all comers with no physician oversight should be illegal.

REFERENCES

American Board of Medical Specialties. (2007). Retrieved June 1, 2007 from http://www.abms.org

American Medial Association. (2007). *Informed consent*. Retrieved June 1, 2007, from http://www.ama-assn.org/ama/pub/category/4608.html

Bang v. Miller, 88 N.W. 186 (Minn. 1958). Retrieved June 1, 2007, from LexisNexis, Cases, Law School database.

Beck, J., & Herrmann, M. (2007). *Drug and device law: HIPAA does not preempt state litigation practice*. Retrieved July 2, 2007, from http://druganddevicelaw.blogspot.com/2007/02/hipaa-does-not-preempt-state-litigation.html

Bogozza, D. (2006). WHO and partners accelerate fight against counterfeit medicines. *PR Newswire US.* Retrieved June 5, 2007, from LexisNexis News

Bommareddy v. Superior Court, 222 272 Cal. Rptr. 246 (Cal. Ct. App.1990). Retrieved from LexisNexis Cases, Law School database.

Boyer, M. C. (2004). Texas administrative agencies tackle compliance with the health insurance portability and accountability act's privacy rule. *Texas Tech Journal of Administrative Law*, *5*, 100–111.

Cal. Civ. Code 56-56.37 (LexisNexis 2007).

Can Google diagnose illness better than doctors? (Nov. 6, 2006). *The Daily Mail* (London). Retrieved June 4, 2007, from http://www.seroundtable.com/archives /006667.html

42C.F.R. § 482.51

Chamness, J. N. *Liability of physicians for communicating over the internet*. Retrieved June 1, 2007, from http://www.Cornelius-collins.com/CM/What's New/asp

Chiang, M., & Starren, J. (2002). *Telemedicine and HIPAA: Data confidentiality and HIPAA*. Retrieved May 23, 2007, from http://www.ideatel.org/syllabus/hipaa.html

Controlling the Assault of Non-Solicited Pornography and Marketing Act of 2003, 15 U.S.C. § 7706.

Cyberdocs today announced the rirst virtual doctors [sic] office on the world wide web (1996). Westlaw M2 Presswire. Retrieved June 1, 2007 from 1996 WL 11276562

Denoon, D. J. (2007). Internet drug pushing up again. More websites advertising, selling controlled prescription drugs. *Health News*. Retrieved June 21, 2007, from WebMD, http://www.webmd.com/news/200770518/interent-drug-pushing-up-again

Doe v. Roe, 93 Misc. 2d 201, 400 N.Y.S.2d 668 (Sup. Ct. 1977).

Food and Drug Administration. *FAQ's*. Retrieved September 26, 2007, from http://www.fda.gov/oc/buyonline/faqs.html

Fox v. Smith, 594 So. 2d 596 (Miss. 1992). Retrieved June 1, 2007, from LexisNexis Cases, Law School database.

Goldfarb v. Virginia State Bar, 421 U.S. 773, 792 (1975).

Granade, P. F., & Sanders, J. H. (1996). Implementing telemedicine nationwide: Analyzing the legal issues. 63 *Defense Counsel,* 67.

Granfield, A. (2000). FTC's bite out of internet fraud lacks teeth. *Forbes.com.* Retrieved July 2, 2007, from http://www.forbes.com/2000/03/27/mu2.html

Gregg, J. (2007). Senator Gregg introduces bill to increase safety for Americans buying on-line prescription drugs. *States News Service*. Retrieved June 5, 2007, from LexisNexis News library.

Harrington, K. (1999). Legal implications of the practice of medicine over the internet, telemedicine and cybermedicine. *Cyberlaw.* Retrieved July 2, 2007, from http://www.gase.com/cyberlaw/toppage11.htm

Health Insurance Portability and Accountability Act of 1996, 42 U.S.C. § 1320(d).

Humphers v. First Interstate Bank, 696 P.2d 527 (Or. 1985).

Iredale, W., & Swinford, S. (2007, February 25). Web supplies prescription drug addicts. *Sunday Times* (London). Retrieved June 3, 2007, from LexisNexis News file.

Johnson, A. (June 2006). Digital doctors. *National Conference of State Legislatures Magazine*. Retrieved June 1, 2007, from http://www.ncsl.org/programs/pubs/slmag/2006/org

Kohlman, R. J. (2006). Existence of physician patient relationship. 46 *Am. Jur., Proof of Facts 2d 373. §§ 1, 2, 3, 8.*

Kramer, D. (2007). *American jurisprudence: Supremacy of constitutions; supreme laws* (2nd ed.). Minneapolis: The West Publishing Company.

Lade, D (2007, July 15). Getting medication in privacy is part of internet appeal, but there are risks. *Sun Sentinel*. Retrieved September 17, 2007, from LexisNexis current News file.

Lewis, C. A. (2004). *Cybermedicine: Do you need to know or see your physician, or is it safe to practice medicine in cyberspace?* Retrieved March 28, 2007, from http://gsulaw.gsu.edu/lawand/papers/fa04/lewis/doc/htm

Lisse, J. (2007). *Bechet disease*. Retrieved June 3, 2007, from http://www. emedicine.com/med.topic218.htm

Mack, A. (2000, January 3). Op-Ed Re: Sometimes the patient knows best. *New York Times.* Retrieved June 5, 2007, from LexisNexis News service.

McGrath, R. (2005). Only a matter of time: Lessons unlearned at the food and drug administration keep Americans at risk. *Food and Drug Law Journal*, *60*, 603–624.

MedicineNet. (2007). *Orphan disease definition*. Retrieved June 4, 2007, from http://www.medterms.com/script/main/art.asp?articlekey=11418

Mencik, S. (1999). *Are secure internet transactions really secure?* Retrieved June 6, 2007, from http://www.jsweb.net/paper.htm

Metz, J. (2004). *Practical insights to HIPAA: Overview and general background regarding HIPAA*. Retrieved May 21, 2007, from http://www.dilworthlaw.com/pdf/hipaa.pdf

Miller, R. D. (2006). *Health care law*. Sudbury, Massachusetts: Jones Bartlett Publishers.

Moser v. Stallings, 387 N.W.2d 599 (Iowa 1986). Retrieved June 1, 2007 from LexisNexis law School database.

Nath, S. W. (2006). Relief for the e-patient? Legislative and judicial remedies to fill HIPAA's privacy gaps. *The George Washington Law Review*, *74*, 532–540.

O'Donnell v. Blue Cross Blue Shield of Wyo., 173 F. Supp. 2d 1176, 1179-80 (D. Wyo. 2001).

Office of Health Information Technology. (2004). Retrieved June 21, 2001 from http://www.Whitehouse.gov/omb/egov/gtob/health_informatics.htm

Ohio Rev. Code Ann. 2743.43 (A)-(D) (LexisNexis 2007) Expert testimony on liability issues. Retrieved June 1, 2007, from LexisNexis Ohio Cases.

Ostrov, B. (2007, March 14). Menlo Park teen's suicide shines light on shadowy market. *The Mercury News*. Retrieved September 18, 2007, from LexisNexis News library.

Patients Rights Conditions of Participation (Revised 2007). 42 C.F. R. 482.13, 482.24 and 482.51.

Pettus v. Cole, 57 Cal. Rptr. 2d 46 (Cal. Ct. App. 1996).

Pillar, C. (2001, November 7). Web mishap: Kid's psychological files posted. *L.A. Times, Nov.,* A1.

Pritts, J. L. (2002). Altered states: State health privacy laws and the impact of the federal health privacy rule. *Yale Journal of Health Policy, Law, and Ethics*, *2*, 334–340.

Privacy Rights Clearinghouse. (2006). *HIPAA basics: Medical privacy in the electronic age*. Retrieved May 23, 2007, from http://www.privacyrights.org/fs/fs8a-hipaa.htm

Public Welfare. 45 C.F.R. § 160 *et seq*.

Salganik, M. W. (2000, August 10). Health data on 858 patients mistakenly emailed to others; medical information was among messages sent out by Kaiser Health Care. *Baltimore Sun,* Aug., 1C.

Schmidt, C. W. (2000). *Patient health information goes electronic*. Retrieved July 2, 2007, from http://pubs.acs.org/subscribe/journals/mdd/v03/i09/html/rules.html

Schmidt v. Dep't of Veteran's Affairs, 218 F.R.D. 619 (E.D. Wis. 2003).

Scott, R. (2001). Health care symposium: E-health: The medical grontier: Cybermedicine and virtual pharmacies. *West Virginia Law Review*, *103*, 412–413.

Shah, R., & Piper, M. H. (2007). *Wilson disease*. Retrieved June 4, 2007, from eMedicine-Http://www.emedicne.com/med/topic2413.htm

Symptoms of Cushing Syndrome. (2007). WrongDiagnosis.com. Retrieved June 3, 2007, from http://www.wrongdiagnosis.com/c/cushings_syndrome/symptoms.htm

Telemedical Report to Congress, 104th Cong., 2d Session (1996).

The Safe Internet Pharmacy Act of 2007, S.596, 110th Congress, 1st Session (Fall 2007) Retrieved June 5, 2007, from LexisNexisCongrssional database.

Tyler, B. J. (1998). Cyberdoctors: The virtual housecall—the actual practice of medicine on the internet is here; is it a telemedical accident waiting to happen*? Indiana Law Review*, *13*, 259–290.

University of Miami Miller School of Medicine Privacy/Data Protection Project. (2005). *Privacy Standard/Rule (HIPAA)*. Retrieved May 22, 2007, from http://privacy.med.miami.edu/glossary/xd_privacy_stds_applicability.htm

Unze, D. (2007, August 3). Internet operation puts man in prison. *St. Cloud Times*. Retrieved September 17, 2007, from LexisNexis Current news file.

42U.S.C. § 290dd-2 (2006).

Wachter, G. W. (2001). *Law and policy in telemedicine: HIPAA's privacy rule summarized—what does it mean for telemedicine?* Retrieved May 30, 2007, from http://tie.telemed.org/articles/article.asp?path=legal&article=hipaaSummary_gw_tie01.xml

SUGGESTED READINGS

Beaver, K., & Herold, R. (2003). *Practical guide to HIPAA privacy and security compliance*. New York: CRC Press.

Hall, G. (2006). *Privacy crisis: Identity theft prevention plan and guide to anonymous living*. United States: James Clark King, LLC.

HIPAA—Health Insurance Portability and Accountability Act of 1996, 42 U.S.C. § 1320(d).

Sanbar, S. S., Fiscina, S., & Firestone, M. H. (2007). *Legal medicine* (6th ed.). Philadelphia: Elsevier Health Sciences.

Slack, W. V., & Nader, R. (2001).*Cybermedicine: How computing empowers doctors and patients for better health care*. United States: Jossey-Bass Inc.

WEB SITES

Data Privacy Lab. (2007). *The laboratory at Carnegie Mellon seeks balanced integrated solutions that weave technology and policy together*. Retrieved, November 4, 2007, from http// www.cs.cmu.edu

Privacy Rights Clearinghouse. (2007). *HIPAA basics: Medical privacy in the electronic age*. Retrieved November 5, 2007, from http://www.Privacyrights.org/inquiryform.html

This work was previously published in Online Consumer Protection: Theories of Human Relativism, edited by K. Chen and A. Fadlalla, pp. 347-369, copyright 2009 by Information Science Reference (an imprint of IGI Global).

Chapter 1.20

Health Technology Assessment and Health Economics

Steven Simoens
Katholieke Universiteit Leuven, Belgium

ABSTRACT

This chapter introduces health technology assessment and health economics as tools for decision makers to allocate scarce resources in the healthcare sector. It argues that information about the safety, efficacy and effectiveness, organizational implications, social and ethical consequences, legal considerations, and health economic aspects of the application of a health technology needs to be taken into account with a view to informing decisions about the registration and reimbursement of a health technology. Also, the author hopes that understanding the methodology and use of health technology assessment and health economics will persuade the reader of the added value of such studies and promote the application of health technologies that support further health improvements, whilst containing health expenditure.

DOI: 10.4018/978-1-60566-356-2.ch005

INTRODUCTION

Over the past decades, health technology has made a major contribution to improving the health status of populations. At the same time, countries of the Organisation for Economic Co-operation and Development (OECD) witnessed an annual average growth in health expenditure per capita of 4% during the 1995-2005 period. Growth in health expenditure outpaced economic growth of 2.2% during the same period. Health expenditure growth can be attributed to a number of factors, including ageing populations, the increasing prevalence of chronic conditions, healthcare resource use price inflation, technological advances, and increased expenditure on drugs. With respect to the latter, annual average growth in pharmaceutical expenditure per capita of 4.6% during the 1995-2005 period exceeded the annual rise in health expenditure (Organisation for Economic Co-operation and Development, 2007).

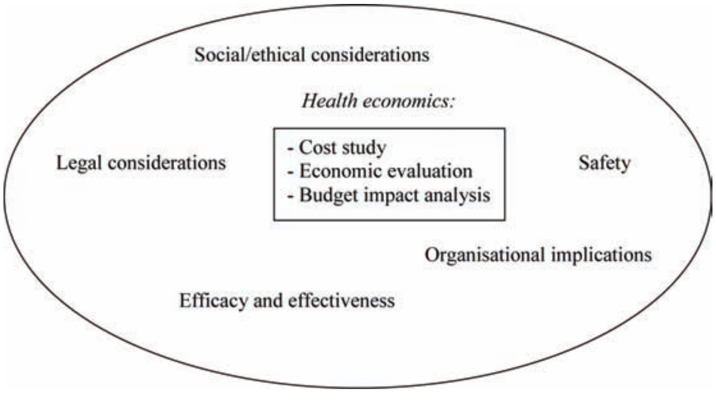
In response to this, Governments seek instruments that can aid the implementation of safe and effective health technologies that support further health improvements, whilst containing health expenditure. Health technology assessment and health economics provide such tools (Carlsson, 2004). Evidence derived from health technology assessments and health economics is used to inform decisions about the registration and reimbursement of health technologies in an increasing number of countries. The requirement for health technology assessment and health economics fits within an overall trend towards evidence-based decision making in healthcare (Perleth et al., 2001).

By carrying out a health technology assessment and a health economic evaluation, companies can demonstrate the value of their health technologies with a view to obtaining registration and reimbursement. For instance, in order to obtain registration and reimbursement, drugs need to overcome a number of so-called hurdles. A new drug needs to demonstrate its quality (first hurdle), safety (second hurdle) and efficacy (third hurdle) with a view to obtaining a *registration*. *Reimbursement* may depend on the value for money of the drug at the time of the reimbursement application (fourth hurdle) and after a number of years following the admission to the reimbursement system (fifth hurdle).

The aim of this chapter is to provide an introduction to the science underlying the assessment of a health technology. This chapter serves as a resource for readers who want a succinct overview of the methodology and use of health technology assessment and health economics. Particular attention is paid to defining the fundamental concepts and terms that are relevant to health technology assessment and health economics. Key references are added for those readers who wish a more advanced understanding of these topics. The chapter concludes with providing some additional resources (suggested readings, scientific journals, international societies and databases) related to health technology assessment and health economics.

Figure 1 presents the conceptual framework for this chapter. In its broadest form, a health technology assessment evaluates a health technology in terms of multiple criteria, one of which consists of a health economic assessment. The different criteria of a health technology assessment and the different forms of a health economic assessment are described in detail in the remainder of this chapter.

Figure 1. Health technology assessment and health economics



HEALTH TECHNOLOGY ASSESSMENT

Health technology assessment can be defined as a type of policy research that explores the safety; efficacy and effectiveness; organizational implications; social and ethical consequences; legal considerations; and health economic aspects of the application of a health technology. For instance, a health technology assessment of orthoses in Belgium covered the following aspects: a critical appraisal of the literature on effectiveness, costs and cost-effectiveness of orthoses; an international comparison of policy regulations on orthoses; a market analysis of orthoses; an international price comparison and production cost analysis of selected orthoses; and policy recommendations (Simoens et al., 2007).

The definition of a health technology assessment identifies three elements. First, health technology assessment seeks to support decision making by formulating recommendations for safe, effective health policies that are patient focused and achieve best value. Second, all relevant implications of a technology are evaluated. This requires a multidisciplinary approach involving physicians, economists, statisticians, ethicists, lawyers, engineers, social scientists, manufacturers and patients. Third, any technology can be the subject of an assessment. In general, a health technology refers to all measures for prevention, diagnosis, treatment and rehabilitation of a disease, including vaccines, drugs, medical and surgical procedures, and medical devices. It also refers to the organisational and support systems in which health care is provided.

The different aspects that are considered by a health technology assessment are now outlined (Goodman, 1998; Busse et al., 2002).

Safety

Safety judges the risks associated with using a technology. A health technology assessment should report the frequency and severity of adverse effects, the impact of the adverse effect on patient morbidity and mortality, and the risk of adverse effects among different groups of patients. A description should be provided of how the adverse effects were caused. Attention also needs to be paid to contextual factors (e.g. learning curve of surgeons) that may influence safety outcomes.

Regulatory authorities, such as the Food and Drug Administration (FDA) and the European Medicines Agency (EMEA), play a role in monitoring safety outcomes. Information about safety can also be gathered from the medical literature. Randomized controlled trials routinely measure safety outcomes, although this study design may not identify all possible harms of a technology. For instance, the time horizon of a randomized controlled trial may be too short to pick up rare adverse effects. Also, patients experiencing adverse effects may be excluded from a randomized controlled trial. Therefore, other study designs, such as observational studies and case reports, may provide valuable information about the occurrence of adverse effects.

Efficacy and Effectiveness

Efficacy and effectiveness both refer to the impact of a health technology on patient health. *Efficacy* refers to the clinical impact of a technology under ideal circumstances of use. *Effectiveness* measures the clinical impact of a technology under conditions of day-to-day practice and use. The effectiveness of a health technology tends to be lower than its efficacy because the clinical impact in daily practice may be influenced by such factors as the skills of the surgeon or patient compliance with drug therapy. For instance, a literature review concluded that the success of antimicrobial treatment of respiratory tract infections depended on patient compliance, with compliance being affected by the frequency of dosing, duration of treatment, adverse events, ease of administering drugs, ease of packaging, and price (Simoens, Decramer, & Laekeman, 2007).

With a view to providing a comprehensive overview of the clinical efficacy and effectiveness of a technology, a health technology assessment typically conducts a systematic literature review. Systematic reviews of the medical literature should be carried out following the guidelines of the Cochrane Collaboration® (Higgins, & Green, 2006). A good review formulates a well-defined research question; implements a search strategy for identification of studies; assesses the methodological quality of studies; extracts data from studies; summarises and interprets results.

Organizational Implications

A health technology assessment needs to examine the organisational issues specific to the local healthcare system that are related to the acquisition and operation of a technology. More specifically, the use of a technology may have implications for the training of staff (e.g. if staff need to have specific skills to apply the technology); for communication channels (e.g. if the technology requires communication between primary care and secondary care physicians), for the location of treatment (e.g. if the technology enables a patient to be treated in general practice rather than in hospital), for the utilization of healthcare services (e.g. if the introduction of a new drug therapy reduces surgical interventions), and for healthcare infrastructure (e.g. if the implementation of the technology reduces hospital length of stay or the need for hospital beds).

Social and Ethical Considerations

The perspective of patients and society can be incorporated in a health technology assessment by considering the social and ethical impact of a technology. Health technologies tend to raise social and ethical questions given that many technologies intervene at the start or the end of a patient's life. Technologies such as genetic testing, use of stem cells to grow new tissues and organ transplantation challenge societal norms and values.

A variety of approaches can be followed to elicit social and ethical issues related to the introduction of a health technology. Social and ethical aspects of a technology can be assessed by reviewing the social sciences literature. The public perspective can also be included in a health technology assessment by carrying out a patient survey; by organizing a focus group discussion with patients; by consulting patient organization websites; or by holding roundtables with ethicists and sociologists.

Legal Considerations

The introduction of a health technology has legal implications for the organization and financing of the healthcare sector and for the rights of stakeholders such as patients, healthcare professionals and manufacturers. For instance, a health technology assessment of weight-loss interventions explicitly took account of the regulation surrounding liability claims initiated by patients who experienced damage or injury following an intervention; the duty for supervision and information following weight loss surgery; patient rights (e.g. the right to informed consent); advertisement on weight-loss interventions; and legal aspects of cross-border healthcare in the domain of weight-loss interventions (Lambert et al., 2006). Consideration of legal aspects in a health technology assessment requires the input from lawyers.

Health Economic Aspects

The *health economic* aspects can be explored by carrying out a cost study, an economic evaluation and a budget impact analysis of the health technology. These three aspects are examined in more detail in the remainder of this chapter.

COST STUDY

A *cost study* can serve multiple purposes. Cost estimates can underline the importance of a disease to society when considered alongside its impact on morbidity and mortality and when compared with the economic burden of other diseases. Furthermore, cost studies may allow the identification of the drivers of diagnosis and treatment costs. Finally, cost data can be fed into economic evaluations, so that decision makers can ascertain the efficiency of various approaches to diagnosing and treating a disease by examining their consequences in relation to their costs.

Information about costs can be derived from a cost-of-illness analysis or from a cost analysis. A *cost-of-illness analysis* quantifies the economic burden of a disease to society by measuring the costs of diagnosing and treating a disease as well as the costs arising as a result of the disease (for instance, productivity loss due to time taken off work). A *cost analysis* compares the costs of two or more approaches to diagnosis and treatment of a disease (for instance, medical versus surgical therapy).

The following categories of costs can be distinguished. Direct healthcare costs refer to the costs of healthcare services such as costs of drugs, physician visits and hospitalisation. Direct non-healthcare costs are related to the provision of healthcare, but are of a non-medical nature. Examples of direct non-healthcare costs are the costs of transportation to the hospital and the costs of child care while the patient is receiving treatment. If healthcare services keep a patient alive, the patient is likely to fall ill in the future and require additional healthcare services. Healthcare costs in the added years of life as a result of keeping patients alive are denoted by indirect healthcare costs. Finally, indirect non-healthcare costs reflect the costs of productivity loss as a result of the disease. These costs not only consist of the productivity loss of the patient, but also of the productivity loss of family or friends who take time off work to care for the patient. The productivity loss may take the form of time lost from work ('absenteeism') or reduced productivity at work ('presenteeism').

Costs originate in the healthcare sector and in other sectors. For instance, treatment of opiate-dependent drug users involves the health sector (through the provision of maintenance or detoxification programmes), but also relies on the input from social care agencies. Furthermore, some studies have demonstrated that treatment costs are offset by savings arising from the prevention of future healthcare use and the reduction in criminal justice expenditure (Simoens, Ludbrook, Matheson, & Bond, 2006). Costs are incurred by the health care payer (i.e. insurance funds or national health service), the patient / family (e.g. drug co-payment, costs of home adaptation) and by the society at large (e.g. costs of productivity loss).

Once the relevant resource use has been identified, measured and valued, costs can be calculated (Jacobs, Ohinmaa, & Brady, 2005). These four steps are now described in detail in the following sections.

Identification of Resource Use

The perspective of the study determines which items of resource use need to be taken into account. A cost study can take a societal perspective by considering all (in)direct (non-)healthcare resource use. Alternatively, the more narrow perspective of the Ministry of Health, health care payer, hospital or patient can be adopted. In these instances, the cost study considers those items of resource use that are relevant from the perspective of the study. For instance, productivity loss as a result of illness is included in a cost study from the societal perspective. However, productivity loss is not relevant to the Ministry of Health and is, thus, excluded from a study with such a perspective.

The time horizon of a cost study needs to cover all relevant resource use. This applies to cost analyses, particularly those of immunization or vaccination programmes. Such programmes are associated with the use of drugs in the short-term, but may lead to savings from reduced healthcare resource use and from less productivity loss in the future. The time horizon needs to be sufficiently long to be able to investigate whether present drug costs are offset by future cost savings. The time horizon is also relevant to cost-of-illness analyses. A cost-of-illness analysis may take the form of a prevalence-based study, which measures costs attributable to a group of patients suffering from a disease during a given time interval. For instance, a literature review indicated that cost-of-illness analyses of endometriosis measured costs during a time period varying from six months to five years. This period was too short to account for the chronic nature of endometriosis which may afflict women during their reproductive years (Simoens, Hummelshoj, & D'Hooghe, 2007). Therefore, cost-of-illness analyses need to take the form of an incidence-based study, quantifying costs of a disease from onset to end.

Measurement of Resource Use

Two approaches can be adopted to measure the volume of resource use. On the one hand, a micro-costing or bottom-up approach identifies and measures each relevant item of resource use. This approach generates estimates of resource use with a high level of precision. However, this approach is time-intensive, expensive, and may yield estimates that are context-specific. On the other hand, a gross-costing or top-down approach measures resource use at the aggregate level (e.g. at the level of diagnosis-related groups) without specifying individual items. Such estimates benefit from increased generalisability and improve comparability of cost studies, but are less precise.

In terms of data sources, resource use can be measured in a sample of patients (primary data collection). A cost study can follow up patients suffering from a specific disease. Such case series that focus on identified patients only may be misleading in the case of diseases where diagnosis is complex and attribution of resource use to the disease is difficult. Studies comparing patients with/without a disease are better suited in that they allow identification of additional resource use related to the disease. Resource use can also be derived from existing sources such as patient medical records, a health care payer claims database or the published literature (secondary data collection). Patient medical records provide detailed information about healthcare resource use. However, such data tend to pertain to a specific institution(s), thus limiting the generalisability of cost estimates. An analysis of claims data benefits from comprehensiveness of information on healthcare resource use, but may suffer from missing data and incorrect diagnostic coding of claims. Resource use data can be gathered from the literature, although differences in the design of primary studies may restrict comparability of estimates.

Valuation of Resource Use

The valuation of resource use puts a monetary value on the resources depleted by the disease and its treatment. To this effect, the volume of resource use is multiplied by market prices. However, market prices do not always exist. For instance, drug prices may be negotiated between the government and the pharmaceutical company. Therefore, researchers use official list prices to calculate charges. Caution needs to be exercised when calculating charges as these do not necessarily reflect the worth of resource use. For instance, charges of surgical treatment in hospital may not accurately measure actual expenditure on administration, billing, capital depreciation, maintenance, laundry and other hospital services related to the surgical procedure.

Alternatively, shadow prices can be used to value resource use in the absence of market prices. This can be illustrated with the valuation of productivity loss. If the patient is an employee, his/her wage can be used to value lost productivity. If the patient is a housewife, this approach cannot be used as a housewife does not receive a wage. Instead, researchers need to draw on a shadow price, i.e. the market price of a similar activity. In this example, the market wage of a professional housekeeper could serve as the shadow price and could be used to value the productivity loss of the housewife.

Calculation of Costs

When calculating the costs of a healthcare programme, the question arises of whether to compute marginal or average costs. Dividing total costs by the number of units generates average costs. Average costs include fixed costs (e.g. costs of hospital infrastructure) as well as variable costs. Marginal costs represent the costs of producing one additional unit and, therefore, include variable costs only. As our interest is in the additional costs incurred by the healthcare programme, a cost study needs to calculate marginal costs. However, if the national implementation of a healthcare programme involves building a new hospital, the use of average costs is recommended as these represent the additional costs imposed by the programme.

ECONOMIC EVALUATION

An *economic evaluation* is in essence a comparative analysis of at least two health technologies in terms of both their costs and outcomes. Figure 2 portrays the components of an economic evaluation of a new drug therapy vis-à-vis a comparator. The comparator is generally chosen to reflect common clinical practice in the setting where the economic evaluation is undertaken. In our example of a new drug therapy, the comparator can be an older drug or a surgical intervention. If the new drug represents the first technology that is available to treat a specific disease, the relevant comparator may be no active therapy.

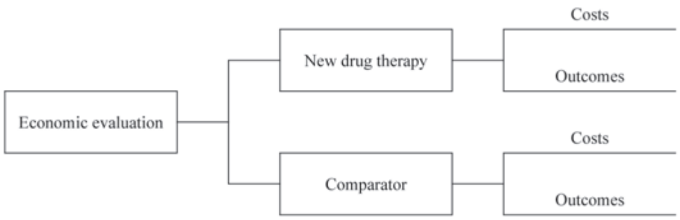
An economic evaluation enables us to answer *efficiency* questions by relating the costs to the effectiveness of alternative health technologies. An *incremental analysis* is carried out to express the results of an economic evaluation. This means that, for meaningful comparison, an economic evaluation expresses the additional costs incurred by one health technology vis-à-vis the comparator in relation to the additional outcomes of the technology vis-à-vis the comparator.

Types of Economic Evaluation

An economic evaluation can take a number of forms.

A *cost-minimisation analysis* is appropriate when the alternative health technologies produce equivalent outcomes (i.e. effectiveness and safety). In this case, a cost-minimisation analysis identifies

Figure 2. Components of an economic evaluation



the least costly health technology. For instance, an economic evaluation examined the efficiency of two antibiotics (teicoplanin and vancomycin) used in the treatment of intensive care unit patients with catheter-related infections (Simoens, De Corte, & Laekeman, 2006). Comparative trials of teicoplanin and vancomycin reported no significant differences in their effectiveness. Therefore, a cost-minimisation analysis compared costs of drug acquisition, materials required for preparation and administration of antibiotics, laboratory tests and nursing time. Treatment with teicoplanin turned out to be more expensive than vancomycin. This was because lower costs of laboratory tests with teicoplanin only partially offset higher drug acquisition costs.

A *cost-effectiveness analysis* denotes an economic evaluation that measures costs in a monetary unit and quantifies a single outcome in a physical or natural unit (e.g. the number of successfully treated patients, the number of life years gained, the number of symptom days averted). Final outcome measures (e.g. life years gained) are preferred to intermediate measures (e.g. cholesterol level) as our interest is in the ultimate impact of a technology on health. Also, as final outcome measures are relevant to multiple health technologies and diseases, their use facilitates comparison of the efficiency of various technologies. The results of a cost-effectiveness analysis are expressed by means of an incremental cost-effectiveness ratio:

Incremental cost-effectiveness ratio $= (C_1 - C_0) / (E_1 - E_0)$ where C_1 is the cost of the health technology; C_0 is the cost of the comparator technology; E_1 and E_0 are the outcomes of the technology and the comparator, respectively.

A cost-effectiveness analysis is only possible if the health technologies affect the same outcome. However, technologies may affect multiple outcomes. In this case, a cost-consequence analysis can be carried out, which presents costs and multiple outcomes. The results can be expressed as several incremental cost-effectiveness ratios, one for each outcome. The drawback is that a cost-consequence analysis does not provide an assessment of the overall efficiency of a health technology.

The previous types of economic evaluation pose a number of challenges. In particular, health technologies may impact multiple outcomes, outcomes may differ between health technologies, and patients may attach more importance to some outcomes than others. In response to this, the two following types of economic evaluation have been developed that combine and value the various outcomes in a single generic measure of health improvement.

An economic evaluation that measures costs and outcomes by means of specific health-related quality of life measures, such as quality-adjusted life years, is referred to as a *cost-utility analysis*. The *quality-adjusted life year* takes into account the quantity and quality of life. The quality of life associated with a health state is measured through the use of health utilities. A utility reflects the preference of the general public for the health state. Utilities are elicited on a scale of 0 (reflecting death) to 1 (reflecting perfect health) using techniques such as the visual analogue scale, the standard gamble or the time trade-off (see Torrance, Furlong, & Feeny, 2002 for more information about health utility estimation). Quality of life data are then combined with estimates of the time period for which the health benefits last to generate quality-adjusted life years. The results of a cost-utility analysis using quality-adjusted life years are expressed by means of an incremental cost-utility ratio:

Incremental cost-utility ratio $= (C_1 - C_0) / (Q_1 - Q_0)$ where C_1 is the cost of the health technology; C_0 is the cost of the comparator technology; Q_1 and Q_0 are the number of quality-adjusted life years associated with the technology and the comparator, respectively.

A *cost-benefit analysis* values outcomes in monetary terms (the 'benefits') in addition to costs. A monetary value can be assigned to outcomes by means of the human capital approach, the revealed preference approach or the willingness-to-pay technique (see Ryan, Watson, & Amaya-Amaya, 2003 for more information about the monetary valuation of outcomes). However, assigning monetary values to outcomes is controversial and further work on methods to value outcomes needs to be carried out. As both costs and outcomes are expressed in monetary terms, costs can be directly compared with benefits and the net worth (benefits minus costs) of a health technology can be estimated. The results of a cost-benefit analysis may be stated in the form of the net benefit (or net loss) of one health technology over another or in the form of an incremental cost-benefit ratio:

Net benefit = $(B_1 – B_0)$ - $(C_1 – C_0)$

Incremental cost-benefit ratio = $(C_1 – C_0) / (B_1 – B_0)$ where C_1 is the cost of the health technology; C_0 is the cost of the comparator technology; B_1 and B_0 are the health benefits of the technology and the comparator, respectively.

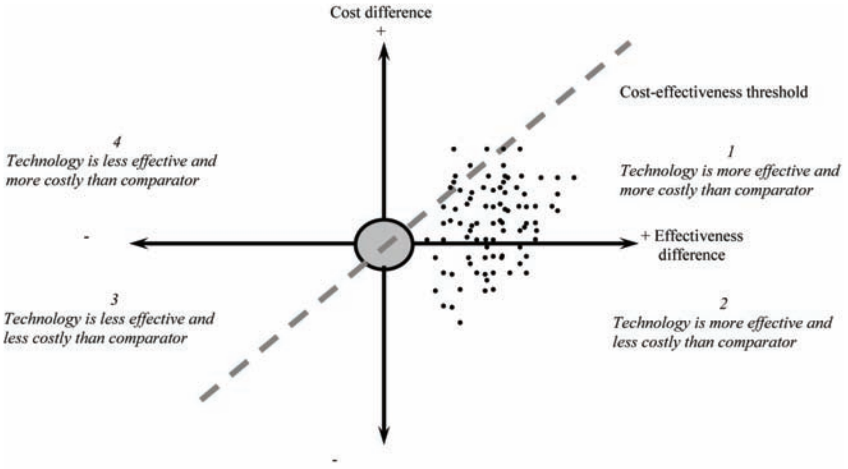
A cost-benefit analysis is not only suited to assess whether the costs of a health technology are justified by its benefits. This type of analysis can also be used to compare the benefits and costs of technologies in sectors other than healthcare. As a consequence, cost-benefit analysis answers the question of allocative efficiency and enables us to allocate resources to the most efficient technologies across sectors. This contrasts with cost-effectiveness and cost-utility analysis, which answer the question of productive efficiency by calculating the additional costs to achieve, for instance, one additional life year or one additional quality-adjusted life year. Assessment of value for money in a cost-effectiveness and cost-utility analysis necessitate a (subjective) judgement of the societal worth of one unit of outcome (e.g. one life-year gained). In response to this, so-called cost-effectiveness thresholds and cost-utility thresholds have emerged. These thresholds represent the maximum cost per (quality-adjusted) life-year gained that authorities are willing to pay for a health technology. For instance, the National Institute for Health and Clinical Excellence has stated that it does not have official thresholds to assess the value for money of health technologies in England and Wales. However, a review of their guidance issued between 1999 and 2005 concluded that technologies having an incremental cost-utility ratio exceeding £30,000 per quality-adjusted life year are likely to represent an unacceptable use of limited resources (Raftery, 2006).

The Cost-Effectiveness Plane

The question whether to conduct an economic evaluation can be answered by looking at the so-called *cost-effectiveness plane* (see Figure 3) (Black, 1990). On the horizontal axis, the difference in effectiveness (e.g. life years) between the health technology and the comparator is portrayed. The vertical axis represents the cost difference between the technology and the comparator. The technology may have higher or lower costs, and higher or lower effectiveness than the comparator, so that its point may fall into one of the four quadrants.

If the point falls into quadrant 2, the technology is more effective and less costly than the comparator. In other words, the technology dominates the comparator. This indicates that the technology needs to be adopted and that there is no need to conduct an economic evaluation. Conversely, if the point falls into quadrant 4, the comparator dominates the technology and the comparator should be adopted. In quadrants 1 and 3, one option is more effective, but also more costly than the other option. In these cases, an economic evaluation needs to be carried out. The efficiency of the technology depends on the cost-effectiveness threshold adopted by the authorities. The gradient of the dashed line represents one cost-effectiveness threshold. The technology is efficient if its point falls to the south-east of this dashed line.

Figure 3. The cost-effectiveness plane



Trial- and Model-Based Economic Evaluation

There are two ways to carry out an economic evaluation: a *trial-based economic evaluation* or a *model-based economic evaluation* (Briggs, Claxton, & Sculpher, 2006).

An economic evaluation can be carried out alongside a clinical trial. Such evaluations are called trial-based economic evaluations or piggy-back studies. In the case of a piggy-back study of a new drug, the economic evaluation can be carried out alongside a Phase III clinical trial, which examines the efficacy and adverse reactions during the drug development process. Such economic evaluations provide timely information with high internal validity that can be used by manufacturers, policy makers, healthcare professionals and patients to assess the value of a new drug. The economic evaluation can also be conducted alongside a Phase IV clinical trial, which examines long-term effectiveness following regulatory approval of the drug. Such economic evaluations explore the efficiency of a new drug under conditions of day-to-day practice and benefit from greater external validity.

There is a wide diversity in the design, conduct and analysis of trial-based economic evaluations. However, a number of good research practices have emerged (Ramsey et al., 2005). A gold standard trial-based economic evaluation should have adequate power with a view to testing hypotheses about expected differences in costs and outcomes. An adequate time horizon needs to capture the long-term impact of the health technology. The choice of clinical outcomes in the trial must be suited for use in the economic evaluation. For instance, quality-of-life values derived from the trial can be used to calculate quality-adjusted life years in a cost-utility analysis. The identification, collection and management of economic data should be fully integrated into the clinical trial. Data analysis should follow an intention-to-treat approach, assess uncertainty, take account of time preference for costs and outcomes, and account for missing or censored data. Appropriate summary measures need to be used to calculate the relative value of the technology vis-à-vis the comparator.

Nevertheless, there are some drawbacks to using piggy-back studies for the purpose of economic evaluation. These include:

- Inadequate sample size
- Restrictive patient selection (patient characteristics, co-morbidities, disease severity)
- Inappropriate comparator
- Short time horizon
- Occurrence of protocol-driven resource use (which leads to over-estimation of costs)
- Artificially enhanced compliance
- Inappropriate outcome measures

Even if a trial-based economic evaluation exists, some *decision-analytic modeling* is likely to be needed. For instance, to examine the full impact of a health technology, modeling beyond the time horizon of the trial may be required. In general, decision-analytic modeling addresses some shortcomings of trial-based economic evaluations by allowing us to compare all relevant options; to incorporate all appropriate evidence; to translate intermediate endpoints into final outcomes; to extrapolate over the appropriate time horizon of the evaluation; and to generalize to other settings or populations (Buxton et al., 1997).

Decision-analytic modeling is a quantitative approach to decision making under conditions of uncertainty. A model can be defined as an analytic methodology that accounts for events over time with a view to estimating the impact of a health technology on costs and outcomes (Weinstein et al., 2003). Decision-analytic modeling can take the form of a decision tree or a Markov model. A decision tree is a graphic representation of the various diagnosis and treatment pathways of a specific disease in combination with the probabilities, costs and outcomes associated with each pathway. A Markov model structures a disease and its treatment process by means of mutually exclusive and exhaustive health states, with patients moving from one health state to another based on transition probabilities. Typically, states have a uniform time period. The time spent in a health state generates costs and outcomes. Estimates of probabilities, costs and outcomes used in decision trees and Markov models are usually derived from the literature or from expert opinion.

With respect to modeling, concerns have been raised about the inappropriate use of clinical data, about biases in observational data, about the difficulties of extrapolation, and about the transparency or validity of models (Buxton et al., 1997). Therefore, it is important to adhere to principles of good practice for decision-analytic modeling in economic evaluation by keeping the model as simple as possible; by presenting the results in a transparent way; by respecting the quality of the data used in the model; and by exploring uncertainty. Attention also needs to be paid to validating the model by comparing the results with those of similar studies and by updating the model when more data become available. Finally, the reader should note that a decision analytic model is only as good (or bad) as the quality of its data and its specification. Thus, model-based economic evaluations need to clearly state the caveat that the results are conditional on the data and assumptions incorporated in the model.

Discounting

The costs and outcomes of a health technology generally do not take place in the same year, but may be spread out over multiple years. For instance, current costs of a vaccination programme need to be compared by future benefits of prevented disease and reduced healthcare costs. An economic evaluation needs to take account of the timing of costs and outcomes because individuals have a positive rate of time preference. This means that individuals attach greater importance to current than to future costs and outcomes. This positive rate of time preference mainly derives from three reasons: a) individuals consider the short run only; b) individuals are uncertain about the future; and c) individuals can invest a Euro now and expect to receive more than a Euro in the future.

Time preference is taken into account in an economic evaluation by the process of *discounting*.

Discounting calculates the present value of costs and outcomes occurring in the future (Brouwer, Niessen, Postma, & Rutten, 2005). By calculating present values, alternative health technologies with differential timing of costs and outcomes can be compared from the same baseline. Although there has been a debate about whether outcomes should be discounted at a different rate than costs, a consensus has emerged that outcomes should be discounted at the same rate as costs. Some countries provide advice on the discount rate to be used. In the absence of such advice, analysts tend to set the discount rate equal to the interest rate on long-term, risk-free investment such as government bonds.

Sensitivity Analysis

Any variable used in an economic evaluation is subject to some uncertainty (Briggs, Sculpher, & Buxton, 1994). This uncertainty can originate from methodological disagreements, researchers' assumptions in the absence of data, imprecise data, need to extrapolate results over time, and the need to generalize results to other settings or other countries. A *sensitivity analysis* determines the direction and the extent to which the results of the economic evaluation vary when estimates of input variables change. There are two approaches to carrying out a sensitivity analysis: deterministic and probabilistic sensitivity analysis.

A deterministic sensitivity analysis explores the impact on results of changes in one input variable (one-way analysis) or of simultaneous changes in multiple variables (multi-way analysis). One application of a multi-way analysis is a scenario analysis. Such an analysis typically includes a best case scenario, where all input variables are changed in the most optimistic way, and a worst case scenario, where input variables take on the most pessimistic values. A scenario analysis provides insight into the efficiency of the health technology in the best case and in the worst case. Finally, a threshold analysis identifies the combination of variable estimates that ensures that the incremental cost-effectiveness or cost-utility ratio of the technology does not exceed the threshold adopted by authorities.

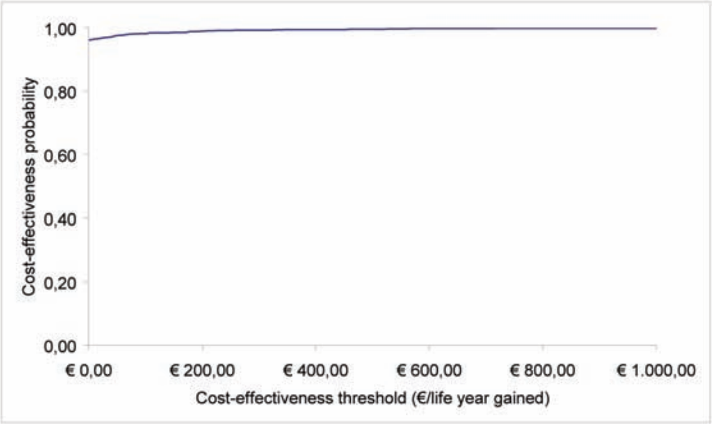
A probabilistic sensitivity analysis is based on a Monte Carlo simulation. The principle is to run the analysis a large number of times (e.g. 10,000 times) with different sets of variable estimates drawn from distributions. This requires that a probability distribution is assigned to each input variable. For each iteration, the simulation draws input parameters at random from their statistical distributions and calculates cost and effectiveness pairs. At the end of the 10,000 iterations, the joint statistical distribution for costs and effectiveness is represented as a cloud of points on the cost-effectiveness plane (see Figure 3).

The gradient of the dashed line in Figure 3 indicates one cost-effectiveness threshold. Typically, this line cuts through the cloud of cost and effectiveness pairs generated by the probabilistic sensitivity analysis. Simulations falling to the south-east of the line support the cost-effectiveness of the health technology. The probability that the technology is cost-effective is estimated as the proportion of points to the south-east of this line. As the cost-effectiveness threshold increases, the dashed line rotates anti-clockwise around the origin, increasing the proportion of points to the right of the line. This allows us to draw cost-effectiveness *acceptability curves* representing the probability that the health technology is efficient for a range of cost-effectiveness thresholds (see Figure 4).

Use of Economic Evaluation by Decision Makers

Is economic evaluation useful? The strength of economic evaluation is corroborated by the dramatic increase in the number of published economic evaluations in recent years. Also, evidence of economic evaluations is taken into account in pricing and reimbursement decisions of health

Figure 4. Cost-effectiveness acceptability curve



technologies in an increasing number of countries. Efficient technologies are rewarded by means of a more favourable price and/or reimbursement. As decision makers appreciate the need to evaluate projects in terms of costs and benefits, economic evaluation offers a framework that presents information about technologies in a format that is familiar and useful to them.

Nevertheless, certain aspects of the decision making process restrict the usefulness of economic evaluations in informing resource allocation decisions. A first aspect relates to institutional features of the healthcare system. For instance, in most European countries, health expenditure is divided across several budgets, with a tendency for decision makers to adopt a silo mentality. This means that decision makers consider each budget separately, but do not take account of the full impact of a technology across budgets. This silo mentality poses challenges for economic evaluation because health technologies are likely to have an impact on multiple budgets. For instance, although the introduction of a new drug may add to the pharmaceutical budget, this may be accompanied by reduced expenditure on other health services utilization. Therefore, there is a need to overcome this silo mentality in order to enhance the value of economic evaluation.

Economic evaluations need to report findings that have practical relevance. For instance, savings arising from fewer hospitalizations are accounted for as a financial benefit in an economic evaluation. However, the benefit does not necessarily materialize in a real setting as vacated beds may be used in the treatment of other patients. If this is the case, researchers are essentially taking into account freed resources, whereas decision makers have an interest in actual financial savings. It is therefore important for researchers to understand the perspective of decision makers, to ascertain for what purpose decision makers wish to use the information derived from the economic evaluation, and to present the results accordingly.

Although decision makers embrace the principle of weighing costs and benefits in making decisions, their actual knowledge of economic evaluation techniques is generally limited and they have doubts about the methodological quality of studies (Drummond et al., 2003). To overcome this barrier, there is a need for better education and training of decision makers in economic evaluation techniques. Moreover, a higher degree of standardization and consensus surrounding methodological principles of economic evaluation is required.

BUDGET IMPACT ANALYSIS

In addition to information about the efficiency of a new health technology, regulatory agencies in an increasing number of countries now require data about the budgetary impact of the technology on national, regional or local budgets. Whereas an economic evaluation allows decision makers to assess the value for money of a health technology, a *budget impact analysis* examines the financial impact of the adoption and diffusion of the technology within a particular setting. Thus, a budget impact analysis considers the affordability of a technology. Specifically, a budget impact analysis explores how a change in the current mix of treatment strategies by the introduction of a new technology will impact spending on a disease. The review by Mauskopf, Earnshaw, & Mullins (2005) presents a number of published examples of budget impact analyses.

Budget impact analysis in combination with cost study and economic evaluation play a crucial part in the comprehensive assessment of a health technology and may inform reimbursement decisions (Cohen, Stolk, & Niezen, 2007). Reimbursement may be withheld from a cost-effective health technology if it has a high budgetary impact. Conversely, a cost-ineffective technology may receive reimbursement if its budgetary impact is limited. The reimbursement of orphan drugs, for instance, shows that decision makers may attach more importance to budget impact and equity considerations than to efficiency.

The methodology of budget impact analysis is still developing, although principles of good practice for budget impact analysis have recently been proposed (Mauskopf et al., 2007). A budget impact analysis starts with providing all relevant epidemiological, clinical and economic information of the disease. Then, the current mix of treatment strategies is described. This may cover no active therapy as well as therapies that may or may not be replaced by the new health technology. The introduction of the technology may lead to technology substitution and market expansion. Therefore, a budget impact analysis considers all patients who might be treated with the new technology, including previously untreated patients who may now seek treatment. Finally, the analysis considers the budgetary impact of various scenarios of how the current mix of treatment strategies changes when the new technology becomes available.

CONCLUSION

Health technology assessment and health economics are suitable tools to evaluate health technologies. Indeed, these instruments present information about the safety, efficacy, effectiveness; organizational, social, ethical and legal implications; and value for money of a technology to decision makers with a view to optimising health policy.

In order to fully exploit the value of health technology assessment and health economics, researchers need to take care to conduct such exercises according to methodologically sound principles. As health technology assessment and health economics are relatively ‘young’ scientific disciplines, further research is needed to refine the methodologies used. Such work will not only enhance the quality of health technology assessment and health economics, but also increase the confidence of decision makers in such exercises and contribute to better health policy.

Additionally, researchers need to take into account the decision making context. Health technology assessment and health economics allow decision makers to maximize health gain subject to the constraint of limited resources. However, one needs to appreciate that such exercises represent only one of the criteria on the basis of which policy makers make decisions, and that they are not necessarily the most important criterion. In addition to health technology assessment and health economics, decision making by policy makers may be guided by the need to achieve certain performance targets imposed on the healthcare system. For instance, a survey of Australian healthcare decision makers found that political factors, the history of existing policies, administrative feasibility, and equity considerations also carried weight in influencing resource allocation decisions (Ross, 1995). Therefore, researchers need to identify the various goals that decision makers pursue and discuss how decision makers can use findings of health technology assessment and health economics to attain these objectives.

More and more countries are using information derived from health technology assessment and health economics to inform decisions to register and reimburse health technologies, particularly drugs. If such studies are well-conducted and have practical relevance to decision makers, health technology assessment and health economics will lead to better decisions about the allocation of scarce resources in healthcare.

REFERENCES

Black, W. C. (1990). The cost-effectiveness plane: A graphic representation of cost-effectiveness. *Medical Decision Making*, *10*, 212–215. doi:10.1177/0272989X9001000308

Briggs, A. H., Claxton, K., & Sculpher, M. (2006). *Decision modelling for health economic evaluation.* Oxford, UK: Oxford University Press.

Briggs, A. H., Sculpher, M. J., & Buxton, M. J. (1994). Uncertainty in the economic evaluation of health care technologies: The role of sensitivity analysis. *Health Economics*, *3*, 95–104. doi:10.1002/hec.4730030206

Brouwer, W. B., Niessen, L. W., Postma, M. J., & Rutten, F. F. (2005). Need for differential discounting of costs and health effects in cost effectiveness analyses. *British Medical Journal*, *331*, 446–448. doi:10.1136/bmj.331.7514.446

Busse, R., Orvain, J., Velasco, M., Perleth, M., Drummond, M., & Gürtner, F.. Best practice in undertaking and reporting health technology assessments. *International Journal of Technology Assessment in Health Care*, *18*, 361–422.

Buxton, M. J., Drummond, M. F., Van Hout, B. A., Prince, R. L., Sheldon, T. A., & Szucs, T. (1997). Modelling in economic evaluation: An unavoidable fact of life. *Health Economics*, *6*, 217–227. doi:10.1002/(SICI)1099-1050(199705)6:3<217::AID-HEC267>3.0.CO;2-W

Carlsson, P. (2004). Health technology assessment and priority setting for health policy in Sweden. *International Journal of Technology Assessment in Health Care*, *20*, 44–54. doi:10.1017/S0266462304000777

Cohen, J., Stolk, E., & Niezen, M. (2007). The increasingly complex fourth hurdle for pharmaceuticals. *PharmacoEconomics*, *25*, 727–734. doi:10.2165/00019053-200725090-00002

Drummond, M. F., Brown, R., Fendrick, A. M., Fullerton, P., Neumann, P., & Taylor, R. (2003). Use of pharmacoeconomics information–report of the ISPOR task force on use of pharmacoeconomic/health economic information in health-care decision making. *Value in Health*, *6*, 407–416. doi:10.1046/j.1524-4733.2003.64245.x

Goodman, C. (1998). Healthcare technology assessment: Methods, framework, and role in policy making. *The American Journal of Managed Care*, *4*, SP200–SP214.

Higgins, J. P. T., & Green, S. (Eds.). (2006). *Cochrane handbook for systematic reviews of interventions*. The Cochrane Library, Issue 4. Chichester: John Wiley & Sons.

Jacobs, P., Ohinmaa, A., & Brady, B. (2005). Providing systematic guidance in pharmacoeconomic guidelines for analyzing costs. *PharmacoEconomics*, *23*, 143–153. doi:10.2165/00019053-200523020-00006

Lambert, M. L., Kohn, L., Vinck, I., Cleemput, I., Vlayen, J., Van De Sande, S., et al. (2006). *Health technology assessment of pharmacologic and surgical treatment of obesity*. Report 36A. Brussels: Federal Healthcare Knowledge Centre.

Mauskopf, J. A., Earnshaw, S., & Mullins, C. D. (2005). Budget impact analysis: Review of the state of the art. *Expert Review of Pharmacoeconomics and Outcomes Research*, *5*, 65–79. doi:10.1586/14737167.5.1.65

Mauskopf, J. A., Sullivan, S. D., Annemans, L., Caro, J., Mullins, C. D., & Nuijten, M. (2007). Principles of good practice for budget impact analysis: Report of the ISPOR task force on good research practices–budget impact analysis. *Value in Health*, *10*, 336–347. doi:10.1111/j.1524-4733.2007.00187.x

Organisation for Economic Cooperation and Development. (2007). *Health at a glance 2007*. Paris: Organisation for Economic Co-operation and Development.

Perleth, M., Jakubowski, E., & Busse, R. (2001). What is 'best practice' in health care? State of the art and perspectives in improving the effectiveness and efficiency of the European health care systems. *Health Policy (Amsterdam)*, *56*, 235–250. doi:10.1016/S0168-8510(00)00138-X

Raftery, J. (2006). Review of NICE's recommendations, 1999-2005. *British Medical Journal*, *332*, 1266–1268. doi:10.1136/bmj.332.7552.1266

Ramsey, S., Willke, R., Briggs, A., Brown, R., Buxton, M., & Chawla, A. (2005). Good research practices for cost-effectiveness analysis alongside clinical trials: The ISPOR RCT-CEA task force report. *Value in Health*, *8*, 521–533. doi:10.1111/j.1524-4733.2005.00045.x

Ross, J. (1995). The use of economic evaluation in health care: Australian decision makers' perceptions. *Health Policy (Amsterdam)*, *31*, 103–110. doi:10.1016/0168-8510(94)00671-7

Ryan, M., Watson, V., & Amaya-Amaya, M. (2003). Methodological issues in the monetary valuation of benefits in healthcare. *Expert Review of Pharmacoeconomics and Outcomes Research*, *3*, 717–727. doi:10.1586/14737167.3.6.717

Simoens, S., De Corte, N., & Laekeman, G. (2006). Clinical practice and costs of treating catheter-related infections with teicoplanin or vancomycin. *Pharmacy Practice*, *4*, 68–73.

Simoens, S., De Coster, S., Moldenaers, I., Guillaume, P., Depoorter, A., Van den Steen, D., et al. (2007). *Health technology assessment of orthopaedic appliances in Belgium*. Report 56A. Brussels: Federal Healthcare Knowledge Centre.

Simoens, S., Decramer, M., & Laekeman, G. (2007). Economic aspects of antimicrobial therapy of acute exacerbations of COPD. *Respiratory Medicine*, *101*, 15–26. doi:10.1016/j.rmed.2006.03.030

Simoens, S., Hummelshoj, L., & D'Hooghe, T. (2007). Endometriosis: Cost estimates and methodological perspective. *Human Reproduction Update*, *13*, 395–404. doi:10.1093/humupd/dmm010

Simoens, S., Ludbrook, A., Matheson, C., & Bond, C. (2006). Pharmaco-economics of community maintenance for opiate dependence: A review of evidence and methodology. *Drug and Alcohol Dependence*, *84*, 28–39. doi:10.1016/j.drugalcdep.2005.12.009

Torrance, G. W., Furlong, W., & Feeny, D. (2002). Health utility estimation. *Expert Review of Pharmacoeconomics and Outcomes Research*, *2*, 99–108. doi:10.1586/14737167.2.2.99

Weinstein, M. C., O'Brien, B., Hornberger, J., Jackson, J., Johannesson, M., & McCabe, C. (2003). Principles of good practice for decision analytic modeling in healthcare evaluation: Report of the ISPOR task force on good research practices-modeling studies. *Value in Health*, *6*, 9–17. doi:10.1046/j.1524-4733.2003.00234.x

SUGGESTED READINGS

Drummond, M. F., & McGuire, A. (2001). *Economic evaluation in health care: merging theory with practice*. Oxford: Oxford University Press.

Drummond, M. F., Sculpher, M. J., Torrance, G. W., O'Brien, B. J., & Stoddart, G. L. (2005). *Methods for the economic evaluation of health care programmes* (3rd ed.). Oxford: Oxford University Press.

Gold, M. R., Siegel, J. E., Russell, L. B., & Weinstein, M. C. (1996). *Cost-effectiveness in health and medicine*. Oxford: Oxford University Press.

SCIENTIFIC JOURNALS

- *Cost Effectiveness And Resource Allocation*
- *European Journal of Health Economics*
- *Expert Review of Pharmacoeconomics and Outcomes Research*
- *Health Economics*
- *Health Technology Assessment*
- *International Journal of Technology Assessment in Health Care*
- *Journal of Health Economics*
- *Journal of Medical Economics*
- *PharmacoEconomics*
- *Value in Health*

INTERNATIONAL SOCIETIES

Health Technology Assessment International - HTAi. http://www.htai.org

International Health Economics Association – IHEA. http://www.healtheconomics.org/

International Network of Agencies for Health Technology Assessment – INAHTA. http://www.inahta.org/

International Society for Pharmacoeconomics and Outcomes Research – ISPOR. http://www.ispor.org/

DATABASES

Health Technology Assessment Database. http://www.york.ac.uk/inst/crd/crddatabases.htm

NHS Economic Evaluation Database. http://www.york.ac.uk/inst/crd/crddatabases.htm

KEY TERMS AND DEFINITIONS

Budget Impact Analysis: Analysis of the financial impact of the adoption and diffusion of a health technology within a particular setting.

Cost Analysis: Comparison of the costs of two or more approaches to diagnosis and treatment of a disease (for instance, medical versus surgical therapy).

Cost-Benefit Analysis: An economic evaluation that values outcomes in monetary terms (the 'benefits') in addition to costs.

Cost-Effectiveness Analysis: An economic evaluation that measures costs in a monetary unit and quantifies a single outcome in a physical or natural unit (e.g. the number of successfully treated patients, the number of life years gained, the number of symptom days averted).

Cost-of-Illness Analysis: Analysis of the economic burden of a disease to society by measuring the costs of diagnosing and treating a disease as well as the costs arising as a result of the disease (for instance, productivity loss due to time taken off work).

Cost-Utility Analysis: An economic evaluation that measures costs and outcomes by means of specific health-related quality of life measures, such as quality-adjusted life years.

Economic Evaluation: A comparative analysis of at least two health technologies in terms of both their costs and outcomes.

Health Technology Assessment: Type of policy research that explores the safety; efficacy and effectiveness; organizational implications; social and ethical consequences; legal considerations; and health economic aspects of the application of a health technology.

Sensitivity Analysis: Analysis of the direction and the extent to which the results of the economic evaluation vary when estimates of input variables change.

This work was previously published in the Handbook of Research on Information Technology Management and Clinical Data Administration in Healthcare, edited by A. Dwivedi, pp. 69-86, copyright 2009 by Information Science Reference (an imprint of IGI Global).

Chapter 1.21

Telemedicine Barriers

María José Crisóstomo-Acevedo
Jerez Hospital, Spain

José Aurelio Medina-Garrido
University of Cadiz, Spain

INTRODUCTION

Telemedicine implies that there is an exchange of information, without personal contact, between two physicians or between a physician and a patient. Thanks to telecommunications technologies telemedicine enables the provision of healthcare services or the exchange of healthcare information across geographic, temporal, social, and cultural barriers (Chau & Hu, 2004).

Through telemedicine, healthcare centers can offer diverse specialty services to other centers, to other physicians, or directly to the patient, such as for example telecardiology, teledermatology, teleendoscopy, telemedicine, telemonitoring, telenursing, telepathology, teleradiology, or telesurgery (Tachakra, 2003).

Telemedicine should not be confused with e-health (or teleHealth). Telemedicine only refers to the provision of medical services (Chau & Hu, 2004). E-health, on the other hand, refers both to medical services and to any other type of service, as long as it has something to do with health and employs information technology (Eysenbach, 2001; Rodger & Pendharkar, 2000). In this respect, e-health would also include healthcare educational activities, research in the health sciences, the handling of electronic files in the healthcare system, and any other use of information technologies in the healthcare system.

Telemedicine requires a new type of worker: the healthcare teleworker. But unlike in other types of telework, the human factor is much more important for the success of projects in telemedicine. Nevertheless, physicians remain wary of adopting

DOI: 10.4018/978-1-59904-883-3.ch122

telemedicine. This work examines the sources of the resistance to incorporate telemedicine. It adopts a focus centering on the difficulties that human factors have in accepting the practice of telemedicine.

It would be useful, for their design, to analyze telemedicine project acceptance among the human factor involved. This would allow managers to make management decisions concerning the design of the project, its implementation, and the subsequent resolution of problems with the personnel involved.

The rest of this article is organized as follows. The second section discusses the relationship between telemedicine and human resource management. The third section tries to identify the obstacles in the way of an adequate acceptance and development of telemedicine. Section four suggests some future research opportunities within the domain of the telemedicine topic.

BACKGROUND

The various barriers to the implementation and development of telemedicine projects include patient acceptance (Eikelboom & Atlas, 2005; Hofmann-Wellenhof, Salmhofer, Binder, Okcu, et al., 2006; Turner, Thomas, & Gailiun, 2001; Wyman, 1994), government regulation (McGee, 2004; Schindler, 2005), the cost of the technology (Guy, 1997; McGee, 2004; Schindler, 2005), the absence of insurance coverage (Guy, 1997), technological barriers (Paul, Pearlson, & McDaniel, 1999), and social and cultural obstacles (Bangert & Doktor, 2002; Jarudi, 2000; Spil, Schuring, & Michel-Verkerke, 2004) among others. Nevertheless, there is consensus that the most important source of resistance comes from the failure to accept such systems by the healthcare workers, precisely the ones who will have to use them (Chau & Hu, 2002; Hu & Chau, 1999; Hu, Chau, Sheng, & Tam, 1999; Qavi, Corley, & Kay, 2001).

Nevertheless, few studies analyze the impact of telemedicine projects on the management of the human resources participating in such projects. Some studies that do so analyze the psychological determinants of the physicians in telemedicine adoption (Croteau & Vieru, 2002; Hu et al., 1999). Of particular note is the hierarchical telemedicine acceptance model proposed by Hu and Chau (1999), which includes human and technological dimensions and organizational levels. At the organizational level they analyze the relation between the decision to adopt telemedicine and the compatibility of the technology to be used with the physicians' previous work routines.

The consideration of a close relationship between technological and human resources is not a new concept. The sociotechnical approach (Emery & Trist, 1965; Miller & Rice, 1967; Rice, 1958; Trist & Bamforth, 1951) was a clear expression of the notion that companies should unite both their human and technological dimensions. The human relations (McGregor, 1960; Roethlisberger & Dickson, 1939) and contingency schools (Lawrence & Lorsch, 1967) also noted this relationship.

This lack of attention given to the human factor in the adoption and implementation of telemedicine projects is surprising, since the healthcare staff's reluctance to accept the new technology or collaborate in it is one of the main causes of the failure of such projects, these professionals being the proposed end-users of the system (Gagnon, Lamothe, Fortin, Cloutier, et al., 2005). This concept is well known in the literature on the adoption of information technologies in organizations (Bruque-Cámara, Vargas-Sánchez, & Hernández-Ortiz, 2004; Khatri, 2006; Melville, Kraemer, & Gurbaxani, 2004; Powell & Dent-Micallef, 1997), but the question has received too little attention in the specific case of telemedicine projects.

The rejection of telemedicine by the healthcare workers involved is often a result of the resistance to change generated by inertias in the existing organizational routines (Pardo & Martinez, 2003;

Rumelt, 1995). These routines are threatened by the need to redefine traditional professional roles and by the professionals' loss of status, since IT blurs the functional and hierarchical boundaries in healthcare organizations (Aas, 2001, May, Gask, Atkinson, Ellis, Mair, & Esmail, 2001).

Technology cannot transform a company by its mere presence. The necessary transformation requires a fundamental change in habits, attitudes, values, expectations, and incentives relating to information management. Thus, attention should focus not on the technology but rather on healthcare itself, as equipment, whether low- or high-tech, does not in itself necessarily help either patients or healthcare professionals; it depends on how such equipment is used by people (Loane & Wootton, 2002).

Telemedicine will not work simply by making certain information technologies available to healthcare specialists. If IT is not integrated with complementary resources then it is not efficient in its own right. Some authors ask why some companies encounter difficulties and yet others prosper when using the same IT, and why IT-based advantages dissipate so quickly. Their response is that integration should be produced between the IT, complementary human resources, and business capabilities (Bruque-Cámara et al., 2004; Khatri, 2006; Melville et al., 2004; Powell & Dent-Micallef, 1997). The integrated management of IT and complementary resources and capabilities can be regarded as the most feasible path towards attaining IT advantages.

TELEMEDICINE BARRIERS

This section analyzes the main factors that may explain practitioners' resistance to accept telemedicine. The most important obstacles to the development of telemedicine are as follows: inertias in the existing organizational routines and employees' resistance to change, lack of time, limitations of the technologies, patients' incompetence, difficulty in using the technologies and understanding their utility, lack of training, and lack of trust.

The inertias in the existing organizational routines are one of the most important obstacles to the adoption of projects, whatever their nature (Pardo & Martinez, 2003; Rumelt, 1995). Among the organizational routines that are typical in the healthcare sector are procedures and medical protocols. Some procedures and medical protocols in healthcare services prevent medicine from being conducted at a distance. Some of these protocols and procedures are inefficient and obsolete (Kirsch, 2002). They also prevent healthcare professionals from accessing more advanced clinical practices or using the available information to improve their diagnoses and treatments.

Employees' resistance to change may be a result of their lack of participation in the project, the failure to consider their interests or needs, the fear that their jobs or status are under threat, lack of training and information, fear of uncertainty of what will happen when the new system is launched, the perception that change is unnecessary, the tendency to concentrate on short-run problems, the refusal to believe that past successes may end unless things change, group pressure on the individual to continue with what has been normal up to now, the risk of failure, the effort required when adopting something new, a lack of strategic vision throwing doubt on whether the right path has been taken, a lack of consensus with regard to the decisions taken, the difficulty in breaking with the established routines, and waiting for others to act so as not to run the risk of changing unilaterally.

Physicians often argue that they do not have time to attend to patients remotely, as they are too busy with the consultations and medical services they provide to the patients who see them in person. This is a shortsighted view from the strategic perspective, since they would be able to attend to more patients if they saved time on traveling and if they automated medical services wherever possible. By using technology to automate existing routine tasks, performance can be optimized (Kirsch, 2002). Better efficiency is driven by better use of information, and this is where telemedicine can be utilized.

One of the most reasonable concerns of telemedicine professionals is the doubt about whether telemedicine can really substitute properly for face-to-face care. Clearly, telemedicine cannot be used as successfully in all circumstances as direct, face-to-face contact with the patient. Using telemedicine to care for patients requires a thorough understanding of its technical limitations. But despite these limitations, telemedicine is still very useful when distance or an emergency situation prevents healthcare professionals from attending a patient in person.

One of the most common misconceptions among healthcare professionals, which leads them to reject telemedicine, is to assume that patients are not able to take decisions, and so they do not need to be given all the information. But telemedicine can provide patients—who are consumers of healthcare services, and consequently the "customers"—with the information they need to participate in their own care and take informed decisions in the choice of hospitals, physicians, and treatments (Thames, 2003). The Internet allows patients to participate from a distance as partners in taking medical decisions during the course of their treatments (Miller & Derse, 2002).

On the other hand, physicians' acceptance of telemedicine is strongly influenced by psychological and perceptual factors. Thus, physicians' acceptance of telemedicine depends on their attitude towards the use of technologies in general, their previous experience in using technologies (Qavi et al., 2001), and their perception that the technologies are easy to use, and that they will prove useful in their work (Hu et al., 1999).

The need for training and preparation in the use of the technologies supporting telemedicine is not reflected in the syllabuses of university medical departments (Ferrer-Roca, 2001). This is why many healthcare professionals fail to see the connection between their work and the technical issues (i.e., use of applications and databases, electronic interchange of data and image files, standards to use, etc.) or legal issues (e.g., IT security, data protection and privacy, international practice of telemedicine, etc.) that concern telemedicine.

Telemedicine often brings physicians who do not know each other into contact so they can share information or work together in virtual healthcare teams. Trust plays a key role in all collaboration relationships (Gefen, 2000), and this is particularly true in virtual relationships. Telemedicine projects that do not inspire trust among the physicians do not tend to encourage team working (Paul & McDaniel, 2004). Nevertheless telemedicine brings its own additional problems in creating and maintaining trust. This is because telemedicine involves the participation of multidisciplinary teams, and in virtual processes that are different from the ones healthcare professionals are used to. Launching a telemedicine project can also be seen as a threat as the first step in the replacement of the healthcare professionals by other professionals delocated geographically, even in other countries.

FUTURE TRENDS

Telemedicine will not work simply by making certain information technologies are available to healthcare specialists. If IT is not integrated with complementary resources then it is not efficient in its own right. Integration should be produced between the IT, complementary human resources, and business capabilities (Bruque-Cámara et al., 2004; Khatri, 2006; Melville et al., 2004; Powell & Dent-Micallef, 1997).

This work has focused on a general analysis of the motives leading healthcare professionals to reject telemedicine. An interesting future line of research would be to analyze acceptance segmented in function of the medical specialty involved, or of whether the objective is to reduce the disparities in the population in access to the healthcare system or not (Ahern, Kreslake & Phalen, 2006; Cashen, Dykes, & Gerber, 2004; Gibbons, 2005).

Future research should also examine whether human resource practices have the same positive impact on the performance of IT-based projects in the healthcare sector as in other industries.

CONCLUSION

The participation of the human resources involved in telemedicine projects is vital for the successful implementation and operation of these projects, since they are the ones who will have to use the telemedicine system when it is put in place (Gagnon et al., 2005).

This work analyzed various factors leading healthcare staff to reject telemedicine. Chief among these have been the obstacles to change generated by inertias in the current organizational routines, the irrational excuse of lack of time, the impossibility of these technologies substituting for personal contact with the patient, the perception of an assumed inability of patients to take decisions, the perception of the ease of use and utility of the technologies to be applied, the lack of training and preparation in the use of the technologies, and problems of trust for working in virtual teams.

Understanding why the human factor involved resists implementation of telemedicine projects should be useful for managers when they make their decisions about the design of the project, its implementation, and the subsequent resolution of problems with the personnel involved.

Some practical recommendations for managers of telemedicine projects follow. These managers would be recommended to develop human resource management practices centering on: (1) the existence of a fluid communication between healthcare staff and the management; (2) flexibility in the procedures; (3) participative decision making; (4) interdepartmental working groups; (5) training for the new technologies; and (6) the fit between the technology used and the human resources' interests (Bruque-Cámara et al., 2004).

REFERENCES

Aas, I. H. M. (2001). A qualitative study of the organisational consequences of telemedicine. *Journal of Telemedicine and Telecare*, *7*(1), 18–26. doi:10.1258/1357633011936093

Ahern, D. K., Kreslake, J. M., & Phalen, J. M. (2006). What is eHealth: Perspectives on the evolution of ehealth research. *Journal of Medical Internet Research*, *8*(1), e4. doi:10.2196/jmir.8.1.e4

Arjonilla-Domínguez, S. J., & Medina-Garrido, J. A. (2002). *La gestión de los sistemas de información en la empresa*. Madrid: Pirámide.

Bangert, D., & Doktor, R. (2002). Telemedicine as an IS implementation problem: Comparison of dynamics in the USA and India. *International Journal of Healthcare Technology and Management*, *4*(6), 525. doi:10.1504/IJHTM.2002.002430

Bruque-Cámara, S., Vargas-Sánchez, A., & Hernández-Ortiz, M. J. (2004). Organizational determinants of IT adoption in the pharmaceutical distribution sector. *European Journal of Information Systems*, *13*(2), 133–146. doi:10.1057/palgrave.ejis.3000490

Cashen, M. S., Dykes, P., & Gerber, B. (2004). eHealth technology and Internet resources: Barriers for vulnerable populations. *The Journal of Cardiovascular Nursing*, *19*(3), 209–222.

Chau, P. Y. K., & Hu, P. J. (2002). Examining a model of information technology acceptance by individual professionals: An exploratory study. *Journal of Management Information Systems*, *18*(4), 191–229.

Chau, P. Y. K., & Hu, P. J. (2004). Technology implementation for telemedicine programs. *Communications of the ACM*, *47*(2), 87–92. doi:10.1145/966389.966396

Croteau, A. M., & Vieru, D. (2002, January). Telemedicine adoption by different groups of physicians. In *Proceedings of the 35th Hawaii International Conference on System Sciences, IEEE*, Big Island.

Eikelboom, R. H., & Atlas, M. D. (2005). Attitude to telemedicine, and willingness to use it, in audiology patients. *Journal of Telemedicine and Telecare*, *11*(Supplement 2), 22–25. doi:10.1258/135763305775124920

Emery, F., & Trist, E. (1965). The causal texture of organizational environments. *Human Relations*, *18*, 21–32. doi:10.1177/001872676501800103

Eysenbach, G. (2001). What is e-health? *Journal of Medical Internet Research*, *3*(2), e20. doi:10.2196/jmir.3.2.e20

Ferrer-Roca, O. (2001). *La telemedicina: Situación actual y perspectivas*. Madrid: Fundación Retevisión.

Gagnon, M. P., Lamothe, L., Fortin, J. P., & Cloutier, A. (2005). Telehealth adoption in hospitals: An organizational perspective. *Journal of Health Organization and Management*, *19*(1), 32–56. doi:10.1108/14777260510592121

Gefen, D. (2000). E-Commerce: The role of familiarity and trust. *Omega*, *28*(6), 725–737. doi:10.1016/S0305-0483(00)00021-9

Gibbons, M. C. (2005). A historical overview of health disparities and the potential of e-health solutions. *Journal of Medical Internet Research*, *7*(5), e50. doi:10.2196/jmir.7.5.e50

Guy, S. (1997). The doctor is in. *Telephony*, *232*(16), 7–8.

Hofmann-Wellenhof, R., Salmhofer, W., Binder, B., & Okcu, A. (2006). Feasibility and acceptance of telemedicine for wound care in patients with chronic leg ulcers. *Journal of Telemedicine and Telecare*, *12*(Supplement 1), 15–17. doi:10.1258/135763306777978407

Hu, P. J., & Chau, P. Y. (1999). Physician acceptance of telemedicine technology: An empirical investigation. *Topics in Health Information Management*, *19*(4), 20–35.

Hu, P. J., Chau, P. Y., Sheng, O. L., & Tam, K. Y. (1999). Examining the technology acceptance model using physician acceptance of telemedicine technology. *Journal of Management Information Systems*, *16*(2), 91–112.

Jarudi, L. (2000). Doctors without borders. *Harvard International Review*, *22*(1), 36–39.

Khatri, N. (2006). Building IT capability in health-care organizations. *Health Services Management Research*, *19*(2), 73–79. doi:10.1258/095148406776829095

Kirsch, G. (2002). The business of eHealth. *International Journal of Medical Marketing*, *2*(2), 106–110. doi:10.1057/palgrave.jmm.5040062

Lawrence, P., & Lorsch, J. (1967). *Organization and environment: Managing differentiation and integration*. Homewood, IL: Irwin.

Loane, M., & Wootton, R. (2002). Guidelines and standards for telemedicine. *Journal of Telemedicine and Telecare*, *8*(2), 63–71. doi:10.1258/1357633021937479

May, C., Gask, L., Atkinson, T., Ellis, N., Mair, F., & Esmail, A. (2001). Resisting and promoting new technologies in clinical practice: The case study of telepsychiatry. *Social Science & Medicine*, *52*(1), 1889–1901. doi:10.1016/S0277-9536(00)00305-1

McGee, M. K. (2004). E-health on the horizon. *InformationWeek*, *989*, 53–59.

McGregor, D. (1960). *The human side of enterprise*. New York: McGraw-Hill.

Melville, N., Kraemer, K., & Gurbaxani, V. (2004). Review: Information technology and organizational performance: An integrative model of it business value. *MIS Quarterly*, *28*(2), 283–322.

Miller, E., & Rice, A. (1967). *Systems of organization: The control of task and sentient boundaries*. London: Tavistock.

Miller, T. E., & Derse, A. R. (2002). Between strangers: The practice of medicine online. *Health Affairs*, *21*(4), 168–179. doi:10.1377/hlthaff.21.4.168

Pardo del Val, M., & Martinez Fuentes, C. (2003). Resistance to change: A literature review and empirical study. *Management Decision*, *41*(1/2), 148–155.

Paul, D. L., & McDaniel, R. R. Jr. (2004). A field study of the effect of interpersonal trust on virtual collaborative relationship performance. *MIS Quarterly*, *28*(2), 183–227.

Paul, D. L., Pearlson, K. E., & McDaniel, R. R., Jr. (1999). Assessing technological barriers to telemedicine: Technology-management implications. *IEEE Transactions on Engineering Management,* *46*(3), 279, 188.

Powell, T. C., & Dent-Micallef, A. (1997). Information technology as competitive advantage: the role of human, business, and technology resources. *Strategic Management Journal*, *18*(5), 375–405. doi:10.1002/(SICI)1097-0266(199705)18:5<375::AID-SMJ876>3.0.CO;2-7

Qavi, T., Corley, L., & Kay, S. (2001). Nursing staff requirements for telemedicine in the neonatal intensive care unit. *Journal of End User Computing*, *13*(3), 5–12.

Rice, A. (1958). *Productivity and social organization: The Ahmedabad experiment*. London: Tavistock.

Rodger, J. A., & Pendharkar, P. C. (2000). Using telemedicine in the Department of Defense. *Communications of the ACM*, *43*(3), 19–20. doi:10.1145/330534.330551

Roethlisberger, F., & Dickson, W. (1939). *Management and worker*. Cambridge, MA: Harvard University Press.

Rumelt, R. P. (1995). Inertia and transformation. In C. A. Montgomery (Ed.), *Resource-based and evolutionary theories of the firm: Towards a synthesis* (pp. 101-132). Kluwer Academic Publishers.

Schindler, E. (2005). Mouse calls. *NetWorker*, *9*(4), 11. doi:10.1145/1103940.1103950

Spil, T. A. M., Schuring, R. W., & Michel-Verkerke, M. B. (2004). Electronic prescription system: Do the professionals use it? *International Journal of Healthcare Technology and Management*, *6*(1), 32–55. doi:10.1504/IJHTM.2004.004824

Tachakra, S. (2003). *Telemedicine and e-Health.* Paper presented at the Business Briefing: Global Healthcare 2003. World Medical Association.

Thames, T. (2003). Telemedicine: The road to higher quality health care. *Vital Speeches of the Day*, *70*(2), 53.

Trist, E., & Bamforth, K. (1951). Some social and psychological consequences of the longwall method of coal-getting. *Human Relations*, *4*, 3–38. doi:10.1177/001872675100400101

Turner, J. W., Thomas, R. J., & Gailiun, M. (2001). Consumer response to virtual service organisations: The case of telemedicine. *International Journal of Medical Marketing*, *1*(4), 309–318. doi:10.1057/palgrave.jmm.5040042

Wyman, G. (1994). The maturing of telemedicine technology. *Health Systems Review*, *27*(5), 57–61.

KEY TERMS AND DEFINITIONS

E-Health: The provision of any healthcare service that is supported by electronic processes and communications.

Electronic Medical Records: Computer-based patient medical records. Patient medical records are a systematic documentation of a patient's medical history and care.

Telemedicine: The use of information and communications technologies to exchange information between practitioners, or to deliver medical services to a patient remotely

Telemonitoring: The remote monitoring of patients' state of health. It is fundamentally used to control and treat chronic patients.

Telenursing: Healthcare services provided by nurses remotely, such as monitoring patients in their homes, or referring patients to the appropriate medical services through the processing of patient data

Telepathology: The digital transmission between healthcare professionals of high-resolution images of, for example, microscope slides, photographs of injuries or smears, among others

Virtual Healthcare Teams: Teams made up of healthcare professionals that share information about patients electronically in order to improve their knowledge and decision making.

This work was previously published in the Encyclopedia of Human Resources Information Systems: Challenges in e-HRM, edited by T. Torres-Coronas and M. Arias-Oliva, pp. 830-835, copyright 2009 by Information Science Reference (an imprint of IGI Global).

Chapter 1.22

Nurses and Telehealth:

Current Practice and Future Trends

Sisira Edirippulige
University of Queensland, Australia

Anthony C. Smith
University of Queensland, Australia

Mark Bensink
University of Queensland, Australia

Nigel R. Armfield
University of Queensland, Australia

Richard Wootton
University of Queensland, Australia

ABSTRACT

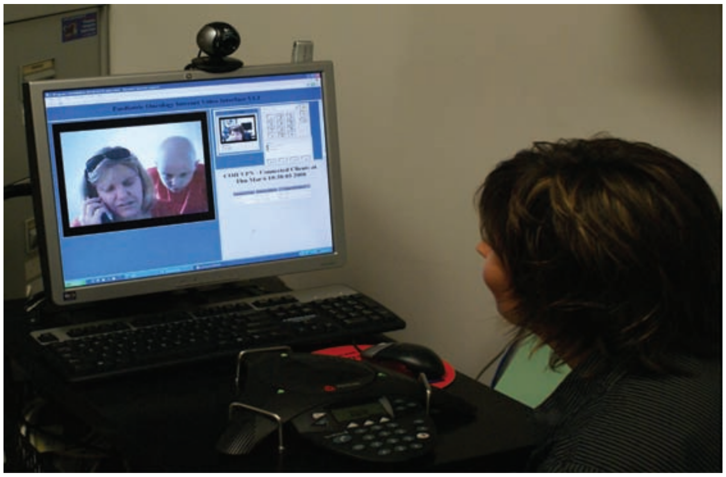
Nurses play a pivotal role in the provision of healthcare. Home telehealth, the use of information and communication technologies to deliver and support healthcare directly to the home, is emerging as an important application for nurses. This chapter provides an overview of home telehealth and how it may be applied to the practical challenges nurses face everyday. We provide a summary of the evidence available to support its use in specific areas and a guide for those thinking of implementing telehealth in their own practice. The future of home telehealth lies in carefully considered and designed research, ongoing education and training and a multidisciplinary approach. This chapter aims to stimulate the consideration of home telehealth as an application that may improve nursing care and ultimately patient outcomes.

DOI: 10.4018/978-1-60566-234-3.ch007

INTRODUCTION

The increasing incidence of chronic diseases (such as cancer, coronary heart disease, diabetes and dementia) and the growing aged population have added to the pressure on health care systems worldwide. The World Health Organization (WHO) predicts that chronic disease will be the leading cause of disability by 2020 and will be the most expensive

Figure 1. Real-time home telehealth using web cams and the Internet. Mother and child at home discussing care with an oncology clinical nurse consultant



problem facing health care systems (Belfield & Colin-Thome, 2004). For example, type II diabetes mellitus is becoming the most common chronic disease in the United States, affecting 7% of the adult population. Congestive heart failure affects about 5 million Americans each year and accounts for around 20% of hospitalised patients over 65 years (ATA, 2007). Studies show that caring for people with chronic diseases consumes approximately 78% of all health care spending in the United States – more than $1 trillion annually (ITAA e-Health Committee, 2004). The Centres for Medicare and Medicare Services estimated that total national health expenditure for home care was $40 billion in 2003, an increase of almost ten percent over the previous year. An additional $111 billion was spent on nursing home care (National Health Expenditures). With the ageing of the population, this rate of growth will increase.

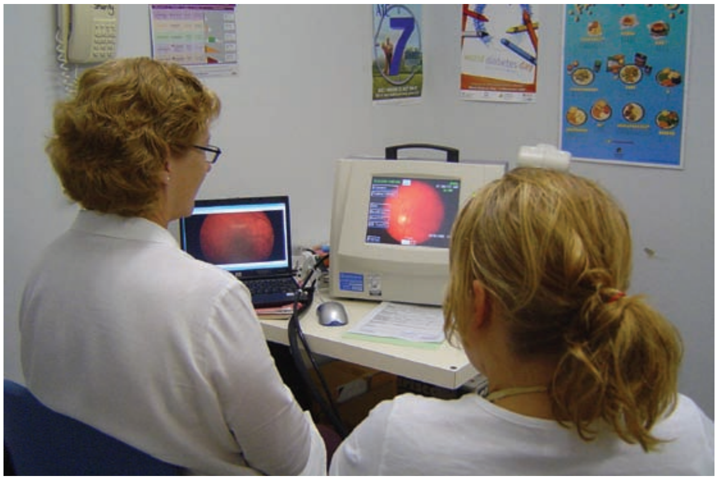
Undoubtedly, these tendencies have put additional pressure on the already overburdened nursing community around the world. Nurses form the largest professional health care group and their role as a care provider has changed significantly since the last century. The lack of nursing professionals is a global phenomenon (Kingma, 2006). Producing more nurses is one answer that requires long term investment and policy implementation. Finding other complementary mechanisms to address these urgent needs is also required.

THE ROLE OF NURSES IN HEALTH CARE

Nurses play an important role in almost every sphere of health care from primary to tertiary care. Nurses have rapidly evolving roles and responsibilities. Terms such as district nurse, health visitor, school nurse, GP practice nurse, nurse consultant, clinical nurse specialist and nurse practitioner reflect just some of the diversity of nursing practice.

Among other roles, nurses are also responsible for delivering care to patients at home, especially elderly patients. There is a continuing demand for such a role. However, statistics show that the lack of nursing professionals and the growing aged population is a prime concern for health systems around the world (Flesner, 2004). Despite these challenges nurses have shown remarkable flexibility and adaptability. The nursing profession has been an early group to embrace home telehealth

Figure 2. Store and forward home telehealth. A nurse screening children with diabetes for eye problems sending clinical information and images to a specialist ophthalmologist via email



which offers an alternative to providing face-to-face care.

WHAT IS HOME TELEHEALTH?

Home telehealth is the use of information and communication technologies to deliver and support health care in a non-institutional setting – that is, at home or in an assisted-living facility (Wootton, Kvedar & Dimmick, 2006). Home telehealth applications may include real time techniques, for example videoconferencing (Figure 1) as well as store and forward techniques, for example email or web-based applications (Figure 2).

In addition, various devices such as alarms, sensors and monitoring equipment are being used in home telehealth applications (Darkins, et al, 1996). Telehealth gives an opportunity to contact patients remotely augmenting and extending conventional care.

There are signs that interest in home telehealth is developing. Recent data shows that 20% of American based home health agencies employ some kind of telehealth in their day to day operations and another 20% plan to offer telehealth services in the next 12 months (Wootton, Kvedar & Dimmick, 2006). An increase has also occurred in the number of home health episodes. During 2001-2003 the number of Medicare home health users increased to 2.6 million and the number of episodes rose to 36 million. At the same time, the average number of visits per episode fell slightly to 17.3 (Wootton, Kvedar & Dimmick, 2006). The last few years have also seen an increase in the number of manufacturers of home telehealth equipment in the USA (mainly) and elsewhere.

HOW CAN TELEHEALTH ASSIST NURSES?

The role of the nurse practitioner, a registered nurse educated to function in an advanced clinical role, (Darkins et al, 1996) has major implications for health services. Experienced nurses have more responsibility in managing patients, particularly where access to medical and health services is inadequate. Telehealth has been reported as a useful tool for nurse practitioners.

To Support Remote Nurses

For example in the United Kingdom (UK) nurse practitioner units have been established to provide care to patients with minor injuries. Telehealth is used in these units as a support for nurses (Darkins et al, 1996). They can use videoconferencing to contact emergency medicine specialists for advice and support. This has effectively reduced the need to refer patients to the tertiary emergency medicine department and to the local general practitioner, saving time and reducing costs. Home telehealth can assist nurses to expand their role, to access direct clinical support for this expansion, and to reach more patients and provide more services (Jenkins & White, 2001).

One nurse practitioner in the USA uses home telehealth to support other nurses in a remote medical facility by conducting patient consultations online (Reed, 2005). This allows the nurse practitioner, working with the remote nurse, to complete patient histories, assess patients using peripherals such as a stethoscope, a camera for viewing eardrums, nasal mucosa, mouths and throats as well as a dermascope used to view and magnify skin lesions. The nurse practitioner can remotely print prescriptions for the patient, order additional investigations or refer the patient to specialist care.

To Support the Patient in the Home

Another benefit of home telehealth is the ability to make more frequent visits to patients. Home telehealth provides a unique opportunity to maintain frequent interpersonal contact using information and communication technologies like videoconferencing. Nurses can ‘visit’ their patients more often, prioritising in-person visits and avoiding unnecessary travel (Ryan, Kobb & Hilsen, 2003; Kobb, Hilsen & Ryan, 2003).

One example of supporting patients in the home using telehealth is wound care. A pilot investigation used a combination of real-time consultation and the capture of digital wound images to provide specialist wound care (Moore, Britton & Chetney, 2003). Outcomes included earlier assessment of patients by a specialist wound care nurse, a reduction in healing time, fewer in-person home visits and an increase in productivity. Additional benefits included improved education of patients and improved education and professional development in the use of wound care protocols for generalist home care nurses. Home telehealth is an alternative means of delivering the knowledge and expertise of a wound care nurse to underserved patients.

Another development in patient in-home support is the smart-home concept. This idea focuses on autonomy and independence with the aim to give people (and those caring for them) added security, safety, quality of life and access to medical care without an in-patient admission (Rialle, et al, 2007). In some cases it may delay or avoid institutionalisation.

In the mid 1990’s, smart-homes were equipped with sensors that turned on lights at night when movement was detected, turned off stoves if overheating or left on, unlocked doors and turned on lights if smoke was detected, alerted staff if residents were out of bed for prolonged periods and, for wandering people, alerted staff if external doors were opened (Bjorneby, 2000).

Newer developments in smart-home sensors include detectors worn by the resident to alert staff if a fall occurs (Gibson, 2003) or if a resident at risk of falling, sits-up in bed (Gelhaus, 2002) and to monitor the mobility and subsequent health status of residents (Prado, 2002).

To Promote and Support Self-Care

The role of home telehealth in helping patients to mange their own health is another growing area. Many elderly people live with at least one chronic disease or condition, such as diabetes or heart disease. On discharge from hospitals (particularly if the patient is newly diagnosed) patients need extensive support to manage their condition successfully. Traditionally this has been done with routine home nursing visits. However, home telehealth provides an opportunity to interact with and instruct patients at home. This may improve self-care, reduce subsequent readmissions and allow people to stay in their own familiar environment.

Telehealth units are available with the ability to add peripheral monitoring devices for tracking a patient's physiological status and providing this information to them as part of an ongoing education and self-management program. Peripherals can include a blood glucose meter, blood pressure cuff, pulse oximeter and other measuring/monitoring devices. Multimedia materials can also be integrated into home telehealth units. These materials may be used to remind patients to track their weight daily, to alter their fluid intake or increase their activity levels. Of course all of these activities require the support of an experienced and qualified health care provider. The use of this type of home telehealth requires frequent communication with patients to reiterate directions, educate and coach.

To Improve Medication Management and Compliance

There is also a growing body of literature on the value of home telehealth in medication management. Medication-related complications are a contributing factor in accidents and illnesses that lead to hospitalization (Joanna Briggs Institute, 2006). Research has shown that patients with greater than nine medications have at least a 22 percent incidence of medication errors which in turn contribute to adverse reactions and hospitalisation (Ahrens, Feldman & Frey, 2002). Home telehealth in medication management has proven effective. For example, a study by the Veteran's Administration in the USA demonstrated a 30 percent improvement in medication compliance after telehealth implementation (Kobb, Hilsen & Ryan, 2003). Medication reminders, interactive voice response (IVR) systems and telemonitoring solutions can improve medication management and enable nurses to improve the quality of care provided.

Given all of these benefits, what evidence is there to support the use of home telehealth?

The Evidence-Base for Home Telehealth

There is much hype surrounding home telehealth; a lot has been written about its potential and promise but little clinical research has been undertaken. A recent review of home telehealth (Bensink, Hailey & Wootton, 2006a) used a comprehensive search of electronic databases including Medline, PsychINFO, CINAHL, EBSCOhost and EMBASE to identify research in the area. These searches identified 769 references to home telehealth. Only 18% of these were controlled studies comparing a home telehealth alternative to a usual care control group. Despite the hype, there are still good to high quality studies in the area (Bensink, Hailey & Wootton, 2007a).

An Emerging Area of Research

The first reports of controlled investigations into the use of home telehealth began emerging in the early 1980s and there has been progressive interest in the area ever since. Not surprisingly, these early investigations used the ordinary home telephone to support patients. Topics of investigation included support after heart surgery; counselling hypertensive patients; and educating, counselling and monitoring patients after a heart attack. Since these early reports the number of published studies has steadily increased. Our review in 2006 identified 138 papers reporting on 130 home telehealth research projects.

The Technologies Used

Given its widespread operation in most areas of industrialised countries, the public switched telephone network (PSTN) continues to provide a readily available, affordable and reliable link to the home for home telehealth. The home telephone can itself be used or alternatively a variety of devices can interface with the telephone network. These devices can connect directly to computers or computer servers in a hospital or provide data over the Internet. Specifically designed devices are also available to provide transmission of vital signs data such as oxygen saturation, blood pressure and blood glucose level. Broadband Internet connectivity over home telephone lines is also emerging as a technology of interest to home telehealth providing higher bandwidth connections than the PSTN network. This is opening new areas of research allowing improved quality video-telephony amongst other applications.

Diseases/Conditions Studied

The majority of the published evidence (over two-thirds) has been from the United States with countries like the UK, Japan, Italy and France contributing a further 19%. The areas with the most supporting evidence are chronic conditions such as diabetes, heart failure, mental health problems and cardiac disorders although evidence exists in other areas such as high risk pregnancy monitoring.

Although the majority of studies have been completed in these areas, telephone counselling targeted at people trying to quit smoking, represents an interesting exception. In this area only six randomised controlled trials supporting the use of different technologies were identified. What set these studies apart was the sample size; over 10,000 people participated in these six trials. Results showed there is evidence that telephone counselling is an effective strategy for assisting self-quitters over and above self-quitting guides alone (Orleans et al, 1991).

Home Telehealth Evidence and Nurses

The primary care providers in over half of the studies identified in our review were nurses, most commonly providing a combination of remote patient monitoring, health counselling and education. One example of this is the use of a “dialogue box” for diabetes related patient monitoring in the home (Chumbler et al, 2005). This device attached to the home telephone line and allowed patients to answer basic questions on diabetes care and metabolic control using a simple key pad. Entered information was then relayed via the Internet and presented to a nurse who determined if any intervention was required for example, either health counselling over the telephone, a home visit or a clinic visit.

Neglected Areas

Some areas of health care are only emerging as topics of home telehealth research; these include paediatrics, neonatal care and obstetrics. Our own investigations in paediatric oncology are some of the first to appear in the literature (Bensink et al, 2004, 2005, 2006, 2007, 2007b) Here the use of videotelephony allows nurses to provide support to the patient and family at home, themselves or to coordinate support from other members of the specialist paediatric oncology team.

Economics

Another, more general area of neglect is the evaluation of the economic benefit of home telehealth. It is perhaps the economics of home telehealth that will encourage health care authorities to support projects as well as acting as a catalyst to the widespread adoption of home telehealth. In our review, only 17% of the 138 studies identified contained economic evaluations.

The care of patients with heart failure is one area where economic evidence does exist. Advanced practice nurses working with a cardiologist, were able to use data collected by the patient and relayed via the Internet, to provide treatment advice over the telephone (Benatar, Bondmass & Ghitelman, 2003). This study identified a reduction in readmissions to hospital and the overall cost of care for these patients. In another study, nurses provided telephone follow-up and received transmissions of one-lead ECG recordings from chronic heart failure patients at home (Scalvini et al, 2005). Again, a reduction in hospital admissions and a reduction in the corresponding cost of care were identified. There is an excellent overview of the main features of economic evaluation methodologies as applied to home telehealth in Scuffham et al, 2006.

Research Quality

Study design is an important point to consider in home telehealth, whether you are assessing the evidence available in a given area, or designing a study into a home telehealth intervention. As in any area of health research, large randomised controlled studies are the gold standard (Egger, Smith & Altman, 2001). Other non-randomised designs provide less reliable estimates of the relative effects of interventions (Clarke, 2004). Other study designs include case-controlled studies, matched cohort studies, time series studies and retrospective studies. Each provides a different level of evidence.

In the home telehealth studies we evaluated, 80% were randomised controlled trials. This, along with assessment of the quality of these studies, (Bensink et al, 2007) provides some reassurance on the level of evidence available for home telehealth in the areas identified. Some problems with the quality of published home telehealth research are still apparent. Patient selection, patient disposal and outcomes reported were areas where studies lacked sufficient information. The use of recognised guidelines, such as the CONSORT statement, (Moher, Schulz & Altman, 2001) can provide guidance not only when preparing trial results for publication, but also much earlier in the planning process when designing studies.

Research Challenges

One problem identified in some areas is the clear identification of exactly what the home telehealth alternative is and what usual care control group it is being compared against.

An example of where confusion can occur is the use of the Internet to provide support for a variety of mental health problems. A number of these studies compared two or more home telehealth interventions. For example, assessing home monitoring of lung transplant patients via the telephone versus an electronic diary (Mullan et al, 2003). Other studies compared a home telehealth alternative to a wait-list control rather than a usual care control group (Devineni & Blanchard, 2005; Andersson, Stromgren & Strom, 2002; Lange et al, 2003). These studies, although they provide interesting information, do not provide clear evidence to support the use of a home telehealth alternative over the care usually provided to patients as part of standard health care services (e.g. in-patient stays, out-patient visits or face-to-face home visits).

Even with a usual care control group, the comparisons are not always straight forward. An example of this is in the area of home uterine activity monitoring (HUAM). Despite the promise identified in early studies, one study found no difference in preterm birth rate, preterm labour incidence, average birth weight or the gestational age of infants with home monitoring (Iam, Johnson & O'Shaughnessy, 1988). The authors of this study concluded that the favourable outcomes credited to HUAM in earlier studies were related not to the home telehealth intervention, but instead to the increased contact with nurses, a focus on symptoms of preterm labour and perceived contractions. This sparked widespread debate in the field. A recent review identified that the use of control groups whose care was, in some studies, more similar to HUAM than the usual care available at the time, was an issue (Morrison & Chauhan, 2003). This set an artificially high standard to compare HUAM against.

What was the final conclusion? When HUAM is used correctly by patients at high risk for preterm birth, with suitable alarm rates and precise monitors, early diagnosis of preterm labour, prolongation of pregnancy, reduced incidence of preterm birth and reduced neonatal morbidity is always demonstrated when compared to a standard care control group. Specifically, for these studies, the authors noted that standard care was the care routinely available to obstetricians in the USA (Morrison & Chauhan, 2003).

Future Research

For health services to embrace home telehealth as a viable and sustainable method of health service delivery more evidence is required. A scientifically sound case requires more randomized controlled trials to be undertaken with appropriate methodological rigour and quality. In any particular area, for example care of patients with diabetes or depression, these trials will need to investigate the use of the same intervention in comparable populations. Ideally, studies will also provide information on the economic, as well as the clinical effectiveness of the intervention. Finally, subsequent meta-analysis of results will provide a clearer view of the evidence available for a particular intervention in a population with specific characteristics.

This process is beginning to occur. A recent review and meta-analysis of home telehealth for patients with chronic heart failure concluded that programmes which include remote monitoring have a positive effect on clinical outcomes (Clark, Inglis & McAlister, 2007).

IMPLEMENTATION

Given the above examples, home telehealth has some benefits. These may be interpreted from a range of perspectives including that of the patient, the health service provider – or society as a whole. It is also important to appreciate the underlying reason(s) for using telehealth in general, whether to the home or for other applications. According to Wootton (2006), there are two broad reasons which may influence the use of telehealth:

The first is that there may be no alternative. An obvious example is if the patient is on a ship at sea or on a space expedition. In these circumstances, it is not logistically possible to visit a medical facility in person, and therefore the patient will depend on information delivered from a distance. A more common example is if the patient lives in a very remote country location with no local health services within close proximity. If the patient is unable to travel it may be reasonable to consider the opportunities for delivering services using telehealth.

The second main reason to develop a telehealth service is that there may be evidence which shows that telehealth is 'better' in some way than the conventional services available. That is, telehealth may be more clinically effective, may provide patients with more regular contact with a specialist, may be cheaper and more sustainable than the alternative, and may be more useful for early intervention and preventative health care services.

In brief, there are a number of practical aspects to consider when starting a new telehealth service.

Getting Started

- Identify the need for telehealth. Why telehealth? What is the clinical problem to be solved?
- What is the best method – real-time; store-and-forward, or a hybrid? This will also

depend on the type of information to be transmitted, i.e. live video, digital photographs, text only, audio etc.

- What equipment will be required for the telehealth service?
- Telecommunications – what will be required?
- Obtain funding? The amount of funding available will influence choice of application.
- What incentive is there for clinicians to do telehealth?
- What support will be provided to clinicians – technical, administrative, executive?
- Identify clinical coordinators at both ends. Who will be responsible?
- Give consideration to change management.
- Have an evaluation plan in place – i.e. evaluate the service – investigate feasibility, cost-effectiveness, satisfaction, clinical effectiveness etc.
- Start small – feasibility testing first and develop service incrementally.

Be Aware

- Identify previous successes and failures and learn from others experiences and mistakes.
- Don't duplicate known failures.

Logistical Factors

Telehealth should not automatically be viewed as a new service. Instead, telehealth may provide an alternative method of delivering services which already exist. It is very important when establishing a telehealth service, to understand the underlying requirements of the service. That is, what are the factors which support the need for telehealth (distance, limited access to specialist services); what telehealth methods are most suitable for the needs identified (real-time, store-and-forward); what is the service going to achieve (perhaps reduced travel for patients, improved recruitment of medical staff to rural areas or improved emergency responses from regional areas).

It is also important to consider how the telehealth service respects and integrates with established working practices (e.g. existing referral mechanisms, patient flows, and dischare support services).

Telehealth requirements in different areas should be judged on individual merit. What works well in one area, does not necessarily guarantee that it will work well in another. Review the literature first and learn from the experiences (positive and negative) reported by others.

The decision to use telehealth instead of conventional methods of service delivery may be directly related to the alternative services available. For instance, if the conventional referral process is easy to use, as is the case in many states in Australia (patients are reimbursed for travel costs), an even more convenient process (incentive) would have to be developed, before clinicians were likely to consider alternatives, such as telehealth. Even today, telehealth is often perceived as being more complex and time consuming for clinicians to set up than the conventional method of sending the patients to see the specialist in person. This may explain why very few clinical telehealth services have emerged as mainstream services in Australia and throughout the world.

Economics

Like any new service, if one is considering establishing a new telehealth service they ought to have a good understanding of the likely establishment and daily operating costs. In addition, one should investigate whether there are economic advantages in doing telehealth, instead of using conventional methods of service delivery, i.e. how do the costs of home telehealth compare to conventional methods of health service delivery such as nurse visits to the patient homes and appointments in specialist hospitals.

Table 1. Types of economic evaluations (Drummond 1996)

Type of analysis	Definition
Cost-benefit	measures costs and benefits in monetary units and computes a cost-benefit ratio
Cost-effectiveness	compares interventions or programmes having a common measurement of health outcome in a situation where, for a given level of resources, the decision maker wishes to maximise the health benefits conferred to the population of concern
Cost-utility	measures benefits in utility-weighted life-years (QALYs) and which computes a cost per utility-measure ratio for comparison between programmes
Cost-minimisation	measures and compares the costs for each service whereby the health outcomes for both services are assumed to be equivalent

There are a various types of economic evaluation methods which may be selected subject to specific factors which need to be assessed. Common examples include cost-benefit; cost-effectiveness, cost-utility and cost-minimisation analysis (see Table 1) (Drummond, 1996).

Perhaps the most common type of economic analysis reported in telehealth studies is the cost-minimisation analysis in which the total costs of two or more services (with comparable health outcomes) are compared to determine the most economical choice of service at a given workload. This type of analysis is also useful to determine what workload (i.e. number of consultations) must be achieved in order for one service to cost the same as another. This point is often referred to as the threshold.

In order to do a cost-minimisation analysis, you will need to identify all of the costs associated with operating your telehealth service and the costs of operating the alternative service. These costs are usually categorised as fixed and variable costs. Fixed costs include equipment, installation and rental of telecommunications, managing staff salaries and facility costs. Variable costs are related to the volume of activity and include telecommunication (call) costs, clinician salaries, travel and accommodation costs. Once these costs are determined, you are then able to calculate the total costs of each service based on a selected workload. It will be possible to calculate the average cost per consultation by dividing the total cost of operating the service by the number of consultations. More importantly, you will be able to determine the cost of providing one additional consultation, assuming all establishment costs are in place. This is referred to as the marginal cost.

Case Example

Although not a home telehealth application, instead providing links between a tertiary paediatric referral centre and regional hospitals, the experiences of the telepaediatric service in Queensland, provides a valuable insight into telehealth implementation.

As an incentive to use telehealth, clinicians at selected regional sites throughout Queensland were given exclusive access to a centralised referral centre - contactable by a single toll-free telephone number. By calling this number, clinicians had a direct link to a telehealth coordinator based in Brisbane. Once a referral was made to the telepaediatric service, the telehealth coordinator took full responsibility for the case, liaised with the appropriate specialists and guaranteed a response within 24 hours. The single point of contact model has been a critical factor leading to the uptake and integration of telehealth services into the routine component of outreach service delivery.

A cost-minimisation analysis was conducted to compare the cost of providing telepaediatric services to two hospitals during a five year period. These costs were compared to the potential cost

Table 2. Telepaediatric service costs and potential costs had all patients travelled to Brisbane

Expenditure	Telepaediatrics ($)	Outpatients ($)
FIXED COSTS		
Equipment (5-year total annuatized cost)	128,191	0
ISDN Installation	2655	0
ISDN Line rental	32,400	0
Coordinators salaries	475,000	0
Sub total (fixed costs)	***638,246***	***0***
VARIABLE COSTS		
Telecommunications *ISDN Line charges*	65,400	0
Staff salaries:		
RCH Consultants ($200 per h)	109,000	109,000
RCH Nursing / Allied Health ($50 per h)	27,250	27,250
RCH Admin Support ($30 per h)	0	16,350
Regional presenter ($150 per h)	81,750	0
Regional admin support ($30 per h)	16,350	0
Patient travel subsidy scheme: *Travel Accommodation*	0 0	1,391,670 8,994
Project costs	18,000	0
Sub total (variable costs)	***317,750***	***1,553,264***
TOTAL COST	**955,996**	**1,553,264**
Average cost per consultation (Divide total cost by the number of consultations)	637.76	1036.20
Marginal cost (Divide the total variable cost by the number of consultations)	211.97	1036.20

of transporting patients to the nearest hospital to see their specialist in person. During this period a total of 1499 consultations were conducted. In this analysis, we assumed that all patients would have had to travel to see the specialist in person, had the telepaediatric service not been available.

All costs are reported in Table 2.

In the above example (at the reported workload actually experienced) telepaediatrics was a much cheaper method of delivering the specialist service, mainly due to the high costs associated with potential travel. Had the workload (number of consultations) been significantly lower, the overall economics of doing telehealth would have been less attractive. Similarly, had the workload been higher, the economics would have been even more favourable.

BARRIERS

Given that home telehealth has the potential to assist health service provision in a number of ways, that evidence exists to support its use in a number of areas and the success demonstrated by a number of telehealth projects, what other factors may be impeding the uptake of home telehealth?

Education and Training

In line with other developments in health care, education and training is a key factor in uptake. Like advances in medical imaging, ongoing education and training are critical for patient safety and for staff to use these systems efficiently and effectively. Advances in telehealth should be no different.

Very little attention has been paid to education and training in telehealth. Research has shown that despite the fact that health practitioners are familiar with computers and other electronic devices the practice of telehealth requires systematic education and training (Edirippulige, Smith & Young, 2006). The lack of knowledge of telehealth, its basic concepts and application is a result of the absence of systematic education (Edirippulige, Smith, Beattie, Davies & Wootton, 2007). Unless students are given education in basic concepts, principles and the variety of applications possible, then it is unlikely that telehealth will become a part of their practice. The potential benefits of telehealth can only be realised if students are provided with formal education as part of their curriculum.

In addition, integrating telehealth into ongoing professional development and support is also important. Health and medical professionals must be supported to acquire (until telehealth is integrated into curricula) and maintain their knowledge and practical skills in telehealth via continuing professional development (CPD) programmes. For this to occur, these courses will need to be recognised by relevant professional bodies through formal accreditation and support provided by employers for staff to attend.

A Multidisciplinary Approach

Another barrier to ongoing development in telehealth is the lack of interdisciplinary collaboration. Successful home telehealth implementation depends fundamentally on the ability to form, and lead, a multidisciplinary team through a lifecycle from initial analysis to the eventual day-to-day routine delivery of the service. It is important to remember that, whilst home telehealth uses technology as the vehicle for delivery of clinical services, there are other important non-technical aspects that must be given equal attention to ensure uptake and successful operation. This of course includes clinical aspects as mentioned previously, but also includes administrative aspects associated with coordination and ongoing operation.

Although the composition of a telehealth team will change over time, the underlying membership of the team must consist of skilled individuals in three key areas:

1. Clinical (e.g. nurses, doctors, social workers)
2. Technical (e.g. application developers, networkers)
3. Administrative (e.g. telehealth service coordinators, medical records staff).

Because these areas are closely interlinked, all members of the team need to be involved from initial inception of the project. The team, and its leader, must posses an uncommonly wide range of skills and experience in both project management and operational service management.

In common with general technology projects, a successful telehealth implementation will result from a delicate balancing act of both project-oriented and operational tasks carried out by a skilled team. In contrast with most general technology projects, the telehealth project requires a multidisciplinary approach and the necessity for each of the disciplines to be represented at all stages of the project. In addition, the project manager must have a broad understanding of all of the issues across clinical, technical and administrative boundaries and be able to manage various demands of the team to successful implementation.

CONCLUSION

Home telehealth is the use of information and communication technologies to deliver and support health care directly to the home. For nurses, home telehealth provides an opportunity, amongst other applications, to support other nurses at a distance, to support patients in the home through direct communication or via passive monitoring techniques, to promote and support self-care and to help patients with medication management and compliance.

Despite the hype, home telehealth is still an emerging application. As in all areas of health service, evidence is required to establish the worth of investing in home telealth examining both the clinical and cost-effectiveness of interventions.

Nurses have an opportunity to place themselves at the forefront of these developments. To achieve this, nurses will need to identify, in their own practice and area of expertise, how telehealth may play a role and why it might be of benefit, which methods are most appropriate and what outcomes might be achieved.

Nurses are also well placed (clinically, practically and historically) to play a key role in multidisciplinary telehealth teams. This collaborative approach is required to bridge the gap between patients and the clinical, administrative and technical aspects inherent in care delivery via telehealth techniques.

Finally, as a catalyst for this type of development, nurses need to know more about telehealth through systematic education as an integral part of undergraduate and graduate nursing curricula.

REFERENCES

Ahrens, J., Feldman, P. H., & Frey, D. (2002). Preventing medication errors in home care. *Centre for Home Care policy & Research Policy Brief, 12*, 1-6.

Andersson, G., Stromgren, T., Strom, L., & Lyttkens, L. (2002). Randomized controlled trial of internet-based cognitive behavior therapy for distress associated with tinnitus. *Psychosomatic Medicine*, *64*(5), 810–816. doi:10.1097/01.PSY.0000031577.42041.F8

ATA's Federal Policy Recommendations for Home Telehealth and Remote Monitoring. (n/d). Retrieved October 20, 2007, from http://www.americantelemed.org/news/policy_issues/FINA_%20 DRAFTHome_Telehealth_Policy_ver3.5.pdf

Belfield, G., & Colin-Thome, D. (2004). Improving chronic disease management.Department of Health, UK National Health Service. Retrieved October 20, 2007, from http://www.dh.gov.uk/en/Publicationsandstatistics/Publications/PublicationsPolicyAndGuidance/DH_4075214.

Benatar, D., Bondmass, M., Ghitelman, J., & Avitall, B. (2003). Outcomes of chronic heart failure. *Archives of Internal Medicine*, *163*(3), 347–352. doi:10.1001/archinte.163.3.347

Bensink, M., Hailey, D., & Wootton, R. (2006a). A systematic review of successes and failures in home telehealth: preliminary results. *Journal of Telemedicine and Telecare*, *12*(Suppl. 3), 8–16. doi:10.1258/135763306779380174

Bensink, M., Hailey, D., & Wootton, R. (2007a). A systematic review of successes and failures in home telehealth. Part 2: final quality rating results. *Journal of Telemedicine and Telecare* 2006 13 (suppl 2) 10-14.

Bensink, M., Shergold, J., Lockwood, L., Little, M., Irving, H., & Russell, T. (2006b). Videophone support for an 8-year-old boy undergoing paediatric bone marrow transplantation. *Journal of Telemedicine and Telecare*, *12*(5), 266–268. doi:10.1258/135763306777889082

Bensink, M., Wootton, R., Irving, H., Hallahan, A., Theodoros, D., & Russell, T. (2007b). Investigating the cost-effectiveness of video-telephone based support for newly diagnosed paediatric oncology patients and their families: design of a randomised controlled trial. *BMC Health Services Research*, *7*(38). doi:.doi:10.1186/1472-6963-7-38

Bensink, M. E., Armfield, N., Russell, T. G., Irving, H., & Wootton, R. (2004). Paediatric palliative home care with Internet-based video-phones: lessons learnt. *Journal of Telemedicine and Telecare*, *10*(Suppl. 1), 10–13. doi:10.1258/1357633042614465

Bjorneby, S. (2000). Smart houses: can they really benefit older people? *Signpost*, *5*, 36–38.

Chumbler, N. R., Vogel, W. B., Garel, M., Qin, H., Kobb, R., & Ryan, P. (2005). Health services utilization of a care coordination/home-telehealth program for veterans with diabetes: a matched-cohort study. *The Journal of Ambulatory Care Management*, *28*(3), 230–240.

Clark, R. A., Inglis, S., Mc, C., Alister, F. A., Cleland, J. G. F., & Stewart, S. (2007). Telemonitoring or structured telephone support programmes for patients with chronic heart failure: systematic review and meta-analysis. *BMJ (Clinical Research Ed.)*, *334*(7600), 910–911. doi:10.1136/bmj.39156.536968.55

Clarke, M. (2004). Systematic reviews and the Cochrane Collaboration. Retrieved November 12, 2007, from http://www.cochrane.org/docs/whycc.htm.

Darkins, A., Dearde, C. H., Rocke, L. G., Martin, J. B., Sibson, L., & Wootton, R. (1996). An evaluation of telemedical support for a minor treatment centre. *Journal of Telemedicine and Telecare*, *2*(2), 93–99. doi:10.1258/1357633961929853

Devineni, T., & Blanchard, E. B. (2005). A randomized controlled trial of an internet-based treatment for chronic headache. *Behaviour Research and Therapy*, *43*(3), 277–292. doi:10.1016/j.brat.2004.01.008

Drummond, M. F., & Jefferson, T. O. (1996). Guidelines for authors and peer reviewers of economic submissions to the BMJ. *British Medical Journal*, *313*, 275–283.

Edirippulige, S., Smith, A., Beattie, H., Davies, E., & Wootton, R. (2007). Preregistration nurses: an investigation of knowledge, experience and comprehension of e-health. *The Australian Journal of Advanced Nursing*, *25*(2), 78–83.

Edirippulige, S., Smith, A. C., Young, J., & Wootton, R. (2006). Knowledge, perceptions and expectations of nurses in e-health: results of a survey in a children's hospital, *Journal of Telemedicine and Telecare, 12*(Suppl. 3), S3, 35-38.

Egger, M., Smith, G., & Altman, D. G. (2001). *Systematic Reviews in Health Care: Meta-analysis in Context*. 2 ed. London: BMJ Publishing Group.

Flesner, M. K. (2004). Care of the elderly as a global nursing issue . *Nursing Administration Quarterly*, *28*(1), 67–72.

Gelhaus, l. (2002). High-tech homes mean a brighter future for seniors. *Provider*, 28, 40-42.

Gibson, F. (2003). Seven Oakes: friendly design and sensitive technology. *Journal of Dementia Care*, *11*, 27–30.

Iams, J., Johnson, F., & O'Shaughnessy, R. (1988). A prospective random trial of home uterine activity monitoring in pregnancies at increased risk of preterm labor Part II. *American Journal of Obstetrics and Gynecology*, *159*, 595–603.

Information Technology Association of America E-Health Committee. (2004). *Chronic care improvement: How Medicare transformation can save lives, save money and stimulate an emerging technology industry*, ITAA May 2004. Retrieved October 20, 2007 from http://www.itaa.org/isec/docs/choniccare.pdf

Jenkins, R. L., & White, P. (2001). Telehealth advancing nursing practice. *Nursing Outlook*, *49*(2), 100–105. doi:10.1067/mno.2001.111933

Joanna Briggs Institute. (2006). strategies to reduce medication errors with reference to older adults. *Australian Nursing Journal*, *14*(4), 26–29.

Kingma, M. (2004). *Nurses on the move, Migration and the global health care economy*, Cornell University Press, Ithaca.

Kobb, R., Hilsen, P., & Ryan, P. (2003). Assessing technology needs for the elderly: finding the perfect match for home. *Home Healthcare Nurse*, *21*, 666–673. doi:10.1097/00004045-200310000-00005

Kobb, R., Hilsen, P., & Ryan, P. (2003). Assessing technology needs for the elderly: finding the perfect match for home. *Home Healthcare Nurse*, *21*, 666–673. doi:10.1097/00004045-200310000-00005

Lange, A., Rietdijk, D., Hudcovicova, M., van de Ven, J.-P., Schrieken, B., & Emmelkamp, P. M. G. (2003). Interapy: A controlled randomized trial of the standardized treatment of posttraumatic stress through the internet. *Journal of Consulting and Clinical Psychology*, *71*(5), 901–999. doi:10.1037/0022-006X.71.5.901

Moher, D., Schulz, K., & Altman, D. (2001). Revised recommendations for improving the quality of reports of parallel group randomized trials. *Annals of Internal Medicine*, *134*(8), 657–662.

Moore, R. S., Britton, B., & Chetney, R. (2005). Wound care using interactive telehealth. *Home Health Care Management & Practice*, *17*(3), 203–212. doi:10.1177/1084822304271807

Morrison, J. C., & Chauhan, S. P. (2003). Current status of home uterine activity monitoring. *Clinics in Perinatology*, *30*, 757–780. doi:10.1016/S0095-5108(03)00112-X

Mullan, B., Snyder, M., Lindgren, B., Finkelstein, S. M., & Hertz, M. I. (2003). Home monitoring for lung transplant candidates. *Progress in Transplantation (Aliso Viejo, Calif.)*, *13*(3), 176–182.

National Health Expenditures Aggregate Amounts and Average Annual Percent. Retrieved October 15, 2007 from http://www.cms.hhs.gov/NationalHealthExpendData/downloads/tables.pdf

Orleans, C., Schoenbach, V., Wagner, E., Quade, D., Salmon, M., & Pearson, D. (1991). Self-help quit smoking interventions: effects of self-help materials, social support instructions, and telephone counselling. *Journal of Consulting and Clinical Psychology*, *59*(3), 439–448. doi:10.1037/0022-006X.59.3.439

Prado, M., Reina-Tosina, J., & Roa, L. (2002). Distributed intelligent architecture for falling detection and physical activity analysis in the elderly. In: *Proceeding of the Second Joint EMBS/BMES Conference, 3*, 1910–1911.

Reed, K. (2005). Telemedicine: Benefits to advanced practice nursing and the communities they serve. *Clinical Practice*, *17*(5), 176–180.

Rialle, V. Rumeau, P, Ollivet, C. & Hervé, C. (2006). Smart homes. In Wootton R, Kvedar J & Dimmick SL. *Home Telehealth: Connecting care within community*, 65-75. RSM, London, Ryan, P., Kobb, R., & Hilsen, P. (2003). Making the right connection: matching patients to technology. *Telemed J E Health, 9*, 81-8.

Scalvini, S., Capomolla, S., Zanelli, E., Benigno, M., Domenighini, D., & Paletta, L. (2005). Effect of home-based telecardiology on chronic heart failure: costs and outcomes. *Journal of Telemedicine and Telecare*, *11*(Suppl 1), 16–18. doi:10.1258/1357633054461688

Scuffham, P. (2006). Economic evaluation. In: Wootton R, Dimmick S, Kvedar J, editors. *Home telehealth: connecting care within the community*. London: Royal Society of Medicine Press Ltd, 21-35.

Smith, A. C., Scuffham, P., & Wootton, R. The costs and potential savings of a novel telepaediatric service in Queensland. *BMC Health Services Research* 2007, 7:35, available online at http://www.biomedcentral.com/1472-6963/7/35

Wootton, R., Kvedar, J., & Dimmick. S. L. (2006). *Home Telehealth: Connecting care within community*. RSM, London.

Wootton, R., & Patterson, V. (Eds.). (2006). *Introduction to Telemedicine* (2 ed.). London: Royal Society of Medicine Press.

KEY TERMS AND DEFINITIONS

Telehealth: The delivery of health-related services and information over distance via telecommunications technologies.

Home Telehealth: The use of telehealth techniques in a non-institutinal setting such as the home or residential care facility.

Evidence: The collection of data through observation and experimentation used to determine or demonstrate the truth of an assertion.

Telepaediatrics: Telehealth applications relevant to the health and wellbeing of children, young people and families.

Real-Time Mode: The use of telecommunications allowing instantaneous two-way interaction between participants e.g. videoconferencing.

Store-and-Forward Mode: The delayed exchange of data requiring first capture using for example a digital camera, voice recorder, X-ray machine or video camera, sub sequent storage and latter transmission.

Health Economics: A specialist field of economics related to the demand and supply of health and health care.

Multidisciplinary: The collaboration of individuals and groups with specialised education and expertise in distinct and different areas.

Telehealth Education and Training: The formal and systematic imparting of the knowledge and skill required to apply best practice principles to the application of telehealth in practice.

This work was previously published in Nursing and Clinical Informatics: Socio-Technical Approaches, edited by B. Staudinger, pp. 94-109, copyright 2009 by Medical Information Science Reference (an imprint of IGI Global).

Chapter 1.23

Process-Based Evaluation of Hospital Information Systems:

Application of an Information Systems Success Model (PRISE) in the Healthcare Domain

Sevgi Ozkan
Brunel University Business School, UK

Nazife Baykal
Informatics Institute Metu, Turkey

Murat Sincan
Informatics Institute Metu, Turkey

ABSTRACT

Although there is limited research and evidence base, it is reasonable to expect that high quality information technology is an integral factor in the success of today's healthcare sector. However, the healthcare sector is considered to be low level investor in information technology (IT) when compared to other sectors. There are studies that look at the sums spent on health IT as a basis for determining how effective the IT systems are. We support the idea that the effectiveness of IT systems is not an exact measure and a more systematic approach needs to be taken when evaluating success of an IT system. In this study, we have evaluated an assessment method, process based information systems effectiveness (PRISE), which is based on a novel model of information systems effectiveness in the healthcare domain. The results of our case series provide specific implications concerning the applicability of a general "information systems assessment" approach, in the medical context.

DOI: 10.4018/978-1-60566-030-1.ch005

INTRODUCTION

Health care organizations and patients can benefit greatly from the appropriate and effective use of information systems (hereafter IS) (Kaushal, Barker and Bates, 2001). Effective implementation of IT in health care has the potential to save billions of dollars while reducing morbidity and mortality (Chaudhry, Wang, Wu, Maglione, Mojica, Roth, Morton, and Shekelle, 2006). As Burke and Menachemi (2004) stated in the paper, in the recent years, health care investment in IT has experienced a significant increase, which in parallel results with an increase in IT capabilities. Empirical research has shown that effective information systems in healthcare organizations are associated with reduced costs and with better care and organizational performance (Chang and King, 2005; Li and Ye, 1999), which suggests a connection between IS process improvement and organizational effectiveness. However the impact of IS implementations are hard to measure and identify (Jayasuriya, 1997). Researchers also suggest that the impact of IS is usually accidental rather than planned (Borum and Christiansen, 2006).

While the effectiveness of information systems is recognized as an important issue, the definition of IS effectiveness in the information systems literature is not yet mature and consistent (Ozkan, Hackney and Bilgen, 2007). Various models such as Capability Maturity Model (CMM/CMMI) (SEI, 2007), Control Objectives for Information Technology (COBIT) (ISACA, 2007) and Information Technology Infrastructure Library (ITIL) (OGC, 2007), have been proposed and used by the IT industry (Ozkan et al, 2007). IS management and evaluation frameworks are not limited to the above mentioned and the list includes approaches that range from the generic ISO 9001 (Braa and Ogrim, 1995), Six Sigma (Schroeder, 2007), and EFQM (EFQM, 2006; Donahue and Vanostenberg, 2000) models through IT specific models such as SPICE (SEI, 2007), ISO 9126, ISO 20000 (ISO,2007), to healthcare-IT specific models such as Q-Rec (Q-Rec,2007), Joint Commission International Information Management Standard (Donahue and Vanostenberg, 2000) and HIS-Monitor (Ammenwerth et al, 2007). Each of these approaches has a distinct focus, and its own strengths and weaknesses.

In their seminal review paper, DeLone and McLean defined IS success in terms of success in six categories. These categories were system quality, information quality, user and user satisfaction, individual impact and organizational impact (DeLone and McLean, 2003). In 2003, they revised their model to include service quality as another quality category and they united individual and organizational impact into one "net benefits" category (DeLone and McLean, 2003).

Proper evaluation and assessment is essential for the ongoing improvement of information systems. Yet, a great number of studies that evaluate the organizational aspects of hospital information systems (hereafter HIS) are based on exploratory methods (i.e. do not test a pre-defined hypothesis) (Ammenwerth and Keizer, 2005). Objective and explanatory measurement methods are needed to better evaluate organizational aspects of IS, both in general IS and in HIS context. Another deficiency of the IS evaluation studies is that the evaluated system usually has a limited focus (Ammenwerth and Keizer, 2005), either in functionality or localization (i.e. departmental systems). Among the explanatory studies that utilize formal assessment and/or measurement data rather than user feedback or satisfaction, there are very few studies that have a wider focus and evaluate enterprise-wide systems (Ammenwerth and Keizer, 2005)

It is logical to think that there must be a strong relationship between "improvement in managing IS" and "overall performance of the organization" as measured by effectiveness. Systematic measurements are needed to test this hypothesis. The first step in attracting attention to this area is to review the current level and status of information systems management practices. As Eccles (1991) says, "What gets measured gets attention". To improve the current status we need to measure IS management and IS effectiveness, although effectiveness is extremely hard to measure (Borum and Christiansen, 2006) because of the highly complex "sociotechnical systems" that make up an information system.

DeLone and McLean emphasize the need for a validated measuring instrument which could provide a standardized evaluation of information systems effectiveness; this would permit comparisons across departments, systems, users and organizations (DeLone and McLean, 2003). Such a measurement would help to build a cumulative research tradition which could clarify effectiveness measures.

IS evaluation is an active and organization-dependent undertaking. Organizations need a comprehensive framework for assessment to help and guide them, in developing an IS evaluation methodology.

This study takes a method used previously in non-medical settings and applies it to the health care domain. We also aim to show how organizational factors are related to the management of IS processes.

RATIONALE FOR THE STUDY

Several studies have looked at the effects of information systems on health care organizations (Jayasuriya, 1997). Electronic health records is the single most important type of system evaluated, followed by clinical physician order entry (CPOE), clinical decision support systems (CDSS), telemedicine, radiology information systems (RIS) and picture archiving and communication systems (PACS) (Keizer and Ammenwerth, 2005). Numerous health care-specific information systems are used in a modern health care facility; their effect on both organizational performance and health care quality is important. The combined effect is also more than the sum of their individual impacts on the organization.

Before we delve more into information systems evaluation, we need to clarify the difference between IT and IS. Information Systems is a wider concept than information technology and is closely related to organizational functions and information requirements (Wilcocks and Lester, 1993; Ozkan, 2004, 2005; Ozkan and Bilgen 2003). IS are both affected by organizational practices and in return have an effect on the organization. Methods are needed to make these relationships between organizational factors (i.e. size, effectiveness, human resources, and financial health) and information systems, visible and measurable. IS projects are more likely to fail than succeed but a correlation between organizational factors and IS success, could guide decision makers in planning and implementing systems.

OBJECTIVES OF THE STUDY

Our objective is to use the PRISE evaluation tool to measure the level of process maturity of hospital information systems. Although the acronym HIS is generally used for “hospital information systems” and “health information systems” interchangeably, our focus in this study is limited to ”hospital information systems” and does not include other information systems used in health care settings. We use the following definition for a Hospital Information System: “Computer system designed to support the comprehensive information requirements of hospitals and medical centers, including patient, clinical, ancillary and financial management” (Shortcliffe and Cimino, 2006).

Information systems are composed of elements; some are easier to measure than others. An assessment framework that only focuses on discrete “easy to measure” elements cannot show the whole picture or provide an exclusive assessment of the success of a system (Perera et al, 2007). Central processor unit utilization time and network load are easily measured, but the usability of a new graphical user interface or the usefulness of a decision support advice might be harder to measure.

The goal of an HIS evaluation framework is to provide a set of measures and performance indicators that can be used to predict the quality of processes that ultimately result in better outcomes at either a user/patient or cost saving level(Perera et al, 2007). Development of a universal set of indicators and measures require best practice data and established validity pertaining to the individual indicators (Perera et al, 2007). This scope of evidence is only possible through many studies that provide this kind of scientific proof from numerous different systems and implementation settings. One of our goals is to provide methodology and data that contributes to this body of knowledge.

PRISE is a novel, comprehensive and innovative approach to assessing the effectiveness of IS processes; it was developed by one of the authors of this paper as part of a PhD thesis (Ozkan et al, 2007) and to help organizations evaluate their IS management with a strong process focus. The PRISE questions can be asked by an external assessor or reviewed internally for self evaluation. PRISE has 10 process areas, all of which are all related to IS. Each area includes more detailed questions which are scored on a scale that has six levels. Each score level from 0 to 5 represents a different level of maturity in IS processes.

PRISE has successfully evaluated IS process maturity in non-health care technology organizations as applied in the original PhD thesis (Ozkan, 2006; Ozkan et al, 2007). Since there is a lack of specific health IS assessment frameworks, we believe that the application of general IS assessment frameworks such as PRISE might suggest how health IS assessment methods should be developed and applied.

We hypothesize that there are correlations between PRISE scores and organizational factors within a health care organization. Identifying these correlations will guide future research in determining causal relationships between these organizational factors and IS success. Our research question is: "*Is there a relationship between certain organizational factors and PRISE scores?*"

RESEARCH METHODOLOGY

Organizational Setting

The assessment was carried out in Turkish health care provider organizations with inpatient capabilities: state hospitals, private hospitals and academic medical centers (university hospitals). The Hospital Information Systems (HIS) were assessed using the information systems success assessment tool: PRISE (Process Research for Information Systems Evaluation). All of the hospitals used commercial software systems with little or no internal development of support or maintenance. The research did not involve any general and administrative systems (i.e. accounting information systems) nor any departmental information system confined to that department.

Study Design

819 hospitals were initially contacted via e-mail. A total of 4 e-mail reminders were sent to all the target hospitals. Total number of institutions which agreed to participate in our study is 17. Each health care organization was sent an e-mail message with an attached copy of the assessment tool (see appendix) and instructions on how to use it. The institutions were asked to assign a senior IS officer to complete the self-assessment process.

Prise Evaluation Tool

The Hospital Information Systems (HIS) were assessed using the information systems success assessment tool: PRISE (Process Research for Information Systems Evaluation). PRISE (Ozkan, 2006; Ozkan, Hackney and Bilgen, 2007) was developed to provide a comprehensive and integrative information systems assessment framework. Jayasuriya et al, note that most other approaches to evaluate IS effectiveness lack an integrated approach; they may yield convenient solutions within their specific contexts, but they do not

Table 1. PRISE process areas

	Process code	Process Definition
People	P1	Definition of the IS organization and relationships
	P2	Education and training of users
	P3	Provision of assistance and advice to IS users
Resources	P4	IS interactions
	P5	Configuration management
	P6	Performance and capacity management
	P7	Operations management
Services and Benefits	P8	Continuous service
	P9	Change management
	P10	Monitoring services

comply with all of the guidelines in the literature (Borum and Christiansen, 2006). PRISE aims to provide an integrated approach to IS evaluation by complying with the guidelines.

The PRISE model consists of three main components: People, Resources, Services and Benefits, with a total of 10 process areas within those components (Table 1). The model consists of 92 questions in 10 process groups, which are assesses on a 6 level scale as shown in Table 2.

Participants

10 of the participants were State hospitals, owned by the government and run by the Ministry of Health. Some of these state hospitals are third level research hospitals but most are secondary level care hospitals. The University hospitals that participated in our study are also owned by the government. Only 2 of the participating hospitals were privately owned. Table 3 shows a detailed distribution of the participants.

We had participants from thirteen different provinces of a total of 81 provinces in Turkey. 13 health care providers were from provincial centers and 4 of them were from smaller towns. The number of beds ranged from 19 to 1200 with a mean of 411. The number of physicians ranged between 10 and 1390 with a mean of 276. 13 of the institutions had an internal IT or IS department independent of an outsource company. Not surprisingly, the hospitals that were located in provincial centers (urban centers) had IT/IS departments and the hospitals in small towns (rural centers) did not; 12 of the hospitals had 2 or fewer people employed in the IT/IS departments. One

Table 2. PRISE scale

Level	Explanation
0	Non existent
1	Initial /Ad Hoc
2	Repeatable but intuitive
3	Defined process
4	Managed and measurable
5	Optimized

Table 3. Hospital type

Hospital Type	Number
State hospital	10
University Hospital	4
Private Hospital	1
Medical Center	1
Mouth and dental health center	1
Total	17

institution employed 31 people in IT/IS services. This large variation in the number of IT/IS services personnel (standard deviation SD=7.9) reflects organizational differences in the approach to IT/IS management.

Our participants had a mean of 4.2 years of experience (SD=3.1) with their enterprise-wide information systems and they had been using their most recent installation for a mean of 3 years (SD=2.9). We found that 10 hospitals had not changed vendors and used only the information system currently in use. The average number of different IS used was 1.6 (SD=0.8). We found that 13 hospitals used only one enterprise-wide information system for their information processing needs.

None of the participating institutions had a model of its enterprise workflow and business processes prior to the last installation. Nor did they have any previous experience with a formal IT/IS assessment or evaluation framework such as COBIT (ISACA, 2007), CMMI (SEI,2007) or ITIL (OGC,2007).

All of our participants utilized an outside company to provide IT services although some health care providers in Turkey use software developed in-house.

Application of the Tool and the Conduct of the Study

Each self assessor was asked to report according to the above scale. The assessment form that was e-mailed to hospitals included instructions about PRISE and information about the logistics of the study; there was a link to a web site that had textual and video training about PRISE and additional questions regarding organizational factors. The respondents had to give a numerical value for each item on the scale based on the level definitions according to a pre-defined scale. Each participant was asked to fill in the assessment forms and return the results to the researchers. There are two main reasons for choosing the self assessment method. First, PRISE is neither a legal nor an industry standard, but rather a publicly available free guideline. For a framework that is not formally endorsed the only viable dissemination method is adoption and self assessment .Second, although self assessment of IS processes is a major undertaking requiring a lot of preparation and effort, we believe this self assessment model can help organizations become aware of weaknesses in their IS processes and practices as they get some practice in IS evaluation. Since there is currently no economic or legal incentive for PRISE adoption, we believe that self assessment and improving the assessment methodology to better support this approach, is the most viable approach at the present time.

FINDINGS

In order to examine the data, statistical and qualitative analysis methods have been used. Descriptive statistics were run to analyze the collected data. The responses to the questionnaire were analyzed using the SPSS (Statistical Package for the Social Sciences) 15.0 Windows software program. Charts and tables were created from the data using SPSS features.

Table 4 shows that PRISE scores ranged between 0.4 – 3.54 (SD=0.86). The mean for all cases was 2.18 and the median was 2.11. The scores for individual process areas varied; the minimum scores for each process area ranged from 0.0-0.7 and the maximums ranged from 3.33-4.7.

13 health care providers (76.5%) received scores of 3 or lower. Level 3 signifies a documented process and a standard way of carrying out IS related management activities. We checked whether there were any statistically significant relationships between process scores and such organizational factors as location (being in a provincial center rather than a smaller town) or size of the target population. Mann-Whitney U tests showed significant differences in P5-Configura-

Table 4. PRISE scores

PRISEProcess	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	Total
Mean	2.47	2.31	2.28	1.53	2.21	2.19	2.35	2.56	1.87	2.02	2.18
Median	2.22	2.44	2.00	1.40	2.09	2.00	2.42	2.56	1.80	2.00	2.11
Std. Deviation	0.97	1.06	1.07	1.20	1.03	1.00	0.76	1.11	0.88	1.10	0.86
Minimum	0.67	0.22	0.70	0.00	0.55	0.33	0.58	0.44	0.18	0.10	0.40
Maximum	4.11	3.75	3.80	3.80	4.09	3.50	3.33	4.78	4.00	4.10	3.54

The process areas, P4 – IS interactions, and P9 – Change management received the lowest mean scores. Process areas, P1- Definition of the IS organization and relationships, and P8 – Continuous service received the highest mean scores.

tion management and in P8-Continuous service process areas for health care institutions with different target populations. We used Spearman's bivariate correlation analysis to see if there were any significant correlations in these differences. Our data shows a strong positive correlation between the target population of the institution and P5-Configuration management scores with a correlation coefficient of 0.573 ($P = 0.02$).

We also explored whether the providers' own size (number of beds and/or number of physicians) were associated with any difference in the PRISE scores. We analyzed the results with Mann-Whitney U test and found that none of the process areas showed any significant differences.

We expected to find a correlation between the number of IT staff and certain process area scores. We found that the higher the number of IT personnel, the higher an institution scored on P8-Continuous service process area; organizations which give importance to maintaining a continuous level of service must have sufficient resources to perform such tasks. The number of IT personnel was also positively correlated with the overall PRISE score (see Table 5). The overall PRISE Score was calculated by taking the mean of all 92 PRISE questions.

DISCUSSION AND LESSONS LEARNED

It is imperative to provide quality care while reducing soaring health care costs. To accomplish, we must know if the models we apply in other industries will also result in efficiency and effectiveness in health care information systems. The only way we can achieve this is through evidence-based health care informatics.

Table 5. Correlation between the number of IT personnel and certain PRISE scores

			P8	PRISE Score	IT personnel
Spearman's rho	P8	Correlation Coefficient	1.000	0.896(**)	0.632(**)
		Sig. (2-tailed)	.	0.000	0.006
	PRISE Score	Correlation Coefficient	0.896(**)	1.000	0.534(*)
		Sig. (2-tailed)	0.000	.	0.027
	IT personnel	Correlation Coefficient	**0.632(**)**	**0.534(*)**	1.000
		Sig. (2-tailed)	**0.006**	**0.027**	.

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

-- N=17

More research should identify factors that result in effective health care information systems. We also need to prove that IT actually reduces costs instead of being a cost center for the enterprise. Information systems assessment and health informatics evaluation are aspects of evidence-based health informatics that can provide answers to these important questions. We believe our study is a contribution and a step forward in showing that health care information systems can benefit from the IS assessment models used in other industries.

PRISE contained some questions that were not really suited to a hospital setting. Despite their many differences, all our participant hospitals had consistently higher or lower scores on certain process areas, indicating that regardless of size, location, ownership model or focus, they shared certain characteristics.

This situation is illustrated by the "P5-Configuration management process" area which contains 11 questions, some of which did not apply closely in health care settings. Although there is a certain amount of software development activity, none of our health care institutions primarily developed software; they all bought or outsourced their IT services. In this situation, contract management and service management activities become more important than management of development activities. Yet, our data showed a strong positive correlation between the target population of the institution and P5-Configuration Management area scores. We believe this is due to the fact that software development, hence configuration-management related activities were only carried out in larger hospitals that were generally located in large urban areas. Our analysis also reflect a similar relationship between IT personnel number and P5- Configuration management process area; these hospitals could afford tailored software (developed either by their own personnel or by contractors) to increase the functionality of their systems, and they reported higher level management practices in the area of configuration-management process. This result suggests that small rural hospitals should be supported in terms of IT personnel and software development since every institution has specific information needs that can be satisfied with appropriate development.

All of the participating institutions had some form of management support and initiatives to implement better IS/IT management practices. Some hospitals were required to plan and document IS management activities for external reasons such as quality improvement and accreditation (i.e. ISO 9001 and/or JCI Accreditation); others had people at the top management level with IT/IS know-how. Both of these resulted in relatively higher scores in P1- Definition of the IS organization and relationships. We believe that these relatively higher scores did not translate into higher scores in other process areas, because of a lack of organizational culture and effective communication in terms of IT/IS management.

We found that despite their differences, all organizations share common strong and weak process areas. It is not surprising that process area "1-Definition of the IS organization and relationships" and process area "8-Continuous services" have higher scores than other process areas. All organizations were aware that good IS management and the provision of continuous service is crucial to the continuity of their business operations and a failure to maintain business continuity could result not just in catastrophic financial losses but even in the loss of patient lives.

Organizations received generally lower scores for the process areas "4-IS interactions" and "9-Change management"; given the current nature of medical services in Turkey, this result is quite normal. Hospitals operate within their own defined domains; they are not concerned about data sharing and interoperability. Process area "9-Change management and monitoring services" is another weak side of these organizations. These results may be partially due to a lack of understanding of general change management and monitoring services, which in turn, affects IS as well. Organizations did not have a clear understanding of either of these concepts; we found that most if not all the items in this section, were implemented only at a very basic level.

Probably our most important finding was the correlation between the Total PRISE score and number of IT personnel in a hospital. IT personnel number was the only organizational factor correlated with total PRISE scores; other factors were found to be correlated with scores for sub process areas. This finding indicates that the human factor is very important in IS processes' success and that appropriate staffing of IT departments is closely related to the quality of information systems.

Although the PRISE model, is very thorough in assessing the IS processes of a general organization, we believe it can be more effectively applied in health care domain if it is modified for the specific needs and attributes of health care organizations.

Some things were not evaluated thoroughly by PRISE. These included the outsourcing model (which was very common in the IS sourcing of our participating organizations) and some other very important health-IS related issues such as privacy and confidentiality, workflow management issues and outcomes management, PRISE covers the breadth of IS assessment, but lacks specific questions or the depth necessary to effectively evaluate issues regarding clinical aspects of hospital information systems. A new model that can address such issues must be developed to improve assessment in the health care IS domain. Such a model can be a promising future research topic.

It is important to note that the findings from this research study are useful for the following IS stakeholders: (1) IS managers, (2) IS users, (3) IS developers. The evaluation of IS processes of an IS organization, i.e. in this study "hospitals", by means of using PRISE model are primarily valuable for the managers of hospitals.

LIMITATIONS

Our study assumed that every health care organization had a functional organization-wide HIS and was capable of using a questionnaire-based self assessment tool to evaluate its own effectiveness in managing IS. We observed that both the motivation and the capability to conduct such a self assessment were less than expected resulting in a low participation rate in our study. More participation could have allowed us to generalize the results of our case study country-wide. A future project that receives financial support may be able to reach more hospitals and perform a more thorough analysis of IS management.

Application of PRISE may yield different results, if a trained assessor carries out the assessment. An increase in the number of hospitals participating in our study would produce a better statistical analysis and might show different relationships between PRISE scores and organizational characteristics. We believe that organizational effectiveness should also be measured and compared with the results of PRISE measurements. It would be very important for future research to study whether higher PRISE scores, meaning a better information system, are related to better financial and medical outcomes. We believe our study is an important attempt to objectively measure management practices related to the information systems in the health care environment. Hopefully our findings will pave the way for improvement in health care information systems, perhaps leading to better health care.

ACKNOWLEDGMENT

We would like to thank Prof. Elske Ammenwerth and Dr. Aysu Betin-Can for their valuable comments on the drafts of our manuscript. This paper is supported by an JMIR Institutional Membership grant form Birim Bilgi Islem Teknolojileri AS . This grant had no support or any requirements that might have had any affect on the scientific quality or content of this research paper. The sponsor had no role in the conduct of our study, in the reporting of our findings or in reviewing our paper.

CONFLICT OF INTEREST

PRISE is a freely available tool. One of the authors is a faculty member at the university that governs one of the participating hospitals; however this fact had no affect on the conduct of our study, nor did it affect our reporting in any way. The authors did not receive any financial support.

REFERENCES

Ammenwerth, E., & de Keizer, N. (2005). An inventory of evaluation studies of information technology in healthcare-trends in evaluation research 1982-2002. *Methods of Information in Medicine*, *44*(1), 44–56.

Ammenwerth, E., Ehlers, F., Hirsch, B., & Gratl, G. (2007). HIS-Monitor: An approach to assess the quality of information processing in hospitals. *International Journal of Medical Informatics*, *76*(2-3), 216–225. doi:10.1016/j.ijmedinf.2006.05.004

Borum, F., & Christiansen, J. K. (2006). Actors and structure in IS projects: What makes implementation happen? *Scandinavian Journal of Management*, *22*(3), 213–237. doi:10.1016/j.scaman.2006.10.006

Braa, K., & Ogrim, L. (1995). Critical view of the application of the Iso standard for quality assurance. *Information Systems Journal*, *5*(4), 253–269. doi:10.1111/j.1365-2575.1995.tb00098.x

Burke, D. E., & Menachemi, N. (2004). Opening the black box: Measuring hospital information technology capability. *Health Care Management Review*, *29*(3), 207–217.

Chang, J. C. J., & King, W. R. (2005). Measuring the performance of information systems: A functional scorecard. *Journal of Management Information Systems*, *22*(1), 85–115.

Chaudhry, B., Wang, J., Wu, S., Maglione, M., Mojica, W., & Roth, E. (2006). Systematic review: Impact of health information technology on quality, efficiency, and costs of medical care. *Annals of Internal Medicine*, *144*(10), 742–752.

de Keizer, N., & Ammenwerth, E. (2005). Trends in evaluation research 1982-2002: A study on how the quality of IT evaluation studies develop. *Studies in Health Technology and Informatics*, *116*, 581–586.

DeLone, W. H., & McLean, E. R. (2003). The DeLone and McLean model of information systems success: A ten-year update. *Journal of Management Information Systems*, *19*(4), 9–30.

Donahue, K. T., & Vanostenberg, P. (2000). Joint commission international accreditation: Relationship to four models of evaluation. *International Journal for Quality in Health Care*, *12*(3), 243–246. doi:10.1093/intqhc/12.3.243

Eccles, R. G. (1991). The performance-measurement manifesto. *Harvard Business Review*, *69*(1), 131–137.

EFQM. (2006). *The EFQM excellence award*. Retrieved on October 10, 2007, from http://www.efqm.org/2006

ISACA. (2007). *COBIT: Control objectives for information and related technology*. Retrieved on November 11, 2007, from www.isaca.org/cobit/

ISO-20000. (2007). *ISO 20000*. Retrieved on August 13, 2007, from http://en.wikipedia.org/wiki/ISO/IEC_20000

ISO-9126. (2007). *The ISO 9126 standard*. Retrieved on August 13, 2007, from http://en.wikipedia.org/wiki/ISO_9126

Jayasuriya, R. (1997). Evaluating health information systems: An assessment of frameworks. *Australian Health Review*, *20*(3), 68–85.

Kaushal, R., Barker, K. N., & Bates, D. W. (2001). How can information technology improve patient safety and reduce medication errors in children's healthcare? *Archives of Pediatrics & Adolescent Medicine*, *155*(9), 1002–1007.

Li, M. F., & Ye, L. R. (1999). Information technology and firm performance: Linking with environmental, strategic, and managerial contexts. *Information & Management*, *35*(1), 43–51. doi:10.1016/S0378-7206(98)00075-5

Office of Government Commerce. (2007). *IT infrastructure library (ITIL), Office of government commerce*. Retrieved on August 13, 2007, from http://www.ogc.gov.uk/guidance_itil_4672.asp

Ozkan, S. (2004) Information systems quality vs. software quality: A process based assessment model within the context of organisation. In *Proceedings of the 9th Association of Information Management Conference, AIM2004*, Paris, France.

Ozkan, S. (2005). All together now: Merging information technology quality and other business performance management frameworks. *Cutter IT Journal The Journal of Information Technology Management*, *18*(3), 16–20.

Ozkan, S. (2006) *PB-ISAM: A process-based framework for information systems effectiveness assessment in organisational contexts*. Unpublished doctoral dissertation, Middle East Technical University, Turkey.

Ozkan, S., & Bilgen, S. (2003). Notes towards IS assessment: A comparison of two models within the context of the Internet. In *Proceedings of the IADIS International Conference WWW/Internet 2003* (Vol. 2, pp.1215-1219), Faro, Portugal.

Ozkan, S., Hackney, R., & Bilgen, S. (2007). Process based information systems for international business evaluation. *Journal of Enterprise Information Management*, *20*(6), 700–725. doi:10.1108/17410390710830736

Perera, R., Dowell, T., Crampton, P., & Kearns, R. (2007). Panning for gold: An evidence-based tool for assessment of performance indicators in primary healthcare. *Health Policy (Amsterdam)*, *80*(2), 314–327. doi:10.1016/j.healthpol.2006.03.011

Q-rec European Quality Labelling and Certification of Electronic Health Record Systems (EHRs). Retrieved on August 13, 2007, from: http://www.eurorec.org/projects/qrec.cfm

Schroeder, R. G., Linderman, K., Liedtke, C., & Choo, A. S. (2007). Six sigma: Definition and underlying theory. *Journal of Operations Management*.

Shortliffe, E. H., & Cimino, J. J. (Eds.). (2006). *Biomedical informatics computer applications in healthcare and biomedicine*. Springer-Verlag.

Software Engineering Institute. *CMMI: Capability maturity model integrated*. Retrieved on November 1, 2007, from www.sei.cmu.edu/cmmi/

Software Quality Institute GU. *SPICE software process improvement and capability determination*. Retrieved on August 13, 2007, from: http://www.sqi.gu.edu.au/spice/

Willcocks, L., & Lester, S. (1993, May 17-19). How do organizations evaluate and control information-systems investments-recent UK survey evidence. In D. Avison, et al. (Eds.), *Human, organizational, and social dimensions of IS development. Proceedings of the IFIPWG8.2 Working Group Conference,* Noordwijkerhout, Netherlands. Amsterdam: Elsevier North Holland.

KEY TERMS AND DEFINITIONS

Information systems effectiveness: Refers to the systematic approach needs to be taken when evaluating success of an information system.

Information systems evaluation: It is the process that contains several criteria through which key areas of the proposed information systems will be evaluated.

Information systems resources: The resources of the information systems refer to people hardware software and data.

Information technology management: According to Michael K. Badawy Information Technology Management is concerned with exploring and understanding **IT** as a corporate resource that determines both the strategic and operational capabilities of the firm in designing and developing products and services for maximum customer satisfaction, corporate productivity, profitability and competitiveness

APPENDIX

Process: P1 Definition of the IS organisation and relationships

Component of PRISE: People

Questions:

1. Does the IS organisation communicate its goals and results at all levels?
2. Is the IS organised to be involved in all decision processes, respond to key organisation initiatives and focus on all corporate automation needs?
3. Is the IS organisational model aligned with the organisation functions and does is adapt rapidly to changes in the organisation environment?
4. Through encouraging and promoting the taking of responsibility, does the IS organisation develop and grow individuals and heightens collaboration?
5. Are there clear command and control processes, with segregation where needed, specialisation where required and empowerment where beneficial?
6. Does the IS organisation properly position security, internal control and quality functions, and adequately balances supervision and empowerment?
7. Is the IS organisation flexible to adapt to risk and crisis situations and moves from a hierarchical model, when all is well, to a team-based model when pressure mounts, empowering individuals in times of crisis?
8. Can a strong management control be established over the outsourcing of IS services, with a clear policy, and awareness of the total cost of outsourcing?
9. Are essential IS functions explicitly identified in the organisation model, with clearly specified roles and responsibilities?

Process: P2 Education and training of users

Component of PRISE: People

Questions:

1. Is there a comprehensive education and training program, focused on individual and corporate needs in place?
2. Are these education and training programs supported by budgets, resources, facilities and trainers?
3. Are training and education critical components of the employee career paths?
4. Do employees and managers identify and document training needs?
5. Is the needed training provided in a timely manner?
6. Is there senior management support to ensure that employees perform their duties in an ethical and secure manner?
7. Do employees receive system security practices training in protecting against harm from failures affecting availability, confidentiality and integrity?

8. Does the corporate policy require that all employees receive a basic training program covering ethical conducts, system security practices and permitted use of IS resources?
9. Is there management acceptance that training costs are investments in lowering the total costs of technology ownership?

Process: P3 Provision of assistance and advice to IS users

Component of PRISE: People

Questions:

1. Are there up-to-date and easily accessible Frequently Asked Questions (FAQs) and their answers available?
2. Do knowledgeable and customer-oriented support staff resolve problems in close co-operation with the problem management staff?
3. Are all user inquiries consistently and thoroughly registered by the help desk?
4. Are the user inquiries that cannot be resolved in a timely manner appropriately escalated?
5. Is the clearance of user inquiries monitored?
6. Are user questions resolved in a timely manner?
7. Are those user inquiries that cannot be resolved in a timely manner investigated and acted upon?
8. Does the management monitor trends to identify root causes in a proactive manner and follow up with analysis and the development of sustainable solutions?
9. Are there corporate policies and programs defined for training users in technology use and security practices?
10. Is there management awareness of the cost of support services and user downtime and of the need to take action on root-cause issues?
11. Are support costs charged back to the business using simple tools and clear policies?

Process: P4 IS Interactions

Component of PRISE: Resources

Questions:

1. Are communication with the customers done via the Internet medium ?
2. Is there an extensive use of the other information systems web pages?
3. Is there an extensive interaction with the customer via the Internet?
4. Is the use of other information systems documented?
5. Is there an extensive use of similar information systems for improvement?

Process: P5 Configuration Management

Component of PRISE: Resources

Questions:

1. Are there owners established for all configuration elements who responsible for maintaining the inventory and controlling change?
2. Is the configuration information maintained and accessible, based on up-to-date inventories and a comprehensive naming convention?
3. Is there an appropriate software library structure in place, addressing the needs of development, testing and production environments?
4. Is there a release management policy and a system to enforce it?
5. Are record keeping and physical custody duties kept segregated?
6. Is there an integration with procurement and change management processes?
7. Are vendor catalogues and configuration aligned?
8. Do configuration baselines exist, identifying the minimum standard components and integration requirements, consistency and integration criteria?
9. Is there an automatic configuration detection and checking mechanism available?
10. Is there an automatic distribution and upgrade process implemented?
11. Is there zero tolerance for illegal software?

Process: P6 Performance and capacity management

Component of PRISE: Resources

Questions:

1. Are the performance and capacity implications of IS service requirements for all critical business processes clearly understood?
2. Are the performance requirements included in all IS development and maintenance projects?
3. Are the capacity and performance issues dealt with at all appropriate stages in the system acquisition and deployment methodology?
4. Is the technology infrastructure regularly reviewed to take advantage of cost/performance ratios and enable the acquisition of resources providing maximum performance capability at the lowest price?
5. Are skills and tools available to analyse current and forecasted capacity?
6. Is the current and projected capacity and usage information made available to users and management in an understandable and usable form?

Process: P7 Operations management

Component of PRISE: Resources

Questions:

1. Are operations instructions well defined, according to standards, and with provision of clear cut-off and restart points?

2. Is there a high degree of standardisation of operations?
3. Is there close co-ordination with related processes, including problem and change management functions, and availability and continuity management?
4. Is there a high degree of automation of operations tasks?
5. Are operational processes re-engineered to work effectively with automated tools?
6. Is rationalisation and standardisation of systems management tools implemented?
7. Is the input and output handling, as much as possible, confined to the users?
8. Are changes to job schedules strictly controlled?
9. Are there strict acceptance procedures for new job schedules, including documentation delivered?
10. Are there preventive maintenance schemes in place?
11. Are the service support agreements with vendors defined and enforced?
12. Are there clear and concise detection, inspection and escalation procedures established?

Process: P8 Continuous Service

Component of PRISE: Services and Benefits

Questions:

1. Is there a no-break power system installed and regularly tested?
2. Are potential availability risks proactively detected and addressed?
3. Are the critical infrastructure components identified and continuously monitored?
4. Is the continuous service provision a continuum of advance capacity planning, acquisition of high-availability components, needed redundancy, existence of tested contingency plans and the removal of single points of failure?
5. Is there a procedural action taken on the lessons learned from actual downtime incidents and test executions of contingency plans?
6. Is the availability requirements analysis performed regularly?
7. Are the agreements used to raise awareness and increase cooperation with suppliers for continuity needs?
8. Is the escalation process clearly understood and based on a classification of availability incidents?
9. Are the costs of interrupted service specified and quantified where possible, providing the motivation to develop appropriate plans and arrange for contingency facilities?

Process: P9 Change Management

Component of PRISE: Services and Benefits

Questions:

1. Are change policies clear and known and are they rigorously and systematically implemented?
2. Is the change management strongly integrated with release management and is it an integral part of configuration management?
3. Is there a rapid and efficient planning, approval and initiation process covering identification, categorisation, impact assessment and prioritisation of changes?
4. Are there automated process tools available to support workflow definition, pro-forma workplans, approval templates, testing, configuration and distribution?
5. Are there expedient and comprehensive acceptance test procedures applied prior to making the change?
6. Is there a system for tracking and following individual changes, as well as change process parameters, in place?
7. Is there a formal process for hand-over from development to operations defined?
8. Do the changes take the impact on capacity and performance requirements into account?
9. Is there a complete and up-to-date application and configuration documentation available?
10. Is there a process in place to manage co-ordination between changes, recognising interdependencies?
11. Is there an independent process for verification of the success or failure of change implemented?
12. Is there segregation of duties between development and production?

Process: P10 Monitoring services

Component of PRISE: Services and Benefits

Questions:

1. Are there useful, accurate and timely management reports available?
2. Have the processes been defined and understood what the targets are and how to achieve them?
3. Do the measurements of IS performance include financial, operational, customer and organisational learning criteria that ensure alignment with organisation-wide goals?
4. Are there clearly understood and communicated process objectives?
5. Is there a framework established for defining and implementing IS management reporting requirements?
6. Is there a knowledge base of historical performance established?
7. Is there a consistent application of the right limited number of performance indicators?
8. Is there an increased number of process improvement opportunities detected and acted upon?
9. Is the management satisfied with performance reporting?
10. Is there reduced number of outstanding process deficiencies observed?

This work was previously published in Handbook of Research on Advances in Health Informatics and Electronic Healthcare Applications: Global Adoption and Impact of Information Communication Technologies, edited by K. Khoumbati; Y.K. Dwivedi; A. Srivastava; B. Lal, pp. 74-90, copyright 2010 by Medical Information Science Reference (an imprint of IGI Global).

Chapter 1.24

A Review of Recent Contribution in Agent Based Healthcare Modeling

Simerjit Gill
University of Regina, and TRLabs Regina, Canada

Raman Paranjape
University of Regina, and TRLabs Regina, Canada

ABSTRACT

This chapter reviews and summarizes eight selected paper in the area of agent-based healthcare systems. The objective of the summaries is to provide an overview of recent research work in the area and to examine the characteristics of agent-based healthcare applications. The chapter also briefly discusses reasons for adopting agent-based simulation and modeling over traditional modeling techniques.

INTRODUCTION

Agent-based modeling and simulation is a modern approach to model complex systems. Agent-based simulation systems are comprised of autonomous agents that interact with each other to create a working dynamic model of a real world system. Today, applications of this new paradigm of modeling and simulation can be found in variety of domains ranging from modeling the stock market and supply chains behaviours to modeling the complexities of the human immune system and predicting the spread of epidemics (Macal & North, 2006). Traditional modeling techniques are no longer sufficient in dealing with the complexities of real world systems as they are becoming increasingly more sophisticated. Software agents can break a large problem or task to smaller tasks and distributes the work over number of agents to provide an optimal solution. The operation of healthcare is complex as it involves large numbers of staff and other resources that work together to deliver healthcare services to patients. The agent-based modeling and simulation approach is increasingly attracting researchers who exploit the capability of agent system in order to explain the complex behaviour of healthcare systems.

Software agents can be defined in numerous ways. Each definition varies depending on the

DOI: 10.4018/978-1-60566-772-0.ch003

context and the application. However the main attributes are common to all the definitions. The common attributes of software agents are: autonomy, pro-activity/re-activity, communicativity, collaborative problem solving and mobility. The mobility attribute refers to the ability of an agent to travel across different platforms to achieve its goal. Autonomy pertains to the ability of an agent to act autonomously with limited or no user interaction and to completely represent an object or entity. Pro-activity/re-activity implies the ability to react to the environment and adapt its behaviour accordingly. Communicativity refers to the capability of agents to exchange messages between each other and with the external users and systems. The collaborative problem solving attribute pertains to the ability of agent to collaborate and work together to accomplish a common goal which no single agent is able to attain on its own.

Software agents should only be used to develop applications for systems which require some or all of the above attributes of agents. Most of these attributes are required in order to create effective and accurate simulations and models of healthcare systems. In this chapter, we review and summarize eight recent papers to provide an overview of the state of research in agent-based healthcare modeling system. Agent-based modeling and simulation is a relatively new approach in healthcare modeling. We observe three common themes in the work presented in this chapter - these are: (i) support for patients and medical professionals; (ii) effective and efficient communication between health professionals; and (iii) optimization of healthcare delivery services.

We provide a brief introduction on each selected paper to give a high level picture of the content of the summaries before proceeding to the actual summaries.

A Multi-Agent Approach to the Design of an E-Medicine System

This paper proposes a multi-agent based framework for the development of an e-medicine system. E-medicine integrates information communication technology with medical technology to deliver healthcare to geographically distributed areas. The paper presents a case study on telemedicine for diabetes to illustrate the development of an e-medicine system.

Building Agent Based Corporate Information Systems: An Application to Medicine

In this paper, author proposes an agent-based framework for supporting collaborative work among human and software agents. The proposed framework is applied in the field of telemedicine to build complex and cooperative decision support systems (DSS) within the context.

A Framework for Building Cooperative Software Agents in Medical Applications

This paper focuses on improving the cooperation and interoperability among different health care professionals engaged in the process of delivering health care services with the aid of software agent technology. This paper experiments the management of patients affected by acute myeloid leukemia (AML) with the help of developed prototype.

HealthSim: An Agent-Based Model for Simulating Health Care Delivery

This paper introduces an agent-based simulation model, called HealthSim, which facilitates users understand various health care delivery issues in a hospital environment through simulations. The system is primarily designed for managers and planners of hospitals who want to identify the effectiveness and efficiency of health care services that are being provided to patients. HealthSim has a potential to address several aspects of health care operations that deals with procurement, distribution, maintenance, and replacement of medical equipment and personnel. It also helps in the management of the details of medical operation.

Mobile Software Agents for the Support of Chronic Illness: A Case Study in Diabetes Management for Rural Areas

This paper presents a framework for managing diabetes particularly in rural areas using mobile agents. This paper presents a framework which has a potential to manage and control diabetes in remote areas that lacks diabetic specialists.

Nature-Inspired Planner Agent for Health Care

This paper presents an agent-based human thinking reasoning model based on past experience. The main purpose of the development of this model is to facilitate elderly people with disabilities, in particular with Alzheimer.

Mobile Agent-Based Framework for Healthcare Knowledge Management System

This paper presents a framework for effective management of information and knowledge in healthcare sector using mobile agents. Authors sense the necessity of transposing stored healthcare data and information into knowledge so that it can serve as a facilitator for making critical decisions during healthcare operations. This paper presents various components that can work together to create an effective knowledge management system (KMS).

A Multi-Agent Security Framework for e-Health Services

This paper presents a multi-agent security framework for e-health services. It describes and categorizes various type of communication into different levels that takes place among health care professionals. Subsequently, the paper identifies security requirements associated to each level of communication and introduces a multi-agent based security approach for e-health services.

REVIEW

Title: A Multi-agent Approach to the Design of an E-medicine System

Authors: Jiang Tian, Huaglory Tianfield

Source: Multiagent system technologies. German conference, Erfurt, ALLEMAGNE (22/09/2003) 2003, vol. 2831, pp. 85-94

Publisher: Springer-Verlag Berlin Heidelberg

This paper proposes a multi-agent based framework for the development of an e-medicine system. E-medicine integrates information communication technology with medical technology to deliver healthcare to geographically distributed areas. The paper first explores the functional and non-functional requirements of e-medicine system and then presents a structural design of agent-based e-medicine system. In the end, the paper presents a case study on telemedicine for diabetes to illustrate the development of e-medicine system.

The four basic functions of medicine presented in the paper are disease prevention, disease diagnosis, disease treatment, and health consultation. According to these functions, authors have divided requirements of an e-medicine system into functional and non-functional requirements. Distant medical services such as telemedicine, e-healthcare, teleconsultation; distant clinical practices such as telesurgery, telementoring, and training patient; establishing medical databases and exchanging medical information are included in the functional requirements of e-medicine systems. On the other hand, security and privacy, efficiency, convenience and reusability are considered as non-functional requirements.

This paper adopts a multi-agent approach to align the complex requirements with the design of an e-medicine system. Design itself is broken into two parts: design of agents and design of multi-agent society. Designing an agent includes the proper identification of roles and responsibilities of each agent in e-medicine systems. And, design of multi-agent society focuses on the architectural design of multi-agent system and interactions between the agents. Authors believe that the general set of requirements provided in the paper can serve as a reference guide to build any kind of e-medicine system.

The proposed framework of an e-medicine system involves a large number of agents. Each agent carries out specific task and may interact with other agents to complete the assigned task. Agents in the e-medicine systems are categorized into three groups: the Control group, the Implementation group, and the Interface group. The interface group consists of agents responsible for providing the user with graphical user interface, initiating a search, or showing the results of a query to the user. The interface group may contain interface agent, search agent, or any other agent responsible for keeping the link between patient and other e-medicine systems. The second group, which is the control group, contains the controller agent, administration agent and department agent. The controller agent controls the whole e-medicine system and resolves the conflict among agents. The administration agent assigns tasks and helps cooperate between departments and agents. The department agent has knowledge of certain medical department and manages the internal department affairs. The third group is the implementation group. The implementation group implements the monitoring, diagnosis, therapy, consultation, and archival function to achieve the goals. The implementation group contains most number of agents namely the monitoring agent, data processing agent, diagnosis agent, therapy agent, archival agent, education agent, decision support agent, training agent, consultation agent, surgery agent, and database wrapper agent.

The interaction in e-medicine systems is divided into the internal model and external model. The internal model is responsible for internal communication while external for external communication. Control group, implementation group, and interface group carry out internal communication. External communication takes place when agents belonging to the implementation group and interface group interact with an external environment.

To illustrate the framework proposed for e-medicine systems, the paper present a case study of telemedicine for diabetes. The Telemedicine system provides diabetic patients with real-time health monitoring and can also provide immediate therapy. After a complete requirement analysis of telemedicine for diabetes, the paper listed down several services that a telemedicine system must provide on a daily basis. These services are visiting the patient and providing individual therapy, monitoring the patients in real time and processing the monitored data immediately, diagnosing the patients in term of monitored data and making a proper therapy for the diabetic patients, training the diabetic patients to monitor themselves and educating the physicians to update their skills, maintaining patients record/database, providing consultations to patients and the system must have a functionality to interact with other systems in e-medicine systems.

The diabetic telemedicine system makes use of several agents in order to fulfill the identified requirements. Agents in the implementation group are monitoring agent, data processing agent, diagnosis agent, therapy agent, consultation agent, decision support agent, training agent, archival agent, department agent, and interface agent. Each of them is responsible for certain task and interacts with other agents. The monitoring agent is responsible for real time monitoring of diabetic patient and transmits the data to the data Processing agent. The data processing agent integrate the data and process it for diagnosis agent. The diagnosis agent plays an important role in implementation group as diagnosis is a complex process. It examines the situation and makes and accurate judgement for the patient. The diagnosis agent not only interacts with other agents in implementation group but also communicate with decision support agent, clinic agent, education agent, and consultation agent. Depending on the decision made by the diagnosis agent, the therapy agent determines a proper therapy method for the diabetic patient. The consultation agent provides consultation to the enquiry of patients. The decision support agent, as name implies, provide decision support. Both consultation agent and decision support agent interacts with diagnosis agent. The Training agent trains patient by giving instructions on the proper intake of medicine and self care. The Archival agent maintains the patient record and used therapy methods. It encrypts the information and links it to the medical database. Control group and Interface group, contains department agent and interface agent respectively. Department agent is responsible for the control of the telemedicine system while interface agent provides the interface with search services and information services.

This paper presents a multi-agent approach to the design of an e-medicine system. The paper examines various functional and non-functional requirements that must be considered in e-medicine system. Based on that, it presents a general structural design of an e-medicine system composed of many software agents. To illustrate the application of the system in the real world scenario, the paper adapts a general design of an e-medicine system to a more specific diabetic telemedicine system.

Title: Building Agent Based Corporate Information Systems: An Application to Medicine

Author: Tung Bui

Source: European Journal of Operational Research 122 (2000) 243-257

Publisher: Elsevier

In this paper, author proposes an agent-based framework for supporting collaborative work among human and software agents. Bui's (2000) framework enables geographically dispersed organizations to distribute the task across the internet and work collaboratively. The system is embedded with the intelligent software agents that are capable of making decisions facilitating the implementation of complex and distributed decision making process. The proposed framework is applied in the field of telemedicine to build complex and cooperative decision support systems (DSS) within the context. Telemedicine is an application of clinical medicine where medical information is transferred via telephone, the internet or other networks for the purpose of consulting, and sometimes remote medical procedures or examinations (AbsoluteAstronomy, 2009).

The paper presented taxonomy of an agent characteristics and the proposed taxonomy can facilitate in identifying different types of agents to support different type of decision tasks. Furthermore, this paper proposed a development lifecycle for building agent-based systems. Author sensed the need of adopting a new approach for the development of an agent-based system. The new methodology supports a two-tier approach to design a given system. The first tier functions as an assignment model which is primarily responsible for searching, identifying and selecting the agent(s) that are believed to be most appropriate to perform required tasks. It covers the first three phases of the lifecycle. The second tier manages a coordination and collaboration strategy for all the participating agents to work together and makes the last two phases of the lifecycle.

The first phase of a software-agent development lifecycle begins with analyzing the problem task. It consists of all the elements necessary for examining the problem task such as decision support requirements and detailed breakdown of all decision processes. The decision processes are collections of partially ordered steps that are required to reach a particular goal. The next phase involves searching of eligible agents in an iterative manner or creation of new agents that meets the requirements determined in the preceding phase. Agents are selected on the basis of their competence, reliability, and cost to perform the given task. The third phase specifies agent's behaviour. Instructions are pre-set for showing identifications, following protocols and utilizing web-resources in a cost effective fashion. The last phase involves assigning appropriate tasks to selected agents. The execution plan to solve the entire problem is sketched in this phase.

The proposed framework is adopted to build a web-enabled telemedicine. Referring to the first phase of software-agent development life cycle where the problem task is analyzed, problem solving associated to the healthcare is categorized into four processes. The processes are (i) medical examination, (ii) diagonosis, (iii) treatment recommendation (Dx), and (iv) treatment plan/prognosis (Tx). In the real world scenario, people involved in the telemedicine are patients, advice nurse, doctors on duty, and other specialists. And in the proposed agent-based web-enabled telemedicine, duties of above people are supported by software agents named as (i) the Exam Manager, (ii) Dx/Tx Manager, (iii) Session Manager, (iv) Speciality Problem Solver, and (v) Negotiation Manager.

In this experimental set up, the Exam Manager gathers the subjective data such as patient's description of symptoms, feelings and other biographical data through web form via internet at the patient site. The data may also be collected through sensors/health monitoring equipments as well. The data is then passed down to the Dx/Tx Manager. The Dx/Tx Manager examines the received patient data and decides which Speciality Problem Solver should take part in generating treatment recommendations. Once all Speciality Problem Solvers are identified and selected, the Session Manager initiates the communication and administers it throughout the session. Problem can be executed, independently or interactively with a human specialist, by the Speciality Problem Solvers to come up with recommendations. Recommendations made by various Solvers are then received by the Negotiation Manager and the Negotiation Manager facilitates in reaching a single consensual solution. Subsequently, the solution is transmitted back to the Dx/Tx Manager and then presented to the field provider through a human interface.

The next phase of the software agent development lifecycle decides whether or not a software agent should be developed to implement that process and if so then selects which would be the most appropriate profile of that agent. The selection of agents is based on the cost-benefit analyzes. Profile of each agent is created through examining each of the agents attributes and gives the most suitable value for it. Intelligence, Mobility, Lifetime, Interaction, Task-specificity, and Initiative are the attributes of agents. Once agent profile is determined, agents are ready to be embedded into workflow.

According to Bui (2000), there are lot of benefits of the proposed system. The biggest benefit is that the data can be collected seamlessly and cost effectively with relatively low investment of the internet infrastructure. Internet provides adequate communication support to carry out the task of medical information system connectivity. Other benefits include that the system has a potential to provide anytime anywhere healthcare as the patient is always in touch with his/her primary care provider no matter where in the world he/she is.

Title: A Framework for Building Cooperative Software Agents in medical applications

Authors: Lanzola G.; Gatti L.; Falasconi S.; Stefanelli M.

Source: Artificial Intelligence in Medicine, Vol. 16, Number 3, July 1999, pp. 223-249(27)

Publisher: Elsevier

This paper focuses on improving the cooperation and interoperability among different health care professionals engaged in the process of delivering health care services with the aid of software agent technology. It is evident that during the course of medical process, a variety of information and knowledge traverses among number of health care staff. This information may range from a simple biographical data of a patient to sensitive contagious disease information. Although there might be different communication channels available to heath care workers, the primary medium of conveying information is typically through phone calls or face-to-face talks. Frequent interruption is very common in this sort of interactions. The interruption may occur in any form such as if a doctor is attending a patient and nurse calls him and asks him to urgently attend another patient which is in a serious condition, the doctor may pass the health related information of the current patient to a nurse and advices her to take necessary steps for the betterment of the patient. Since, it is an emergency situation, a nurse may not be able to comprehend all the information bombarded by the doctor at her and there is a very good chance that a nurse may make wrong assumptions. Authors believe that this may cause serious consequences if some sensitive information is lost or misinterpreted. Such situations arises primarily because of the intrinsic nature of hospitals which are highly event driven environments where professionals are required to regularly move across several departments and sometimes even off campus.

As described in the paper, the process of delivering health care services involves large number of people like clinicians, nurses, laboratorists, etc. and features a high distribution of expertise, knowledge and physical resources. Thus the effectiveness and proficiency strictly depend both on the skills of the professionals involved as well as on the level of cooperation and coordination reached by them within the clinical context. As such authors insist that there is a need of improvement in the clinical communication infrastructure. A careful deployment of the information technology will have a great impact on improving the interoperability among people working together in the health care settings and minimizes the problems associated to it. In this paper, an information technology tool called Software Agent has been proposed to achieve effective and efficient flow of information among health care professionals.

Software Agents have the tendency to act on behalf of some entities and make intelligent decisions based on the working environment. They may also interact with each other to achieve their goal. This paper tends to simulate the real world interaction of different health care professionals through Cooperative Software Agents. These Agents are equipped with the Task Specific Knowledge and Cooperation Knowledge. The Task Specific Knowledge handles information required to achieve a certain task. For instance, if it is an optometrist agent then it is responsible for providing instructions pertaining to eye related illness. The Cooperation Knowledge, on the other hand, tells an agent how to cooperate with other agents to perform a specific task. It also constitutes Agent Communication Language module which implements communication protocol and administers agent-interaction over the network. Each Agent is linked to the Knowledge-Based System. The Knowledge-Based System is an information repository which has a reference to a database of knowledge of any particular subject. Thus, in the given computational model one section is concerned with the interconnection among Software Agents and enabling of the exchange of information and knowledge among them through a suitable Agent Communication Language (ACL), while other one addresses the problem of effectively modelling and representing cooperation knowledge within each Agent. Authors have followed KQML specifications to develop a tool that has a tendency to achieve a high-level communication between Software Agents. KQML is declarative, syntactically simple, extensible and easily readable by humans. This framework facilitates in developing a generic communication model which could be coupled with pre-existing legacy systems or other available applications, thereby helping them converting into Software Agents while preserving much of their internal coding and functionality.

The paper also states that even though ACL is powerful tool that has a capacity to provide a solid foundation for exchanging information and knowledge among agents, the ability to interoperate with other agents and to exploit some kind of social behaviour demonstrated by each agent in the environment cannot be accomplished by the language alone. Authors sensed the need of enhancing task specific knowledge already available within agents with a set of suitable primitives that should be able to contour their behaviour to be adopted while interoperating with others.

This paper experiments the management of patients affected by acute myeloid leukemia (AML) with the help of developed prototype. Several Software Agents were implemented tailoring the specific need of a particular health care professional and enforcing his/her cooperation with others involved in the treatment of a patient suffering from AML. Participating agents in this experimental set up are the General Practioner, Hospital Administration, Hematologist, Nurse, Donor Bank, BMT Unit, and Oncologist. These agents interact with each other and may get multiple task requests from different agents at a given point of time. Agent allocates resources to different task on the basis of its importance and priority. The information collected by these agents in the course of this process is stored in the database and can be fetched for a later use.

This paper provides a framework that has a potential to achieve an effective and efficient communication among agents. Old legacy systems and other standard applications utilized by Hospitals may be converted to agents following the given framework. Moreover, it also opens the door for many other researchers to exercise the idea and develop agent based information system for hospitals for their specific needs.

Title: HealthSim: An Agent-Based Model for Simulating Health Care Delivery

Authors: John H. Christiansen and A. Peter Campbell

Source: Argonne National Laboratory, Chicago, Illinois

This paper introduces an agent-based simulation model, called HealthSim, which facilitates users understand various health care delivery issues in a hospital environment through simulations. The system is primarily designed for managers and planners of hospitals who want to identify the effectiveness and efficiency of health care services that are being provided to patients. HealthSim is flexible enough to be deployed in a small to large scaled organizations. It can be used in a small department in a hospital, for a single-practioner surgery, or in a major medical centre with hundreds of thousands of patient each year.

HealthSim has a potential to address several aspects of health care operations that deals with procurement, distribution, maintenance, and replacement of medical equipment and personnel. It also helps in the management of the details of medical operation.

HealthSim runs various models with thousands of agents in a single simulation to understand the relation of different dynamic behaviours associated to health care. These behaviours may include human physiological processes such as beginning and progression of disease, development of signs and symptoms, and effects of interventions; human cognitive behaviour such as response to symptoms and making and keeping appointments; clinical/logistical processes such as clinical practice guidelines, office procedures and personnel policies; and medical monitoring equipment response.

The system has a potential to address various health care management issues depending on type of simulation performed. For instance, the response to various perturbations in health care delivery service can be investigated by simulating the inpatient and outpatient loads for a hospital unit within a health care system. Inpatient is a patient who is admitted to the hospital and stays overnight in hospital for quite some time depending on the illness. Outpatient on the other hand is not hospitalized overnight but regularly visits a doctor for diagnosis or treatment. In this simulation, the main inputs are service provider's schedules, outpatient visit rates for each type of visit, inpatient visit rates for each diagnostic related group (DRG), and call center operator schedules. The main outputs are appointment wait times, average phone waits, costs, revenues and many more. These outputs help the management in making critical decisions. The system can also be used to examine the effects of new technology or equipment, efficiency of new treatment paths, cost effectiveness of new drugs, and consequences of changes to management procedures or policies.

HealthSim accepts number of adjustable inputs from the user to perform the simulation providing a great deal of flexibility. The input and output items of the system can be easily replaced, added or deleted with no or minimal effect on the overall simulation structure. The paper has listed down several results that can be obtained from the simulation. Few of them are average appointment length (in minutes) by department, average appointment wait (in days) by department, admittance trends report, average length of stay by DRG, average phone waits (in seconds), inpatient bed-days per month by DRG, hospital financial report by month and year, daily number of beds occupied, and number of appointment by department.

HealthSim is an agent-based framework that is based on the Dynamic Information Architecture System (DIAS) and the Framework for Addressing Cooperative Extended Transactions (FACET). Both DIAS and FACET are developed at Argonne National Laboratory (ANL). HealthSim is largely implemented in SmallTalk with some of key functionalities coded in C++. The system runs on Unix or Windows platform and may be configured to run in a distributed environment.

DIAS executes time-ordered event simulations where event objects and associated data structures are distributed to the appropriate objects. All event posting are managed by the DIAS global even manager. Each object response to the even posted by itself or by another object. DIAS object class definition supports abstraction where abstraction description of object behaviour is given with no implementation details. As it is indicated in the paper, DIAS is a general framework for building simulation systems which consists of many models. In DIAS, objects are interlinked to other objects appropriately in the system during their activation depending on the state of the simulation. These factors make DIAS ideal for simulating the complex operations involved in health care delivery.

In HealthSim, models of social behaviour patterns are constructed with the aid of FACET. It is composed of several software objects that can be used to build and run complicated and cooperative behaviour models of agents. In FACET, complex operations are broken into several courses of actions (COA's), and these courses of actions are further sub-divided into COA steps. Each step of COA represents an action or series of actions which are tied to some constraints and negotiate with participating entities for their cooperation. In case the condition does not meet, COA step is broken down further until all the conditions are met.

Both DIAS and FACET are incorporated into HealthSim. There are various Objects and Processes that are modeled in HealthSim. The general classes of the objects include Persons such as patients, doctors, nurses, administrators etc; Organizations such as different medical departments, Infrastructure such as rooms, utilities etc; any equipments either medical, safety or administrative; medicines and supplies; and financial and usage records. The classes of the processes that are modelled in the system are normal physiological processes in each patient, disease processes in each patient, diagnostic equipment response and behaviour pattern models for patients, staff, and organizations. Models of normal physiological processes and pathophysiology behaviour are embedded in Person objects. Pathophysiology is the study of the disturbance of normal mechanical, physical, and biochemical functions normally caused by a disease (NationMaster, 2009). Sofware Agents in HealthSim represent patients, healthcare workers of all type, administrative/management personnel and hospital departments. Each patient agent has a detailed physiological model and a set of disease model. Disease model is heavily based on the differential-equation-solver model that simulates the beginning and progression of the disease, development of signs and symptoms of the disease, and physiological response to interventions. Furthermore, the progression of any existing disease will alter the physiological state for other disease as the disease models are linked through common risk factors.

HealthSim is a flexible event simulation tool which contains numerous models and agents to represent different entities involved in the health care delivery mechanism. Authors believes that the system can be used for various kinds of applications ranging from small work flow involved in a single surgery to the management of complex operations in large hospitals. The tool can be very useful to executives and administrator of medical centres in various decision-making processes.

Title: Mobile Software Agents for the Support of Chronic Illness: A Case Study in Diabetes Management for Rural Areas

Authors: Tarapornsin, V.; Ray, P.; Chowdhury, A.

Source: e-Health Networking, Applications and Services, 2006. HEALTHCOM 2006. 8th International Conference on Volume, Issue, 17-19 Aug. 2006 Page(s): 72 – 77

This paper presents a framework for managing diabetes particularly in rural areas using mobile agents. As stated in the paper, diabetes is one of the serious and most widely spread diseases. Approximately 150 million people are affected with this chronic illness and their numbers are growing rapidly. Diabetes can result in a variety of complications if it is not properly managed or left untreated. These complications include heart disease, kidney disease, eye disease, impotence and nerve damage. Diabetes can be managed by doing exercise, eating healthy food, measuring blood glucose levels on a regular basis, and having a regular consultation with the doctor. According to authors, most patients in rural areas do not have the advantage of having their blood test regularly due to lack of facilities and diabetic specialists. This factor lowers the treatment of diabetes in rural areas. This paper explores the possibility of mobile agents to address this problem assuming the availability of internet in rural side.

The paper points out several efforts in the past to control diabetes by designing tools and models for monitoring and managing diabetic patients. Among them are “Fit for Life” programme by Ministry of Health in Singapore, “Check Your Health” programme of Alexandra Hospital, An Ontology-driven Multi-agent approach for Diabetes Management (Ganendran G. et al, 2002), A multi-agent Healthcare System- An Example for Diabetes Management (Vivian, A., Venky, S., & Y.Y.Zhu., 2001), and 3G Network Oriented Mobile Agents for Intelligent Diabetes Management: A conceptual Model (Li, M., & Istepanian, R.S.H., 2003). This research focuses on the improvement of diabetes in rural areas where most of the diabetic care is provided by generalists. The paper addresses the challenge of creating a system where a patient, generalist and a diabetic specialist coordinate and work together to improve the care of diabetic condition. The authors implements mobile agents to improve the quality of diabetic care in rural areas. They also affirm that with the aid of mobile agents, patients can receive better consultation on time no matter where a diabetic specialist is physically located.

The paper deploys the mobile agent system to address this problem as the mobile agent technology has a capacity to travel across network which may help health care professionals such as diabetic specialists, general practitioner, clinicians, and patients locate one another and transact diagnose electronically. Furthermore, authors have specified that the implementation of mobile agents in health care to control diabetes will allow the interconnection and interoperation of multiple existing systems such as legacy patient health information, patients decision support systems, or other e-health systems; improve scalability of the system as agents have the capability to deal with dynamic environments; and provide solutions withdrawn from distributed information sources.

According to the architecture presented in the paper, each village (node) is connected to a city hospital (speciality hub) with adequate number of diabetic specialist. Village generalist registers the patient details to the diabetic support system by entering the medical data and history such as blood glucose measurements and other symptoms of his/her patient in it. The data is carried to the speciality hub, which in this case is a city hospital, where diabetic specialists can access the medical data. In this way, diabetic specialists may view medical record of all the patients suffering from diabetes from various villages on a single site and coordinate the intervention of all available diabetic specialists to response to symptoms of rural patients throughout the year. To make the system more effective, villages located within the region are connected to their Regional Hub. There can be number of regional hubs such as northern hub, southern hub etc. Each Regional Hub is further connected to various diabetic specialists through several Central Agencies. Each central agency contains adequate number of diabetic specialist agents. Each central agency containing diabetic specialist agents are linked to the database wrapper which first retrieves internal medical information from the diabetic departmental database and then stores in its database. Central Agencies are also connected to each other to provide coordination. Village patient and central agencies connects to the Regional Hub, which serves as a centralized information repository, at each state to provide and receive medical treatments and follow -ups.

Mobile agents involved in the system are the Village Agent and Diabetic Specialist Agent. When a patient is registered in the system by a local generalist, the Village Agent is created which hold medical information of the patient. Patient's medical information contains the name of the patient, patient identification number, address, date of birth, allergies, medical history which contains information about medical examination, date of visit, problem description, medical centre ID, generalist ID, and Specialist ID. Specialist ID is not available until the completion of the first cycle of the diabetic support system. Once the village agent is created and loaded with the required information, it travels across the network from a village health care centre to the regional hub and wait for the central agency to provide list of available diabetic specialists. The regional hub holds general information of each central agency such as list of diabetic specialists in each centre in the area. It also checks the availability of each diabetic specialist in that area and directs the village agent to available specialist in a timely fashion. The diabetic specialist agent is responsible for maintaining the schedule of the specialist and holding his appointment times. Once the diabetic specialist is chosen, the regional hub directs the village agent to meet the diabetic specialist agent at the central agency. After the completion of interaction between the village agent and diabetic specialist agent, the village agent goes back to the village health centre and provides the obtained recommendations and consultations to the village generalist.

According to authors, the idea of keeping a centralized database in each region brings numerous advantages such as huge amount of data of patients can be compacted for easy storage, data processing becomes faster, easier maintenance of patient data, and better availability of information. This paper presents a framework which has a potential to manage and control diabetes in remote areas that lacks diabetic specialists.

Title: Nature-Inspired Planner Agent for Health Care

Authors: Javier Bajo, Dante I. Tapia[2], Sara Rodríguez, Ana de Luis and Juan M. Corchado

Source: Computational and Ambient Intelligence, 2007, Volume 4507, pages: 1090-1097

Publisher: Springer Berlin / Heidelberg

This paper presents an agent-based human thinking reasoning model based on past experience. The main purpose of the development of this model is to facilitate elderly people with disabilities, in particular with Alzheimer. Alzheimer is a progressive and fatal brain disease in the form of dementia (loss of memory and other intellectual abilities serious enough to interfere with daily life) with no current cure (Alzheimer's Association, 2009). The paper presents an autonomous deliberative Case-based Planner agent named AGALZ or Autonomous Agent for Monitoring Alzheimer Patients. AGALZ integrates with an environment aware multi-agent system called ALZ-MAS to improve health care of aged people. ALZ-MAS exploit RFID technology which is mounted on bracelets worn on the patient's wrist or ankle to learn about the environment. The RFID technology uses radio waves to automatically identify people or objects (Webopedia, 2009).

Authors incorporates the Case-Based Planning (CBP) mechanism (a derivative of Case-Based Reasoning architecture) together with the BDI (Believe, Desire, Intention) architecture to develop nature inspired deliberative agents, AGALZ, which have a capability to respond to events, take the initiative according to their goals, communicate with other agents, interact with users, and make use of past experience to identify best plans to achieve goals. The CBP helps AGALZ generate plans using past experiences and planning strategies. CBP cycles through four stages. The function of each stage is as follows: the retrieve stage to recover the most similar past experience to the current one; the reuse stage to combine the retrieved solutions in order to obtain a new optimal solution; the revise stage to evaluate the obtained solution; and the retain stage to learn from the new experience. Each cycle of CBP is implemented through goals and plans. AGALZ implements multi-agent system to work coordinately with other agents to solve problems in a distributed fashion.

AGALZ formulate plans in such a way that each plan is composed of a sequence of tasks. These tasks have to be carried out by a nurse to execute a plan. A task creates a problem description for a nurse to carry out, resources available, and times assigned for their shift. Similar problem descriptions with an original problem are recovered during the retrieve stage of AGALZ. To achieve this, AGALZ applies various similarity algorithms and upon the selection of most similar problem description, it recovers the solutions associated to these problems. A solution contains all the plans and these plans are combined later in the reuse stage to determine available resources that are needed to fulfill the global plan. The resources that are required to complete some of tasks can be food, equipments, rooms and some other. Availability of time of nurse can be a problem restriction.

In this paper, the model is tested in the Alzheimer Santisima Trinidad (ST) Residence of Salamanca to improve the current services being offered to its patients. This residence is build for elderly people, specifically over 65 years old. The residence offers variety of services and facilities such as TV, room, geriatric bathroom, hairdressing, salon, medical service, religious attention, occupational therapy, technical assistance, terrace, garden, laundry service, clothes adjustment, infirmary, reading room, living room, visitors' room, cafeteria, social worker, chapel, elevator, customized diet, and multipurpose room. Authors selected 30 patients from the residence to test the system. They also installed 42 ID door readers, one on each door and elevator, 4 controllers, one at each exit, and 36 bracelets mounted with RFID one for each patient and nurses. The ID door readers get the ID number from the bracelets and send the data to the controllers which send a notification to the Manager Agent. Manager agent is located in a central computer. For the purpose of testing, authors instantiated 30 Patient agents, 10 AGALZ agents, 2 Doctor agents, and 1 Manager agent. Together these agents make a framework called ALZ-MAS Each one of these agents is explained below.

The Patient Agent runs on a central computer and manages the personal data of patient and its behaviour such as monitoring location, daily tasks, and anomalies. According to authors every hour a patient agent validates the patient location, monitors the patient state and sends a copy of its memory base, which is patient state, goals and plans, to the manager agent for the backup purposes. At the time of execution, the patient state is created as a set of beliefs. These beliefs are controlled through goals that must be achieved or maintained. These beliefs define the general state of the patient at residence. The beliefs are in the form of weight, temperature, blood pressure, feeding (diet characteristics and next time to eat), oral medication, parenteral medication, posture change, toileting, personal hygiene, and exercise. The paper also states that the beliefs and goals set for every patient depend on the treatment plan or plans that the doctors prescribe. The state of the patient is known by the patient agent by means of accomplished or failed goals. To track whether the goal has been accomplished or has failed, the patient agent maintains continuous communication with the rest of the ALZ-MAS agents especially with AGALZ. AGALZ can send the result of nurse agent's assigned tasks to the patient agent. Authors also state that the communication between the patient agent and the nurse agent must take place at least once per day depending on the corresponding treatment.

The second agent involved in ALZ-MAS framework is the Manager Agent. It also runs on a central computer. The paper lists down two roles of the Manager Agent: the security role and the manager role. In security role, the manager agent controls the patients' location and manages locks and alarms and during the manager role, it manages the medical record database and the doctor-patient and nurse-patient assignment.

The Doctor agent is the third agent of ALZ-MAS. In simple words, Doctor agent treats patients. The doctor agent interacts with all the agents of ALZ-MAS. It sends treatment to the patient agent and receives periodic reports. It communicates with the manager agent to consult medical records and assigned patients and it transact with AGALZ agent to determine patients' evolution.

The fourth and the last agent of the proposed framework is the AGALZ. As it is discussed above the main responsibilities of the AGALZ include scheduling the working day of nurse, managing nurse's profile, tasks, available time and resources. The AGALZ agent runs on a mobile device so that each nurse can see her plans task by task. System has placed a limit of 8 hour working time for any nurse.

Upon the implementation of the system, authors have derived some useful results. According to authors, the workers have reduced the time spent on routine tasks. Activities of the patient and staff are also monitored and the monitored data can be used for the purpose of analysis to further improve the quality of health care to patients. Authors further affirms that the system also improves the security of the residence as it monitors the location of the patients which guarantees that there are in the right place and secondly, only authorised personnel can gain access to the residence protected areas.

Title: Mobile Agent-Based Framework for Healthcare Knowledge Management System

Authors: LEE Sang-Young, LEE Yun-Hyeon

Source: Mobile ad-hoc and sensor networks, International conference, Wuhan, China, December 13-15, 2005, vol. 3794, pp. 1103-1109

Publisher: Springer Berlin / Heidelberg

This paper presents a framework for effective management of information and knowledge in healthcare sector using mobile agents. Authors sense the necessity of transposing stored healthcare data and information into knowledge so that it can serve as a facilitator for making critical decisions during healthcare operations. The architecture has a number of components which are further divided into sub-components. Each component is responsible for carrying out specific task. The Knowledge Identification Agent and the Knowledge Interchange Agent are the two main agents that are implemented in the proposed healthcare knowledge management system. The system is further supported by the knowledge organization agent, knowledge reusability agent, knowledge query agent, knowledge visualize agent, new knowledge discovery agent and mobile dynamic planning agent.

Proposed healthcare knowledge management framework is primarily divided into two areas: the application area and the service area. The application area is responsible for tasks such as acquisition, identification, organization and reusability of knowledge. It consists of the knowledge acquisition tool which facilitates healthcare experts to insert basic information into the system. It is also equipped with the identification and interchange tool which is useful in sharing knowledge, provided by healthcare professional, with others or for personal use with the aid of mobile agents. Another tool that is a part of application area of the system is the organization and reusability tool. This tool provides systematization and reformatting of information for special purposes.

The second area of the proposed healthcare knowledge management system is the service area. This area is in charge of making strategic plan and assessment, and consists of three tools. The first tool is the dynamic healthcare knowledge visualize tool. As the name implies, the main functionality of this component is to visualize healthcare knowledge acquired from repository for better understanding. The second tool is the dynamic healthcare planning tool with customization feature which is intended for personal use. The third and the last tool which is a part of service area is the healthcare coalition information tool. This tool exercises plans, schedules, and resources to formulate the optimal team to execute work in healthcare administration.

The application area of the framework is based on mobile agents and, as discussed above, is composed of three tools: the knowledge acquisition tool, the identification and interchange tool and the organization and reusability tool. Basic functionalities of these tools are summarized above however the paper further breaks down each of these tools into its sub-components.

The first tool which is the knowledge acquisition tool is composed of three components: the mail server, the application server, and the mail repository. The mail server is responsible for handling email transactions, email forwarding and formulation of an auditor group (specialized for health issues) controlled by intellectual email administrator, and the re-formatting of emails before they are stored into the database or forwarded to a receiver. The application server component is in control of receiving services required by users and evaluation of emails in the form of usage, accuracy and pertinence. The last component of knowledge acquisition tool is the mail repository which is the main mechanism for saving mails into database.

The knowledge management framework of mobile agent base, the knowledge identification agent and the knowledge interchange agent are part of the knowledge identification and interchange tool. The knowledge management framework of mobile agent base provides basic and general architecture to mobile agent sub-components. The knowledge identification agent implements a search protocol which facilitates the non-professional healthcare people to perform their queries effectively and fetches the most proximate healthcare related results. The Multi-query acquisition, query optimization, knowledge delivery and knowledge matching are the sub-components of the knowledge identification agent. These components are linked together to provide the most efficient results to the user. The last element of the knowledge identification and interchange tool is the knowledge interchange agent. This agent is equipped with three components: the interchange knowledge detection, knowledge formatting, and knowledge interchange delivery component. The knowledge interchange agent carries out various tasks such as detecting knowledge through searching documents and emails, providing formatting, and sharing knowledge by transmitting it to other platforms.

The third tool is the knowledge organization and reusability tool. It consists of two agents: the knowledge organization agent and the knowledge reusability agent. The knowledge organization agent organizes the stored knowledge autonomously and keeps the database up-to date and removes unnecessary data from the repository. The second agent is the knowledge reusability agent and it is responsible for the effective re-use of healthcare knowledge. It has an ability to apply the existing healthcare knowledge for solving new problem. It also personalizes the solutions based on the user of the system.

The service area of the proposed healthcare knowledge management framework is in charge of providing tools for knowledge visualization, healthcare planning, and healthcare coalition. The knowledge visualization tool includes knowledge discovery engine, knowledge query agent, knowledge structure engine, knowledge structure DB, graphic rendering engine, knowledge visualize agent, knowledge delete engine and new knowledge discovery agent. All of these components work together to provide efficient knowledge visualization services.

Another tool in the service area of the proposed system is dynamic healthcare planning tool which provides support for healthcare planning. The subcomponents of this tool are: the general planning repository, resource and schedule repository and mobile dynamic planning agent which are responsible for healthcare plan storage, individual health condition and information resource storage, and dynamic planning with the help cooperation with other two components respectively.

This paper presents various components that can work together to create an effective knowledge management system (KMS). Authors believe that this framework has a potential to address issues with regards to the management of knowledge in healthcare.

This paper presents a multi-agent security framework for e-health services. It describes and categorizes various type of communication into different levels that takes place among health care professionals. Subsequently, the paper identifies security requirements associated to each level of communication and introduces a multi-agent based security approach for e-health services.

The paper begins with the thought that the internet is not a secure place to communicate and share sensitive information. Computer systems are often compromised for illegitimate purposes and organizations that transact business through internet must make sure that their systems are secured. For example, e-health exercises information technology to deliver its services to people. During this process, sensitive information is communicated among users in e-health either through wired or wireless media. Thus, it is necessary to safeguard the communication mediums between medical professionals and patients to ensure the confidentiality and integrity of the transmitted information. To address this, the paper presents a security framework for e-health services based on the multi-agent system.

Communication occurs among various actors or users over network in e-health settings. To demonstrate this, authors present a scenario in e-health where a doctor in a hospital communicates with another doctor from another hospital through internet and a paramedic at an accident spot communicate with a system coordinator at the hospital to update current status of a patient using his personal data assistance (PDA). Authors identify seven actors which may participate in the given scenario. These are the Doctor, Patient, Nurse, Social Worker, Paramedic, System Coordinator, and System Administrator. In addition to that the type of communication among these actors are identified as (1) Doctor <=> Doctor, (2) Doctor <=> Patient, (3) Doctor <=> Nurse, (4) Nurse <=> Patient, (5) Paramedic <=> Social Worker, (6) Social Worker <=> Doctor, (7) System Administrator <=> (Doctor, Nurse, Patient, Social Worker, System Coordinator, and Paramedic).

Each of the above communication paths requires different level of protection depending on the sensitivity of information involved in the communication process. For instance Doctor <=> Doctor and Doctor <=> Patient communication exchange more sensitive information compared to Doctor <=> Social Worker interaction since social worker does not have to know all the details of the patient illness. Taking this into account, the paper categorises these communications into five levels on the basis of the sensitivity of information transmitted. Level 1 is classified as Extremely Sensitive Communication and requires highest protection which includes Doctor <=> Doctor, Doctor <=> Patient, Doctor <=> Nurse, Nurse <=> Patient communications. Level 2 is classified as Highly Sensitive Communication that involves System Coordinator <=> paramedic communication as information on patient's current condition is exchanged which is considered highly sensitive as well. Level 3 being a Medium Sensitive Communication only involves general information which does not require a great deal of protection but a medium security protection would suffice. Social Worker <=> Doctor can be considered a level 3 communication. Then comes the level 4, also referred as Low Sensitive Communication, which engages low sensitive information but high in confidentiality such as communication regarding user accounts or passwords. Interaction between the System Administrator and all other users falls under level 4 communication. The last type of communication is Level 5, named Public, and is open for public. Broadcasted announcements and seminars is an example of level 5 communication.

From this point, the paper identifies distinct security requirements associated to each communication level in order to design a secure system environment. Authentication to enter the system, confidentiality to prevent disclosure of sensitive information, and anonymity are the general requirements listed in the paper for a system used in health care. It further states that, these requirements can be met by securing the communication processes among users, analyzing and monitoring the network to protect against security breaches, and organization security policies. These policies include but are not limited to access control policy, site policy, hardened host policy, incident and disaster response, and auditing policy. Furthermore, authors concerns about the client and server communication and urge that the messages must be encrypted or digitally signed before transmission. Web servers can be compromised easily if they are physically accessible therefore all authorized users must follow the access control policy to access data and all the actions of users must be logged for auditing purposes. Authors also recommend that the email client must support digital certificate technology and signs and encrypts the message before sending it. With that, all activities from the firewall, intrusion detection system, and software patches and updates should be logged in to analyze any irregularity in the system. At last but not the least, authors insist that all the security policies of organization must be enforced for suitable results.

Taking all the security requirements into account, the paper presents a multi-agent based security framework for e-health. The framework is structured into three main components which are the Organizational Policies, Communication Manager Agent (CMA), and Network Analysis and Monitoring Agent (NAMA). The framework also has an Interface Agent and Authentication Agent. The Interface Agent gets information from the user such as ID and password and passes down to the Authentication Agent which is responsible for authentication process. The Communication Manager Agent manages other agents such as

Multi-level communications agent, Message Encryption/Detection Agent, and Email Agent based on services needed. Multi-level communication agent determines the level of communication for a user based on the user's role such as doctor, nurse, patient, etc. The Communication Manager Agent makes sure that all the types of communications adhere to the standard security processes as encryption algorithm required in level 1 is stronger than level 3. The Email Agent also plays an important role in the proposed framework as it assures that there is certificate installed at the user's machine to encrypt the message before sending it out to the network. The Network Analysis and Monitoring Agent monitors and track agents such as Intrusion Detection System Agent, Firewall Agent, Patch Server updates Agent, and Anti-virus Agent. These Agents communicates with Network Analysis and Monitoring Agent to provide on-going state of the system to analyze the network traffic for any malicious activity.

This paper presents a multi-agent based security framework for e-health at a superficial level. It introduces a multi-level communication approach to provide more effective and efficient security to the network. Authors believes that this framework will be implemented in future to study the capability of agents to coordinate and cooperate together to improve the performance of the security processes.

REFERENCES

AbsoluteAstronomy. (2009). Retrieved February 25, 2009, from http://www.absoluteastronomy.com/topics/Telemedicine

Alzheimer's Association. (2009). Retrieved February 7, 2009, from http://www.alz.org/alzheimers_disease_what_is_alzheimers.asp

Bajo, J., Tapia, D., Rodríguez, S., Luis, A., & Corchado, J. (2007). Nature-Inspired Planner Agent for Health Care. *Computational and Ambient Intelligence, 4507*, 1090-1097. Berlin/Heidelberg: Springer

Bui, T. (2000). Agent Based Corporate Information Systems: An Application to Medicine. [Elsevier.]. *European Journal of Operational Research*, *122*, 243–257. doi:10.1016/S0377-2217(99)00231-3

Christiansen, J., & Campbell, P. (2003). *Health-Sim: An Agent-Based Model for Simulating Health Care Delivery*. Chicago, Illinois: Argonne National Laboratory.

Ganendran, G., Tran, Q., Ganguly, P., Ray, P., & Low, G. (2002). An Ontology-driven Multi-agent approach for Healthcare. *Proceedings of the Health Informatics Conference (HIC2002)*, Melbourne.

Lanzola, G., Gatti, L., Falasconi, S., & Stefanelli, M. (1999). A Framework for Building Cooperative Software Agents in medical applications. [Elsevier]. *Artificial Intelligence in Medicine*, *16*(3), 223–249. doi:10.1016/S0933-3657(99)00008-1

Li, M., & Istepanian, R. S. H. (2003). 3G Network Oriented Mobile Agents for Intelligent Diabetes Management: A conceptual Model. *Information Technology Applications in Biomedicine* (pp. 31-34).

NationMaster. (2009). Retrieved March 2, 2009, from http://www.nationmaster.com/encyclopedia/Pathophysiology

Sulaiman, R., Sharma, D., Ma, W., & Tran, D. (2007). A Multi-Agent Security Framework for e-Health Services. *Knowledge-Based Intelligent Information and Engineering Systems and the XVII Italian Workshop on Neural Networks on Proceedings of the 11th International Conference, 4693*, 547-554. Berlin/Heidelberg: Springer.

Tarapornsin, V., Ray, P., & Chowdhury, A. (2006). Mobile Software Agents for the Support of Chronic Illness: A Case Study in Diabetes Management for Rural Areas. e-*Health Networking, Applications and Services; 2006 HealthCom 2008. 10th International Conference* (17-19, 72-77)

Tian, J., & Tianfield, H. (2003). A Multi-agent Approach to the Design of an E-medicine System, *Multiagent system technologies, 2831*, 85-94. Berlin/Heidelberg: Springer.

Vivian, A., Venky, S., & Zhu, Y. Y. (2001). A Multi-agent Healthcare System-An Example for Diabetes Management. [Aquila, Italy.]. *Proceedings of IEEE Healthcom*, *2001*, L.

Webopedia (2009). Retrieved February 10, 2009, from http://www.webopedia.com/DidYouKnow/Computer_Science/2005/rfid.asp

This work was previously published in Multi-Agent Systems for Healthcare Simulation and Modeling: Applications for System Improvement, edited by R. Paranjape; A. Sadanand, pp. 26-43, copyright 2010 by Medical Information Science Reference (an imprint of IGI Global).

Chapter 1.25

Overview and Analysis of Electronic Health Record Standards

Spyros Kitsiou
University of Macedonia Economic and Social Science, Greece

Vicky Manthou
University of Macedonia Economic and Social Science, Greece

Maro Vlachopoulou
University of Macedonia Economic and Social Science, Greece

ABSTRACT

A fundamental requirement for achieving continuity of care is commonly accepted to be the integration and interoperability of different clinical oriented systems towards the realization of a "longitudinal" Electronic Healthcare Record. To enable seamless integration of various kinds of IT applications into a healthcare network, a commonly accepted framework based on international relevant standards has become an urgent need. However, there is much marketplace confusion today in the healthcare domain, due to the variety of overlapping or complementary interoperability standards and initiatives, which have evolved over the years addressing integration of applications at different levels. This chapter provides a brief overview of the most relevant Electronic Healthcare Record standards, by examining the level of interoperability and functionality they provide, in terms of context, structure, access services, multimedia support, and security, to provide healthcare decision-makers and system integrators with a clear perspective regarding the capabilities and limitations of each standard.

INTRODUCTION

In order to manage the safe and effective delivery of complex and knowledge intensive healthcare, clinical practitioners increasingly require timely access to detailed, accurate, and complete patient healthcare records, along with efficient communication methods to share segments of a patient's record within and between care teams (Smith, 1996). Also,

DOI:

as the focus of healthcare delivery, over the years, has shifted progressively from medical centres of excellence to primary care, community settings, and to the patient's personal environment (e.g., home care), patients nowadays require as well access to their own healthcare records to an extend that allows them to play an active role in their health management (Lewis et al., 2005). The development of a longitudinal, patient-centred electronic healthcare record (EHR), which has been a key research field in the health informatics domain for many years, is a much anticipated solution to these issues.

According to Tang and McDonald (2006), "an EHR is a repository of electronically maintained information about an individual's lifetime health status and health care, stored such that it can serve the multiple legitimate users of the record". Iakovidis (1998) also argues that the purpose of an EHR should be toward the support of continuity of care, education and research. On the other hand, an EHR system is defined as a set of interoperable information system components establishing appropriate mechanisms to generate, use, store and retrieve an EHR, while ensuring confidentiality at all times (Blobel, 2002). Ideally, an EHR shall include information such as patient identification, observations, vital signs, physical examinations, treatments, therapy interventions, administered drugs, allergies, diagnostic and laboratory tests, as well as imaging reports.

Yet, much of these fine-grained clinical information on which quality care depends is usually stored in distributed, isolated clinical systems and databases in different kinds of proprietary formats within healthcare organizations. Typical formats may include mixtures of narrative, structured, coded, and multimedia entries, unstructured or structured document-based storage, relational database tables, as well as digitized hardcopies maintained in a document management system. One of the major impediments towards the realization of an EHR is the fact that healthcare organizations, all too frequently, consist of a large number of disparate and heterogeneous information systems, which have been deployed to support specific departmental needs Most of these information systems today are proprietary and have been designed autonomously by different vendors, in order to optimize specific processes within various departmental units. Therefore, each system, required to participate in the co-operative healthcare process and facilitation of an EHR, usually differs in technological and architectural aspects (e.g., user interface, functionality, presentation, terminology, data representation and semantics), preserving the problem of system integration prevalent and of significant complexity (Xu et al., 2000; Lenz and Kuhn, 2002). This has constituted a severe interoperability problem in the healthcare informatics domain, allowing healthcare organizations to be left with islands of heterogeneous systems and technologies that are difficult to integrate. Thus, the requirements to provide clinical professionals of any speciality with an integrated, and relevant to their profession, view of the complete health care history of each patient under their care has so far proved to be a significant challenge. Nevertheless, this need is now widely recognised to be a major obstacle to the safe and effective delivery of healthcare services, by clinical professions, by health service organisations and by governments internationally.

There are many perceived benefits of making EHR systems interoperable. EHRs can contribute to more effective and efficient patient care by facilitating the retrieval, acquirement, organization, processing, communication, and view of patient health record data from different sites (Tang and McDonald 2006). Duplicate data entry and prescribing can be avoided, while real-time transferring of patient data between care sites can be improved, if information is captured, maintained, and communicated securely and consistently, in line with clinical needs. Moreover, EHR systems complimented by clinical decision support tools are capable of reducing errors, improve productivity and decision-making choices, benefit patient care by providing automatic reminders, alerts to possible drug interactions, flag of abnormal values and lists of possible explanations for those abnormalities, along with other possible functions too numerous and constantly evolving to mention (Garg et al., 2005). Nevertheless, meeting these potential requirements and benefits necessitates the interoperability among various clinical oriented information systems that support the seamless communication of health record data, while preserving faithfully the clinical meaning of the individual authored contributions within it.

Generally speaking, interoperability is the ability of different information technology systems and software applications to communicate by exchanging data accurately, effectively, and consistently, and to use the information that has been exchanged. More specifically, according to Brown and Reynolds (2000), the term interoperability is defined as follows:

Interoperability with regard to a specific task is said to exist between two applications when one application can accept data (including data in the form of a service request) from the other and perform the task in an appropriate and satisfactory manner (as judged by the user of the receiving system) without the need for extra operator intervention.

The above definition implies the following

- The ability to communicate data (connectivity).
- The data received by the receiving system is sufficient to perform the task and the meaning attached to each data item is the same as the understood by the creators and users of the sending and receiving systems.
- The task is performed to the satisfaction of the user of the receiving system

Given the continuous evolution of technological innovation and the important need for EHR interoperability, over the years a number of interoperability standards have been developed and continuously refined, in order to improve the compatibility among a variety of healthcare applications and systems. Standards such as the Health Level 7 (HL7) Clinical Document Architecture (CDA), CEN EN 13606 EHRcom, and the OpenEHR initiative, aiming to structure the clinical content of an EHR with the purpose to facilitate the exchange of meaningful clinical data, as well as industry initiatives and de facto standards such as integrating the healthcare enterprise (IHE), and digital imaging communications in medicine (DICOM), have played so far a significant role towards the development of interoperable EHR systems. However, given the plethora of international standards and industry initiatives, and also the fact that different types of integration requirements, all too frequent, can not be satisfied by one standard or integration approach only, selecting the most appropriate solution can be a complex task both for system and service providers (Mykkanen, et al., 2003).

This chapter aims to provide an analysis of the aforementioned prominent EHR standards, in order to provide healthcare decision-makers and system integrators with a clear perspective regarding the capabilities and limitations of each standard by examining the level of interoperability and functionality they provide, in terms of context, structure, access services, multimedia support, and security.

The GEHR/OpenEHR Initiative

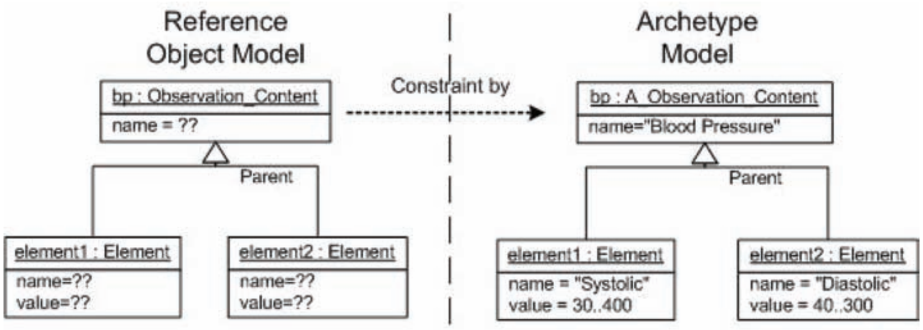
Realising the electronic health record has been at the heart of the EU health telematics programmes for the past fifteen years (Iakovidis, 1998). Considerable research has been undertaken, in order to explore the user requirements for adopting EHRs, as well as proposed architecture formalisms to capture healthcare data comprehensively and in a manner which is medico-legally rigorous and preserves the clinical meaning intended by the original author.

One of the most well known Research and Development Projects, funded by the EU Health Telematics research programme in 1991, is the Good European Health Record (GEHR) initiative (Ingram 1995; Griffith et al., 1995). From 1991-1995, the GEHR Project, who's consortium involved 21 participating organisations in seven European countries, and included clinicians from different professions and disciplines, computer scientists in commercial and academic institutions, and major multi-national companies, explored a wide range of clinical requirements for the wide-scale adoption of electronic health records (EHRs), in place of paper records within primary and secondary care and across different specialities. The outcome of this effort was the development and evaluation of different EHR prototypes, which were based on a set of architecture models, exchange formats, specifications of access and integration tools and a standard architecture, all made available and placed in the public domain. This initiative was later continued under the name Good Electronic Health Record with strong participation from Australia. Currently, this initiative is maintained by an international online, non-profit organization, called the OpenEHR Foundation[1], whose aim is to promote and facilitate progress towards the development of high-quality and interoperable EHRs to support the needs of patients and clinicians.

The most noteworthy concept of these initiatives, proposed and defined independently by the Australian GEHR team, is a knowledge-based model, also known as the archetype modelling technique, which facilitates on one hand the specification of a generic clinical record structure, and on the other hand the specific semantic definitions of clinical contents that need to be standardized (Beale, 2002). This model utilizes a dual-level methodology to define the EHR structure. More specifically, the first level is used to define a small, but constant in time, Reference Object Model (ROM) for an EHR, which typically contains only a few generic, non-volatile, concepts/classes (e.g., role, act, entity, participation, observation, etc). In addition, at this level (the level of the ROM), additional methods on how to organize and group clinical information, capture contextual information, query and update the health record, and use of versioning to safely manage clinical information from a medico-legal point of view, are specified (Beale, 2005; Beale and Heard, 2005). Although the ROM has rich capabilities, it is generic enough to store any type of clinical information. Subsequently, in order to overcome the problem of modelling and specifying the concepts and semantic definitions of clinical contents (e.g. blood pressure, lab results, etc.), the proposed methodology utilizes a second level, in which the constraint rules and mechanisms, called archetypes, specialize the generic data structures that have been implemented using the ROM. Figure 1, illustrates a simple example of the dual-methodology concept. A generic class called "Observation_Content" (implemented in the ROM) can be constraint and restricted by an archetype model class called "A_Observation_Content". This later class is further defined and constraint by an instance archetype called "Blood Pressure". The "Blood Pressure" archetype in turn specifies to the Archetype Model and subsequently to the ROM that the first element in the blood pressure group of elements, will have the name "systolic", and its value must be an integer between 40 and 300 mm[Hg], while the second element will have the name "diastolic" with the same constraints on its value. Of course it has to be noted that in real clinical practice much richer and complicated models usually exist.

A formal language called Archetype Definition Language (ADL) (Beale and Heard, 2003) has been introduced by the OpenEHR initiative in order to describe for each archetype three basic parts: descriptive data, constraint rules, and

Figure 1. Blood pressure instance in the dual-methodology approach



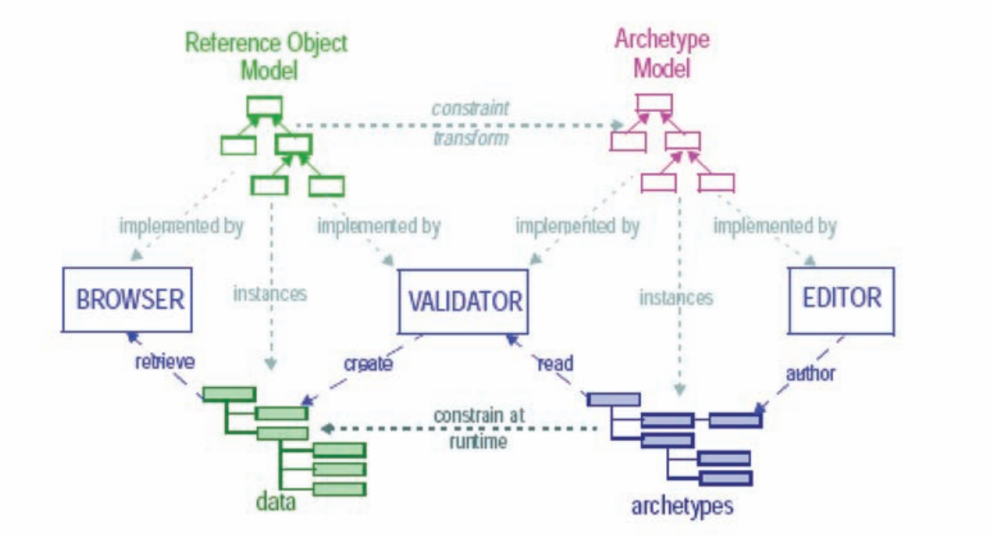
ontological definitions. Descriptive data usually contain a unique identifier for the archetype, a machine readable code describing the clinical concepts modelled by the archetype, as well as various metadata such as author, version, and purpose. Also, due to the fact that an archetype may be a specialization of another archetype, the ADL language also states probable specializations. In turn, the constraint rules are the core aspects of each archetype, defining the potential restrictions on the valid structure, cardinality, and content of the EHR component models. In addition, the ontological part defines the controlled vocabulary that can be used in specific places within an instance archetype.

The main advantage of the dual-level methodology and the archetypes approach is that clinical concepts (represented by the archetypes) are modelled externally and separately from the reference information model of the EHR system. In other words, instead of following the traditional "single-level" development method of a clinical information system, where the domain concepts and semantics which the system has to process are hard-coded directly into its software and database models, the archetype methodology allows domain concepts to be defined separately by domain specialist (e.g., doctors, nurses, clinical bodies, etc.) without worrying about the internal mechanics of the static application software model (the ROM). Derived from this perspective, a basic requirement of an EHR system, illustrated in Figure 2, is to provide three building blocks that are specific to the archetype approach:

- An editor for creating and maintaining the archetypes
- A validator that enforces the constraints are runtime, and
- A browser component who will allow an optimized display of specific archetypes, such as the example archetype illustrated in Figure 1.

Based on the above building blocks, user data entries that need to be stored into an EHR system are guided and validated at runtime against the constraints which are defined in the archetypes for each specific concept. The dual-methodology also allows for the development of "OpenEHR templates". Templates aim to describe the organization and order of models and entries into a record or document (e.g. discharge summaries, antenatal examination, etc.) by using a set (a specified number) of archetypes that can be used for a particular data collection. The OpenEHR foundation maintains libraries of validated templates and archetypes, which can be re-used as a starting point towards the easier and faster development of an EHR system as opposed to a development from scratch approach.

Figure 2. Meta-architecture of the OpenEHR methodology approach (Beale 2002)



Overall, the framework of the OpenEHR foundation includes a Reference Information Model, the ADL language specification for expressing archetypes, an archetype library, implementation technology specifications such as XML schemas, IDL specifications, and a collection of open source implementations for OpenEHR specifications, all published in the OpenEHR web site (www.openehr.org).

The CEN/TC 251 AND ENV/ EN13606 EHRcom

Much of the work and experience of the GEHR project and the OpenEHR foundation, along with other European research and development projects such as the EHCR Support Action (Dixon et al, 2001), and the Synapses project (Grimson et al, 1998), have provided significant input and opportunities for progress on the CEN and ISO standardization organizations.

The CEN/TC 251 (CEN/TC 251), supported by the European Commission DGIII (industry), healthcare organizations, suppliers of ICT-solutions and users, is the technical committee on Health Informatics for the European Committee for Standardization. Its mission is to achieve compatibility and interoperability between independent health information systems and to enable modularity by means of standardization. The TC 251 team comprises of four working groups, which cover: information models, systems of concepts and terminology, security, and technologies for interoperable communications. In particular, the overall scope of the CEN Working Group I (WPI) focuses on standards for the representation of the electronic healthcare record and standards for messages to meet the specific business needs for the communication of healthcare information. In the framework of this working group two work items in the 1990s were intended to be studied and further defines. The first work item, developed as the pre-standard ENV 12265 was the Electronic Healthcare Record Architecture (EHCRA). The ENV 12265 was a foundation standard defining the basic principles upon which electronic healthcare records should be based (CEN ENV 12265). The majority of the requirements for this work item were mainly derived from the GEHR mentioned in the previous section. The second work item, called Electronic Healthcare Record Extended

Architecture, published in 1999, was a four-part EHCR successor standard called ENV 13606.

The CEN standard ENV 13606 Electronic Healthcare Record Communication, is predominantly a message-based standard for the exchange of electronic healthcare records. This is mainly due to the fact that the ENV 13606 does not attempt to specify a complete EHR system, but instead, it focuses on the following main parts:

- The Domain Termlist, which provides a set of measures to be used in order to structure the EHR content.
- The Distribution rules, which specify a set of data objects that represent the rules under which certain EHR content may be shared with other systems, and finally.
- The Messaging, which defines a set of request and response messages enabling the partial or entire communication and also the updating of a patient's EHR.

Several EHR demonstrator projects and few suppliers in the UK (Booth et al., 1999; Markwell et al., 1999), Spain, the Netherlands, Denmark (Bredegaard, 2000), and Greece (Deftereos et al., 2001) have selected to use the ENV 13606, however, implementation efforts and experiences were not successful due to the fact that the standard suffered many weaknessess. The single-level modeling approach made the information model extremely complex with lots of optionatiality and levels of abstraction. These weaknesses unfortunately enforced the implementor parties to pursue several adaptations to the ENV 13606, made in an ad hoc approach, defeating therefore the main objective of the standard.

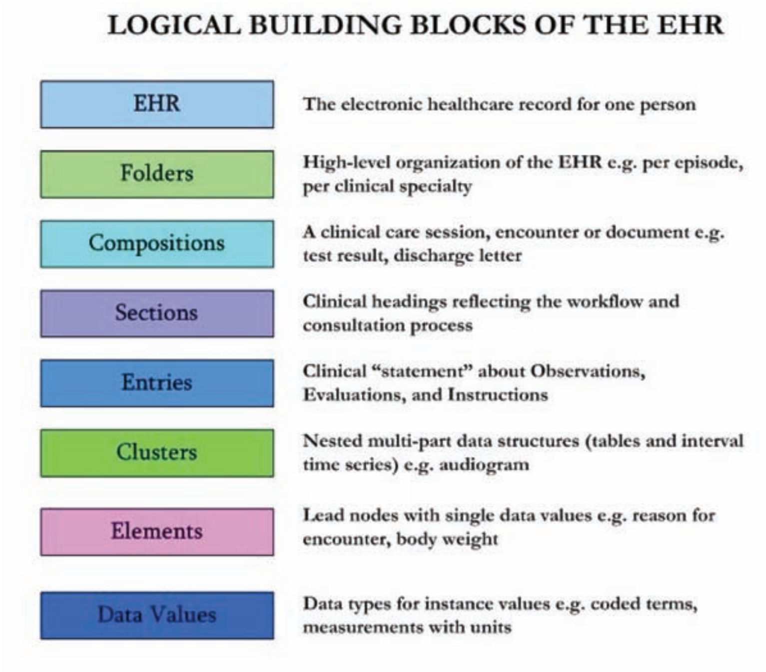
In December 2001, the Health Informatics Technical Committee of the European standards organisation CEN appointed a Task Force, known as EHRcom, to review and revise its 1999 four-part pre-standard ENV 13606 relating to EHR Communications, to produce a definitive European Standard. The mission of the EHRcom Task Force is to produce a rigorous and durable information architecture for representing the EHR, in order to support the interoperability of systems and components that need to interact with EHR services (Kalra, 2006):

- As discrete systems or as middleware components;
- To access, transfer, add or modify health record entries;
- Via electronic messages or distributed objects;
- Preserving the original clinical meaning intended by the author;
- Reflecting the confidentiality of that data as intended by the author and patient.

The revised ENV 13606 (CEN ENV 13606:2000), also called EHRcom, is a five-part standard consisting of the following parts:

- **Part 1—The Reference Model:** A comprehensive, generic EHR model drawing on 14 years of R&D and 2 previous CEN standards. The Reference Model will also be mapped to the HL7 RIM and Clinical Document Architecture (see next section about HL7 and CDA).
- **Part 2—The Archetype Interchange Specification:** An information model and exchange syntax for communicating archetypes; this specification is an adoption of the OpenEHR archetype approach, and will also be compatible with the emerging HL7 Template specification.
- **Part 3—The Reference Archetypes and Term Lists*:*** Contain a set of vocabularies and term lists to support the Reference Model. It also contains guidelines on how to use the Reference Model classes and attributes, and how to design archetypes.
- **Part 4—The Security Features:** Defines measures to support access control, consent and audit of EHR communications.

Figure 3. Main hierarchy of classes of the EHR in the EHRcom (Kalra 2006)



LOGICAL BUILDING BLOCKS OF THE EHR

EHR	The electronic healthcare record for one person
Folders	High-level organization of the EHR e.g. per episode, per clinical specialty
Compositions	A clinical care session, encounter or document e.g. test result, discharge letter
Sections	Clinical headings reflecting the workflow and consultation process
Entries	Clinical "statement" about Observations, Evaluations, and Instructions
Clusters	Nested multi-part data structures (tables and interval time series) e.g. audiogram
Elements	Lead nodes with single data values e.g. reason for encounter, body weight
Data Values	Data types for instance values e.g. coded terms, measurements with units

- **Part 5—The Exchange Models:** Define messages and service interfaces to enable EHR and archetype communication.

Currently, parts 1 and 4 are officially approved and published as European Standards, while parts 2,3, and 5 are still in work progress and are expected to be approved in 2008. It should also be noted that there is a wide international interest in this CEN work, and the Reference Model (Part 1) has been adopted by the International Organisation for Standardisation (ISO) as a draft standard for consultation and subsequent voting. In general, the CEN Reference Model for EHR communication is a generic model capable of representing the structure and context of part or all of the electronic health record of one subject of care, to support interoperable communications between systems and services that might request or provide EHR data. It is not intended to specify the internal architecture or database design of such systems. Figure 3, shows the logical hierarchy of building blocks which allows EHR content to be mapped.

On the highest level, folders may contain compositions by reference. A composition, ideally corresponds to a clinical document, and usually contains various sections defined by section headers and different entries, which in turn consists of specific elements or in some cases consist of clusters of elements. Each element contains values, and each value is based on a specific data type.

Similarly, with the GEHR/OpenEHR initiative, the most important approach that the EHRcom establishes, as opposed to the 1999 version, is dual-methodology based on archetypes. As described in the previous section, archetypes are used to specify clinical concepts (e.g. blood pressure, heart rate, ECG measurements, etc.) that work as constraint rules to restrict possible values or even relationships of the record components in an EHR composition. An Archetype Definition Language, similar to the one utilized by the OpenEHR will be defined by the EHRcom. Efforts are also made by the EHRcom group to harmonize the concept of archetypes with other standards, such as that of the HL7 and the Clinical Document Architecture, which is further described in the next section.

Overall, the completion of the EHRcom standard, which have drawn important lessons from the previous ENV 13606 standard as well as the experiences from several R&D projects, is very much anticipated by the European health informatics industry, since it will provide a revolutionary solution to the EHR interoperability issues. However, at this point there is no evidence neither for implementation outcomes or market acceptance, since the standard is not fully completed.

The HL7 and Clinical Document Architecture

Health Level 7 (HL7) is an ad hoc standards group organization that was formed in 1987, as a result of efforts to develop an integrated Hospital Information System by interconnecting function specific systems that deal with several aspects of patient's care in a hospital (e.g., patient admission, transfer or discharge, orders for drugs, procedures or tests and their results, finance and billing information, etc). The number "7" in its name refers to the application layer in the OSI reference model (Tanenbaum, 1988). HL7 is now an American National Standards Institute (ANSI) approved Standards Developing Organization (SDO) operating in the healthcare area. HL7 is presently being used in the United States, Australia, Canada, Germany, the Netherlands, Greece, Israel, Japan, and New Zealand, while additional countries are joining each year[2].

HL7 provides a collection of communication standard formats specifying syntactically and semantically standardized messages as well as interfaces for the electronic interchange, management, and integration of data between computer applications from different vendors within a healthcare network. It does not assume or make any assumption of data storage within applications; neither comprises an architectural framework for health information systems. For this reason, it doesn't tackle any aspects of functional integration between different software components, but only integration at the data level. Moreover, the HL7 standard does not focus on the requirements of a particular department within a healthcare organization. It simply supports various healthcare systems by specifying the precise messaging syntax to be used, including definitions of segments and internal code strings. In general, it can be viewed as a message oriented standard designed to support communication among distributed systems by utilizing a trigger event model that causes the sending system to transmit a standard pre-defined message to the receiving unit with a subsequent response by the receiving unit. For example, when an event occurs, such as the admission of a patient in a healthcare facility, in an HL7 compliant system (e.g., and admission discharge transfer (ADT) system), an HL7 message is prepared by collecting the necessary data (e.g. demographics data) from the underlying application system and it passes them on to a number of other requestor systems (e.g. a Billing Information System), usually as an Electronic Data Interchange message.

Currently, HL7 supports two message protocols, Version 2 and Version 3. The HL7 Version 2 messaging standard is the most widely, internationally implemented standard within a hospital information system (HL7 2.5: 2000). It has been developed and refined over the years to reflect standardised reporting data sets for several aspects of a patient's care in hospital. However, despite its wide uptake, being an HL7 Version 2 compliant does not necessarily guarantees full scale interoperability between healthcare applications and systems. This is mainly due to the fact that Version 2 does not rely on an underlying reference information model. The definitions for many data are rather vague, and there are also multiple optional fields that can be used or excluded from the implementation. Although, these optional fields provide a degree of flexibility, any implementation effort towards the interoperability between healthcare systems requires primarily a detailed bilateral agreement, also known as a "conformant statement". However, this solution is not scalable and requires a great effort of analysis work. In many cases, the use of HL7 Version 2 standard has created the problem of inconsistent implementations due an enormous and unsystematic growth of message segment definitions that have limited the realization of interoperability.

In order to remedy this problem, the HL7 has created a Version 3 standard (HL7 V3). The key feature of Version 3 is an object-oriented model, called the Reference Information Model (RIM) (HL7 RIM). The RIM is a formal information model representing the core classes and attributes, which specify and ensure the validity of content for any Version 3 messages that need to be exchanged between healthcare systems. In general, the RIM defines four major classes of information:

- Entities, (e.g., for persons, organisations, places and devices)
- Roles (e.g. a patient or an employee;
- Participation relationships (e.g. a patient and a clinician relationship), and
- Acts, (e.g. for the recording of appointments, patient encounters, procedures, etc).

In addition, the HL7 organization in Version 3 has introduced the Clinical Document Architecture (CDA), previously known as Patient Record Architecture (PRA), in order to facilitate the exchange of messages between medical information systems. CDA is currently on its second release and was approved as an ANSI standard in May 2005 (HL7 CDA Release 2:2005). The CDA is a document markup standard that defines a generic structure of messages and semantics for the communication and exchange of clinical documents (e.g. discharge summaries, progress notes, etc.), encoded in Extensible Markup Language (XML). By leveraging the use of XML, the CDA makes documents both machine-readable for XML-aware Web browses, so they are easily parsed and processed electronically, and also human-readable so that they can be easily retrieved and used by the people who need them. CDA documents derive their meaning (coded vocabulary) and data types from the HL7 Reference Information Model. More specifically the CDA, based on its letter "A", which stands for Architecture, can be thought of as a set of hierarchically related XML Document Type Definitions (DTDs) or schemas. In the current CDA standard three levels of hierarchy are defined:

- **Level One — Document Header and Body:** The document header, which is derived from the RIM, is consisted of four parts: the document information, encountered data, service actors and service targets (Dolin et al., 2001). It defines the semantics of each entry in the document and conveys the context in which the document was created. Its primary purposes are to make clinical document exchange possible across and within institutions and also facilitate the compilation of an individual patient's clinical documents into an EHR. The Body contains the clinical document context and can comprise either an unstructured text or nested containers such as sections, paragraphs, lists and tables through structured markup.
- **Level Two—Section Level Templates:** In this level the fine-grained observations and instructions within each heading are defined, through a set of RIM Act classes. In level two a set of Templates that can be layered on top of the CDA Level One specification specify or else constraint both the structure and the content of a document, supporting in this way the interoperability since the receiver knows what to expect. A Template may specify a document type (e.g. physical examination) and

further define its sections (e.g. Vital signs, or Cardiovascular examination, etc.), however the specific semantics of each entity are defined in Level Three.

- **Level Three—Entry Level Templates:** This label enables clinical content and semantics to be formally specified to the extend that they can be expressed in an HL7 Version 3 message based on the RIM model. For instance, this level can allow messages to be extracted from a clinical document for a laboratory order or a representation of symptoms findings.

Many national and international implementation projects, as well as commercial products, use the HL7 CDA as a formal format for defining clinical documents, particularly those who have used the HL7 standards for clinical information systems. However, it has to be pointed out that the HL7 clinical document architecture (CDA) is not an EHR standard per say, since it only defines parts of an EHR architecture. Nevertheless, it can form an important component of an EHR, and for this reason, efforts are made to harmonize the release two with the equivalent components of the EN 13606 Reference Model as well as the OpenEHR initiatives.

Digital Imaging and Communications in Medicine

The digital imaging and communications in medicine (DICOM) (DICOM, 2004) is a de facto standard published in 1993 jointly by the American College of Radiology (ACR) and the National Electrical Manufacturers Association (NEMA), building on two previous ACR-NEMA specifications originating from 1985. It addresses the issue of vendor-independent data formats and data transfers for digital medical images, in order to achieve compatibility and to improve workflow efficiency between imaging systems and other clinical information systems within the healthcare environment. Both CEN and ANSI have adopted DICOM by reference in their imaging standards. Nevertheless, given the fact that the DICOM standard was published in 1993, it precedes the development of Web Technologies, such as XML and Web services. Thus, it utilizes a binary encoding, as opposed to the aforementioned standards, with lists of hierarchy for data elements that are identified by numerical tags. In order to remedy this problem, DICOM issued two additional supplementary standards, called Web Access to DICOM Persistent Objects (WADO), and DICOM Structured Reporting (SR).

Web Access to DICOM Persistent Objects (WADO)

Web Access to DICOM Persistent Objects (WADO) standard was published in 2004, as an extension to the initial DICOM standard, and was a collaboration effort among DICOM and ISO (DICOM Supplument 85, 2004; ISO 17432, 2004). Generally speaking, WADO defines a Web-service that can be utilized by web clients who do not speak DICOM, in order to access particular DICOM objects (e.g. radiology images) via HTTP or HTTPS from a Web server. Although, this may sound a straight forward and simple process, it has to be pointed out that DICOM does not support any query mechanisms, and for this purpose every time a client wants to retrieve an object, it has to specify that object by its unique identifiers. In order perform this task the standard provides a method to harmonize the HTTP query syntax with pre-existing DICOM-enabled servers. In addition, there are a number of other options that can be passed on to the web server. The first and most common option, used for teaching purposes and clinical trials, is a request by the client to the server to hide during the transition any fields containing names or other unique identification data from that specific object. Other options include the conversion of the image presentation (e.g. from

DICOM to JPEG), the selection of the size transformation for the requested image, the quality, the selection of a specific region of that image, and so on.

The WADO standard provides a good approach to be utilized by EHR web-based system that need to gain access to DICOM objects, and make them available to other systems (e.g. via email) within and between healthcare organizations. A number of commercial implementations of the standard are already available.

DICOM Structured Reporting (DICOM-SR)

Another extension to the initial DICOM standard is the DICOM structuring reports (SR) specification, which was published in 2000 (Hussein, 2004a, 2004b). The SR specification provides primarily a standard information model for the electronic representation of medical image structured reports in DICOM's tag-based format for inclusion within an EHR. Based on this model, the actual content of a structured report is represented by a document tree, which specifies the structure (nesting level), the depth, and in a hierarchical way, the relationships among contents. Every content works as a node and comprises its own information (semantics), which are described based on machine-readable codes. In addition, the standard, just like other standards, specifies a range of different templates (e.g. template for diagnostic imaging report) in order to facilitate improved document structuring and harmonization among implementations. Although, its information model provides a high degree of flexibility to store different kinds of data, ranging from text reports to completely structured documents, it is not sufficiently rich in medico-legal and revision attributes to satisfy the requirements of an EHR. Thus, it is highly unlikely that the standard will be accepted in the near future by commercial implementers away from the imaging field.

ISO/TC 215 Health Informatics and the EHR Architecture (ISO TS 18308)

The ISO Technical Committee 215 (Health Informatics) was formed in 1999 to support the compatibility and interoperability of independent information and communication technology (ICT) systems in healthcare. This scope includes also the development of EHR standards. However, the ISO committee is still somewhat in a phase of trying to define its role, since relatively few work items have been formally approved, although a number of projects have been initiated. Regarding the focus on the development of an EHR architecture the ISO committee has only provided individual building blocks but not yet a complete comprehensive standard that defines the architecture itself. One of these standardization building blocks has been the Web Access to DICOM persistent object, mentioned in the previous section, which was a joint-effort with the DICOM.

In addition, the technical committee 215 published in 2004 another important specification the TS 18308 – Requirements for an electronic health record Architecture (ISO/TS 18308). This specification lists and collates a set of clinical and technical requirements for the implementation of an electronic health record architecture that shall support the use and communication of EHRs across different health sectors, countries, and models of healthcare delivery. However, the TS 18308 provides only requirements and not the actual technical architecture itself. Thus, the primary target groups of this specification document are developers of EHR reference architecture standards such as the CEN EN 13606 and other the OpenEHR. In fact the OpenEHR has harmonized its own requirements for the development of the EHR architecture with the TS 18308. In addition, the TS 18308 is complemented by a technical recommendation draft (ISO/TR 20514), published by the ISO Committee in 2005. This draft describes "a pragmatic classification of electronic health records" and furthermore provides "simple definitions for the main categories of EHR and supporting descriptions of the characteristics of electronic health records and EHR systems." These definitions also support legislative and access control requirements that are applicable to all kinds of EHRs.

Integrating the Healthcare Enterprise (IHE)

Integrating the healthcare environment (IHE)[3] is a recently-formed industry sponsored organization, founded in 1998, in the USA by the Radiological Society of North America and the Healthcare Information and Management Systems Society (HIMSS). Overall, the IHE is seeking to promote interoperability between systems within specialist departments such as radiology, and the conventional hospital systems used to order such investigations and to receive imaging study reports. It is working closely with standards organisations such as CEN and HL7. The IHE initiative does not develop standards, however, it selects and promotes appropriate standards from other organizations for specific cases, while also develops application profiles that work as restrictions for these standards. Among these integration profiles, describe in the next subsections, are the "retrieve information for display (RID)" and the "cross-enterprise document sharing (XDS)". Both address methods on how to access EHRs in various formats (IHE, 2005a).

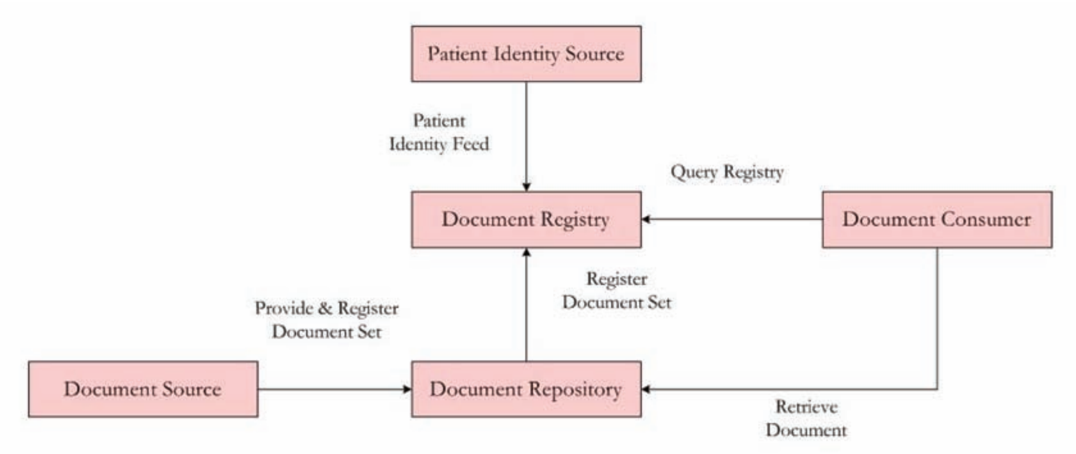
Retrieve Information for Display (RID)

The RID is best described as a Web service and provides through its WSDL (Web Service Description Language) a simple and rapid read-only access to patient-centric clinical information located outside a user's application. It supports access to existing persistent documents in well-known presentation formats such as HL7 CDA Level One, PDF or JPEG, as well as access to specific key patient-centric information for presentation to clinicians. Overall, the main focus of the RID integration profile is visual presentation and not a complete integration of structured databases. It is the responsibility of the information source to convert the healthcare specific semantics into a suitable presentation format. The display, on the other hand, may process and render this presentation format with only generic healthcare semantics knowledge, but will in general not be able to provide any processing of the healthcare information beyond document display. In addition to the above, the RID integration profile does not address access control or security measures for the transmitted information. Other integration profiles offered by the IHE, such as the enterprise user authentication (EUA) and audit trail and node authentication (ATNA) can be used to facilitate these tasks. The RID profile was initially published in August 2003 and has seen a rather quick market uptake. Several prototype implementations from different vendors have been successfully tested for their interoperability at the IHE cross-vendor testing events, and several commercial products are already available on the market.

Cross-Enterprise Document Sharing (XDS)

Another IHE specification aiming to provide means for EHR document archiving is the cross-enterprise document charing (XDS). XDS is a rather new since the final implementation documentation was released in 2005 (IHE 2005b). It defines registry and repository services, by using an ebXML registry with one or more attached repository systems, and can function as a centralised or distributed warehouse for clinical documents. However, XDS is document centric and "content agnostic" in the sense that any kind of document can be stored in an XDS archive, provided that the metadata for the document, for which XDS has a detailed specification, are available. Figure 1, offers a simple view of the systems (actors) and transactions (interfaces) that are defined by the

Figure 4. Actors and transactions of the IHE XDS integration profile (IHE 2005b)



XDS integration profile. A *Document Source* represents a healthcare information system that acts as a point of service where care is provided and clinical information is collected. Subsequently, a document source provides clinical documents (along with metadata) to one or more *Document Repositories* which store the document and then forward the metadata to the central *Document Registry,* in order to register the document. In other words, the document registry does not actually store any document per say, it simply stores the related to the document meta information along with reference regarding the repository from which a document can later be retrieved. A *Document Consumer* is a service application system where care is provided and access to clinical documents is needed. The document consumer queries the central registry for certain documents and receives as a response a list of corresponding to the query documents. Access to the documents and retrieval is then possible through direct access to the document repositories where the documents are stored. The *Patient Identity Source*, finally, is the central system that assigns and manages patient identifiers for one XDS installation.

Based on this simple description it becomes evident that the XDS integration profile mainly provides a storage, indexing and distribution mechanism. However, through specific collaborations between the involved parties, it will be capable of supporting and complementing HL7 CDA documents and EHRcom (13606) equivalent structures, but not a full EHR system.

DISCUSSION

Based on the above overview of the standardization efforts toward the realization of interoperable and compatible EHRs, it becomes evident that the related standards vary widely with regard to their scope and content. Some of them offer a specific content and structured format while others do not. Moreover, some standards define access services, and security features for retrieving and submitting EHR content. For this reason, it is necessary to provide the readers with a simple yet comprehensive guide, presenting all the standards described earlier along with their most important capabilities (Table 1).

Table 1, initially assesses the EHR scope of each standard in terms of content structure and access services. Afterwards, it investigates each standard by utilizing specific EHR aspects (e.g. for content structure, access services, and security features). Features that are not supported

Table 1. Overview of features and service of EHR standards (Adapted by Eichelberg et al., 2005)

	CEN EHRcom	HL7 CDA	DICOM WADO	DICOM SR	IHE RID	IHE XDS
EHR Scope						
EHR content structure	Yes	Yes	No	Yes	No	No
EHR access services	Yes	No	Yes	No	Yes	No
EHR content structure						
EHR contains persistent documents	Yes	Yes	**N/A**	Yes	**N/A**	**N/A**
EHR can contain multimedia data	Yes	Yes	**N/A**	Yes	**N/A**	**N/A**
EHR can contain references to multimedia data	Yes	Yes	**N/A**	Yes		
EHR structured content suitable for processing	Yes	Yes	**N/A**	Yes	**N/A**	**N/A**
EHR supports archetypes /templates	Yes	Yes	**N/A**	Yes	**N/A**	**N/A**
EHR specifies library of archetypes/ templates	Yes	Yes	**N/A**	Yes	**N/A**	**N/A**
EHR specifies distribution rules	Yes	No	**N/A**	No	**N/A**	**N/A**
EHR standard covers visualization	No	Yes	**N/A**	No	**N/A**	**N/A**
EHR supports digital signatures on persistent documents	No	No	**N/A**	Yes	**N/A**	**N/A**
EHR access services						
Service for querying EHR content	Yes	**N/A**	No	Yes	Yes	Yes
Service for retrieving EHR content	Yes	**N/A**	Yes	Yes	Yes	Yes
Service for submitting EHR content	Yes	**N/A**	No	Yes	No	Yes
Document-Centric storage/retrieval	No	**N/A**	Yes	Yes	Yes	Yes
Content format agnostic	No	**N/A**	No	No	Yes	Yes
EHR security features						
Supports transport level encryption	Yes	**N/A**	Yes	Yes	Yes	Yes
Protocol allows to transmit user credentials	Yes	**N/A**	Yes	Yes	Yes	Yes
Protocol enforces access rules	Yes	**N/A**	No	No	No	Yes

by specific standards are characterized with the initials N/A, meaning “Not Applicable”. In addition, bearing in mind that some EHR standards have overlapping areas, it makes an absolute sence to consider the combination of different aspects of EHR standard functions and services. However, this is a complicated task with many hidden risks, since implementation project needs, scope and targeted areas may vary. Nevertheless, an important initiative that can work as a source for finding a plethora of important information regarding not only the technical specifications and capabilities of each standard, but also the possibility of standard’s combination, is the RIDE Project[4] (Funded by the European Union). RIDE is “a roadmap project for interoperability of eHealth systems leading to recommendations for actions and to preparatory actions at the European level”. This roadmap will “prepare the ground for future actions as envisioned in the action plan of the eHealth Communication COM 356, by coordinating various efforts on eHealth interoperability in member states and the associated states".

CONCLUSION

The ever increasing demand for cost containments and provision of quality patient care has led to making healthcare organizations heavily dependent on Information and Communication Technology (ICT). However, the rapid evolution of software applications and healthcare information systems has created an urgent demand for standardization in the healthcare IT market. This demand for standards has also become an urgent need, in order to enable EHR information to be shared between different healthcare facilities. Standards to support EHR communication are at an advanced stage of development, however, further research and implementation work to refine and improve these standards is a must. Overall, standards can support affordable and scalable systems that can be upgraded, as opposed to risky investments in proprietary solutions. Communication standards can allow products from multiple vendors to easily exchange clinical information and contribute to the improved compatibility and interoperability among a variety of applications and systems. Moreover, by utilizing standardized products, healthcare organizations can start with low-entry systems for single departmental solutions and gradually build up larger scale systems up to a comprehensive Electronic Health Record spanning across healthcare enterprises.

REFERENCES

Beale, T. (2002). Archetypes: constraint-based domain models for future-proof information systems. In *OOPSLA 2002 Workshop on Behavioural Semantics*. Retrieved from http://www.deepthought.com.au/it/archetypes/archetypes new.pdf

Beale, T. (2005). The openEHR Integration Information Model. openEHR Reference Model. *The openEHR foundation*.

Beale, T. and Heard, S. (2003). Archetype definitions and principles. *The openEHR foundation*.

Blobel, B. (2002). Evaluation and harmonisation of electronic healthcare record architecture approaches. *Business Briefing: Global Healthcare,* 1-5.

Booth, N., Jain, N. L., & Sugden, B. (1999). *The TextBase project — implementation of a base level message supporting electronic patient record transfer in English general practice*. Proceedings of the AMIA Annual Symposium, 691-5.

Bredegaard, K. (2000). National standardisation of electronic health care records in Denmark. *Toward an Electronic Health Record Europe 2000*, 98-102.

Brown, N., & Reynolds, M. (2000). Strategy for production and maintenance of standards for interoperability within and between service departments and other healthcare domains. *Short Strategic Study CEN/TC 251/N00-047, CEN/TC 251 Health Informatics*. Brussels: Belgium.

CEN ENV 12265. (1997). *Medical informatics { electronic healthcare record architecture*. European Prestandard ENV 12265. European Committee for Standardization. Brussels: Belgium.

CEN ENV 13606. (2000). *Medical informatics { electronic healthcare record communication. european prestandard ENV 13606*. European Committee for Standardization. Brussels: Belgium. CEN/TC 251. *European committee for standardization - technical committee on health informatics*. Retrieved from http://www.centc251.org/.

Deftereos, S., Lambrinoudakis, C., Andriopoulos, P., Farmakis, D., & Aessopos, A. (2001). A java-based electronic healthcare record software for beta-thalassaemia. *Journal of Medical Internet Research*, *3*(4), e33. doi:10.2196/jmir.3.4.e33

DICOM. (2004). Digital imaging and communications in medicine. *NEMA Standards Publication PS 3, National Electrical Manufacturers Association*. Rosslyn: VA, USA.

Dixon, R., Grubb, P. A., Lloyd, D., & Kalra, D. (2001). Consolidated list of requirements. *EHCR Support Action Deliverable 1.4. European Commission DGXIII*. Retrieved from http://www.chime.ucl.ac.uk/HealthI/EHCR-SupA/ del1-4v1_3.PDF.

Dolin, R. H., Alschuler, L., & Beebe, C. (2001). The HL7 clinical document architecture. *Journal of the American Medical Informatics Association*, *8*(6), 552–569.

Eichelberg, M., Aden, T., Riesmeier, J., Dogac, A., & Laleci, G. B. (2005). A survey and analysis of Electronic Healthcare Record standards. *ACM Computing Surveys*, *37*(4), 277–315. doi:10.1145/1118890.1118891

Garg, A. X., Adhikari, N. K. J., McDonald, H., Rosas-Arellano, M. P., Devereaux, P. J., & Beyene, J. (2005). Effects of computerized clinical decision support systems in practitioner performance and patient outcomes: A systematic review. *Journal of the American Medical Association*, *293*, 1223–1238. doi:10.1001/jama.293.10.1223

Griffith, S., Kalra, D., Lloyd, D., & Ingram, D. (1995). A portable and communicable architecture for electronic healthcare records: The good European Healthcare Record Project (AIM project 2014). Greenes, R. A. and others, eds. *Medinfo 8*(1995), 223-226.

Grimson, J., Grimson, W., Berry, D., Stephens, G., Felton, E., & Kalra, D. (1998). A CORBA-based integration of distributed electronic healthcare records using the synapses approach. *IEEE Transactions on Information Technology in Biomedicine*, *2*(3), 124–138. doi:10.1109/4233.735777

HL7 2.5 (2000). HL7. Application protocol for electronic data exchange in healthcare environments, version 2.5. *ANSI Standard*. Ann Arbor: MI, USA.

HL7 V3. HL7. *Version 3 message development framework*. Retrieved http://www.hl7.org/library/mdf99/mdf99.pdf

HL7 CDA Release 2.0 (2005). The HL7 version 3 standard: Clinical data architecture, release 2.0. *ANSI Standard*. HL7 RIM. HL7. *Reference information model.* Retrieved from http://www.hl7.org/library/data-model/RIM/modelpage non.htm

Hussein, R., Engelmann, U., Schroter, A., & Meinzer, H. P. (2004a). DICOM structured reporting: Part 1. Overview and characteristics. *Radiographics*, *24*(3), 891–896. doi:10.1148/rg.243035710

Hussein, R., Engelmann, U., Schroter, A., & Meinzer, H. P. (2004b). DICOM structured reporting: Part 2. Problems and challenges in implementation for PACS workstations. *Radiographics*, *24*(3), 897–909. doi:10.1148/rg.243035722

Iakovidis, I. (1998). Towards personal health record: Current situation, obstacles and trends in implementation of electronic healthcare records in Europe. *International Journal of Medical Informatics*, *52*(128), 105–117. doi:10.1016/S1386-5056(98)00129-4

IHE. (2005a). *IT infrastructure technical framework revision 2.0*. Retrieved from http://www.ihe.net/Technical Framework/index.cfm.

IHE. (2005b). *Cross-enterprise document sharing for maging (XDS-I)*. IHE Radiology TechnicalFramework, Supplement 2005-2006, Trial Implementation, Integrating the Healthcare Enterprise. Retrieved http://www.ihe.net/Technical Framework/upload/IHE RAD-TF Suppl XDSI TI 2005-08-15.pdf

Ingram, D., Griffith, S., Maskens, A. P., Kalra, D., Lloyd, D., & Southgate, L. (1995). The Good European healthcare record project - the results of a three year project to design a common architecture for healthcare records across Europe AIM project A2014. *Future of Patient Records - Care for Records of Care. May 1995*, 415-419.

ISO 17432. (2004). *Health informatics - messages and communication - Web access to DICOM persistent objects*. International Standard IS 17432, International Organization for Standardization, Geneva, Switzerland.

ISO/TR 20514. (2005). *Health informatics - electronic health record - definition, scope and context*. Technical Report TR 20514. International Organization for Standardization. Geneva: Switzerland.

ISO/TS 18308. (2004). *Health informatics - requirements for an electronic health record architecture*. Technical Specification TS 18308. International Organization for Standardization, Geneva: Switzerland.

Kalra, D. (2006). Electronic health record standards. *IMIA Yearbook of Medical Informatics*, 136-144.

Lenz, R., Kuhn, K. (2002). *Integration of heterogeneous systems in hospitals*. Business briefing: data management and storage technology

Lewis, D., Eysenbach, G., Kukafka, R., Stavri, Z., & Jimison, H. B. (2005). *Consumer health informatics informing consumers and improving health care* (Eds.). Health Informatics Series, Springer Science+Business Media, Inc., USA, 2005.

Mykkanen, J., Porrasmaa, J., Rannanheimo, J., & Korpela, M. (2003). A process for specifying integration for multi-tier applications in healthcare. *International Journal of Medical Informatics*, *70*, 173–182. doi:10.1016/S1386-5056(03)00058-3

Smith, R. (1996). What clinical information do doctors need? *British Medical Journal*, (Oct): 313, 1062–1068.

Supplement, D. I. C. O. M. 85 (2004). Web Access to DICOM Persistent Objects (WADO). *Joint DICOM standards committee / ISO TC215 Ad Hoc WG on WADO, final text*. Retrieved from ftp://medical.nema.org/medical/dicom/_nal/sup85 ft.pdf.

Tanenbaum, A. S. (1988). *Computer networks, 2nd ed*. Englewood Cliffs, N.J: Prentice-Hall.

Tang, P. C., & McDonald, C. J. (2006). Electronic health record systems. In Cimino, J. J. and Shortliffe, E. H. (eds.) *Biomedical Informatics: Computer Applications in Health Care and Biomedicine (Health Informatics)*. Springer-Verlag, New York, Inc.

Xu, Y., Sauquet, D., Zapletal, E., Lemaitre, D., & Degoulet, P. (2000). Integration of medical applications: the mediator service of the SynEx platform. *International Journal of Medical Informatics*, *58-59*, 157–166. doi:10.1016/S1386-5056(00)00084-8

KEY TERMS AND DEFINITIONS

E-Health: It is a relatively recent term for healthcare practice which is supported by electronic processes and communication. The term is inconsistently used: some would argue it is interchangeable with health care informatics and a sub set of Health informatics, while others use it in the narrower sense of healthcare practice using the Internet. The term can encompass a range of services that are at the edge of medicine/healthcare and information technology like electronic health records, telemedicine, evidence-based medicine, virtual healthcare teams etc.

Electronic Health Record: An electronic health record (EHR) refers to an individual patient's medical record in digital format. Electronic health record systems co-ordinate the storage and retrieval of individual records with the aid of computers. EHRs are usually accessed on a computer, often over a network. It may be made up of electronic medical records (EMRs) from many locations and/or sources. A variety of types of healthcare-related information may be stored and accessed in this way.

Health Level Seven (HL7): It is an all-volunteer, not-for-profit organization involved in development of international healthcare standards. HL7 is also used to refer to some of the specific standards created by the organization (i.e. HL7 v2.x, v3.0, HL7 RIM etc.).

Electronic Health Record (EHR) Standards: Standards are documented agreements containing technical specifications or other precise criteria to be used consistently as rules, guidelines, or definitions of characteristics, to ensure that materials, products, processes and services are fit for their purpose. There are three main organizations that create standards related to EHR- HL7, CEN TC 215 and ASTM E31. HL7, operating in the United States, develops the most widely used healthcare-related electronic data exchange standards in North America, while CEN TC 215, operating in 19 European member states, is the preeminent healthcare information technology standards developing organization in Europe.

Interoperability: Interoperability is the ability of information and communication systems and business processes to support data flow and to enable the exchange of information and knowledge. Interoperability must be secured at the technical (norms and standards for linking computer systems and services), semantic (meaning of data) and process levels (defining business aims, modelling business processes and actualizing cooperation between various management units). Interoperability can be achieved by adopting national and international technical norms.

ENDNOTES

[1] OpenEHR available at http://www.openehr.org.

[2] See http://www.hl7.org for current information on HL7 and its evolution.

[3] IHE. Integrating the Healthcare Enterprise. http://www.ihe.net/.

[4] For more information you can visit http://www.srdc.metu.edu.tr/webpage/projects/ride/index.php.

This work was previously published in Handbook of Research on Distributed Medical Informatics and E-Health, edited by A. Lazakidou; K. Siassiakos, pp. 84-103, copyright 2009 by Medical Information Science Reference (an imprint of IGI Global).

Chapter 1.26

Process Level Benefits of an Electronic Medical Records System

Abirami Radhakrishnan
Morgan State University, USA

Dessa David
Morgan State University, USA

Jigish Zaveri
Morgan State University, USA

INTRODUCTION

The challenges faced by U.S. health care system are vividly explained in the U.S. Government's health information technology plan,

> The U.S. health care system faces major challenges. Health care spending and health insurance premiums continue to rise at rates much higher than the rate of inflation. Despite spending over $1.6 trillion on health care, there are still serious concerns about preventable errors, uneven health care quality, and poor communication among doctors, hospitals, and many other health care providers involved in the care of any one person. The Institute of Medicine estimates that between 44,000 and 98,000 Americans die each year from medical errors. Many more die or have permanent disability because of inappropriate treatments, mistreatments, or missed treatments in ambulatory settings. It has been found that as much as $300 billion is spent each year on health care that does not improve patient outcomes – treatment that is unnecessary, inappropriate, inefficient, or ineffective. All these problems – high costs, uncertain value, medical errors, variable quality, administrative inefficiencies, and poor coordination – are closely connected to inadequate use of health care information technology. (U.S. Federal Government Health Information Technology Plan, 2004).

These challenges have resulted in formidable and compelling pressures on the U.S. Federal Government, professional bodies, and accreditation authorities to undertake measures to bring about significant improvements in the quality of health

DOI: 10.4018/978-1-59904-889-5.ch136

care in both inpatient and outpatients settings. Quality is defined by the Institute of Medicine as having three overlapping domains: safety of patients and practitioners, practice consistent with current domain knowledge, and patient centered care (Kohn, Corrigan, & Donaldson, 2000). In the current environment, one of the important measures undertaken to improve quality of health care is adoption and use of computers and information technology such as electronic medical records system (EMR) by health care providers and medical institutions.

Introduction of EMR has received considerable attention because of its potential effectiveness in (a) implementation of decision support, (b) reducing practice expenses, (c) increasing revenues by improving office efficiency, and (d) making health records more up to date, accessible, legible, and modifiable (Gill, Ewen, & Nsereko, 2001; Hippisley-Cox, Pringle, Carter, Wynn, Hammersley, & Coupland, 2003; Singh, Servoss, Kalsman, Fox, & Singh, 2004).

Even though a few studies in the literature have tried to examine the usefulness of EMR at organizational level (Gill et al., 2001; Hippisley-Cox et al., 2003; Miller & Sim, 2004; Singh et al., 2004), very little research has been done on examining the various components of EMR systems and the process level benefits of these systems. As Barua, Kriebel, and Makhopadyay (1995) point out, by attempting to relate IT implementation directly to output variables at the organizational level, the intermediate processes through which IT impacts are felt are totally ignored. When information technologies such as EMR systems are deployed effectively, they interact with intermediate organizational processes, and deliver value by building unique process level benefits, which finally result in organizational level outcomes. Therefore, there is a need for more granular studies that explicate the underlying linking mechanism (process) between IT implementation and organizational level impacts (Radhakrishnan, Zu, & Grover, 2007).

In this article, we pursue this line of thought and examine the various components of EMR and the potential process level benefits of EMR systems by presenting case summaries. This article contributes to the literature and practice in two ways: First, it provides insights into various modules of EMR system and how they interact with each other to bring out value to users. Second, we present six case summaries (based on qualitative case analysis and content analysis of Web sites) to illustrate the potential process level benefits of EMR systems. The remainder of this article is organized as follows. The next section provides an overview of EMR and its components. In the following section, we present six case summaries to illustrate the potential process level benefits of EMR systems.

OVERVIEW OF EMR

What is EMR?

Electronic medical records system (EMR) is defined as an interorganizational information system that captures the essential components of a patient's medical encounter with the medical provider, including storage and retrieval of subjective, objective patient information, and assessment and plans for patient care (Lenhart, Honess, Covington, & Johnson, 2000). EMR systems facilitate physicians and other health care professionals to:

- Monitor the health status of their patients with electronic medical charts.
- Support health care decisions with evidence-based guidelines.
- Expedite referrals to specialists and other health care providers.
- Computerize ordering of prescription drugs, laboratory tests, and radiology results.
- Store and retrieve patients' medical records from different locations.

Why EMR?

While conducting a field study involving hospitals in countries such as UK and USA, Lederman (2005) found that there are several problems faced by health care professionals while handling patients' medical records. These problems are listed below:

First, in many hospitals, only paper-based records are maintained. Management of paper-based records becomes a significant problem due to the possibilities of losing or misplacing records.

Second, data inconsistency and data integrity are other problems related to paper-based records. Patient files can be changed with no assurance that changes made would be incorporated into a central repository or vice versa. This could lead to a possibility of different, conflicting records being held for the same patient. This increases the probability of incorrect information being accessed.

Third, nonintegrated databases across hospitals pose a significant problem, providing a major impediment to collection, access, and ability to view patient records. The medical staff in each hospital manually enters patients' records into the system. This may cause potential problems like inefficient use of time, loss of productivity, and data entry errors.

EMR can help in overcoming these problems (Bria, 2006; Doyle, 2006; Simon & Simon, 2006). In a survey of 703 practicing family physicians in the U.S., Karsh, Beasley, and Hagenauer (2004) found that the physicians preferred electronic medical records to paper based records as they were up to date, modifiable to meet individual needs, accessible when needed that resulted in better record quality. These studies highlight the value of EMR systems.

Components of EMR

An EMR system has several different modules. Organizations can implement specific modules or all the modules depending upon their needs.

Patient Registration Module (PRM)

This module helps with patient's registration. It helps track and maintain relevant details on the patient (such as name, date of birth, address, contact number, financial class), health insurance plans (insurance company, type of insurance policy, and level of copay), and historical as well as scheduled appointments.

Appointment Scheduling Module (ASM)

This module helps with scheduling appointments. Appointment reservations are scheduled for specialists, general practitioners, and for other resources such as medical labs, emergency rooms, operation theaters, and so forth. It provides flexible appointment schedules where one can request convenient time slots. Patients and support staff can search and view availability of resources within various departments, specialties, and locations.

Medical Billing and Receivables Module (MBRM)

This module helps with "super-bill" (i.e., comprehensive bill) creation and collection of receivables. This module helps track charges associated with diagnosis, medical check-ups, medical procedures, surgical procedures, lab tests, and medical prescriptions. Then super-bills are created by bundling all the charges for a variety of services provided by different departments. The co-pay amounts from patients are recorded. This module retrieves patients' insurance details and sends medical claims to insurance clearance agencies. This module tracks all the accounts receivables from insurance agencies. If payments are not received from insurance agencies within the stipulated period, it rebills the customers for outstanding dues.

Ambulatory Care Module (ACM)

This module maintains patient's medical records. It maintains patients' family and social history, statistics on vital parameters, immunization records, allergies, surgical procedures, physical examination reports, diagnosis results, lab reports, radiology reports, EKG charts, MRI, CT scan reports, medication reports, and any other remarks from other physicians in a central repository. This module permits users to record and retrieve digital photos, transcriptions, drawings, radiology images, MRI, CT scan charts, texts, graphs, and voice. Physicians can have their dictated progress notes transcribed and imported into the EMR, or record handwritten progress notes using a tablet PC.

E-Prescription Module (EPM)

This module generates and tracks electronic prescriptions. Physicians can write prescriptions electronically, which are then transmitted to the associated formularies and retail drug stores. Physicians can even electronically order referrals and laboratory and radiology tests. Users can track test-order status and extent to which a particular prescription is filled by a drug store.

Workflow Management Module (WMM)

This module manages the workflow within a health care organization. This module creates work lists for various professionals such as Specialists, General Practitioners, Nurses, and Lab Staff. This module interacts with the Appointment Scheduling Module and creates work lists for various professionals who are working in a health care organization.

Knowledge Base Module (KBM)

EMR system maintains a repository of clinical references for various disorders, medical complications and tracks information on latest drug dosages and delivery systems. Medical professionals can search this repository for any reference information.

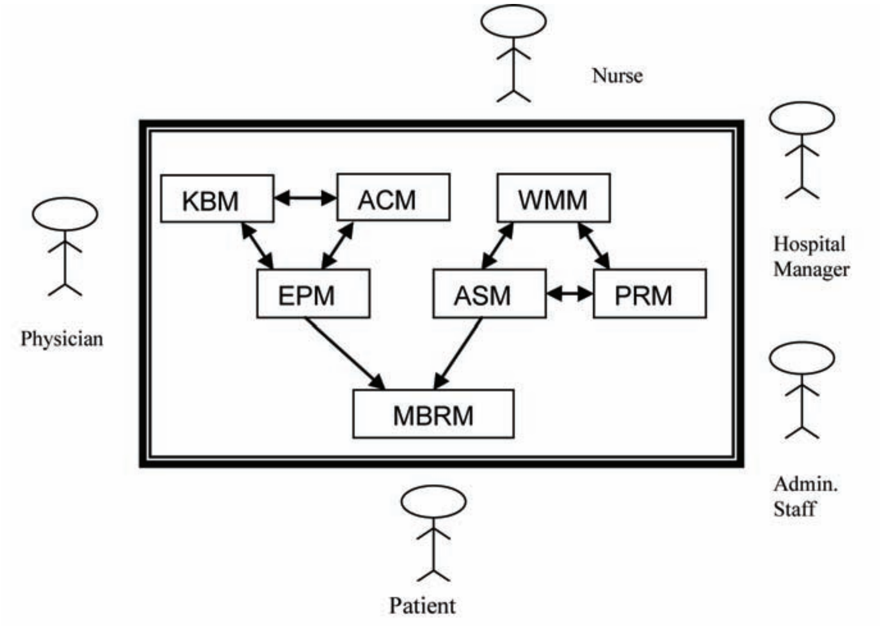
Figure 1 shows the different modules and their interaction. The appointment scheduling module (ASM), patient registration module (PRM) and workflow management module (WMM) frequently interact with each other while knowledge base module (KBM), ambulatory care module (ACM) and e-prescription module (EPM) frequently interact with each other. ASM and EPM feed into medical billing and receivables module (MBRM). As shown in Figure 1, physicians, nurses, hospital managers, administrative staff, and patients use EMR system.

RESEARCH METHODOLOGY

We conducted an exploratory case study on process level benefits of EMR systems. A case study is appropriate for an exploratory investigation like this (Yin, 2002). We employed a case study design using six organizations. We conducted interviews with EMR managers, physician champions, nurses, radiologists, and EMR vendors associated with a few hospitals and physician organizations that had adopted an EMR. We conducted the interviews during the period 2005-06. Using six different organizations allowed comparisons between them for more general research results (Benbasat, Goldstein, & Mead, 1987; Yin, 2002).

We triangulated qualitative data from multiple sources. As mentioned earlier, we conducted telephonic interviews with EMR managers, physician champions, nurses, radiologists, and EMR vendors. We relied heavily on the support of these experts. We used a structured interview guide for our interviews. This interview guide had both closed ended questions and open ended probing questions. Findings from closed ended responses were compared with answers to the open-ended questions. We verified answers by having interviewees review our notes on their responses. We also conducted several face-to-face meetings with

Figure 1. Modules of EMR system and their inter-relationship



representatives from one hospital who were willing to participate in our project.

We also reviewed reports from secondary sources such as trade journals. We also conducted content analysis of Web sites of organizations. We considered data associated with the period 2001-2006. Krippendorf (1980) defines content analysis as a technique wherein a researcher searches for structures and regularities in the content and draws inferences on the basis of these regularities. Here content refers to process level benefits. For consistency, the same researcher did content analysis of the various Web sites.

We conducted cross-case analysis and identified consistent patterns regarding process level benefits of EMR systems.

ANALYSIS AND DISCUSSION OF PROCESS LEVEL BENEFITS

We present six case summaries to highlight the process level benefits of EMR systems.

Case Summaries

Case #1: Oconee Memorial Hospital (http://www.oconeememorial.org/index.cfm?PageID=72)

Oconee Memorial Hospital operates in South Carolina, USA, and is considered progressive in the use of health care IT systems. In late 2003, they got interested in implementing an EMR system known as Practice Management Plus and Horizon Ambulatory Care. It is a part of a larger information network known as Foothills Health Information Network. They initially implemented the system in the radiology section in early 2004 before using it hospital wide. Radiologists used EMR to create and interpret images derived from a variety of modalities: radiography, ultrasound, magnetic resonance imaging (MRI), positron emission tomography (PET), and computed tomography (CT). EMR captures both analog and digital images. EMR also captures metadata concerning who viewed, annotated, printed, and sent specific data and when those activities occurred. This ability of EMR to capture and replay aspects of invisible work resulted in information richness as well as new accountabilities. The search and retrieval processes were enhanced in a digital environment. Now this hospital uses many modules such as appointment scheduling, billing and receivables, patient registration, ambulatory care, and workflow management. Based on the post-implementation evaluation, they have identified the following process level benefits: improved coordination among departments within the hospital, improved access to the patients' medical records from remote locations, improved throughput of diagnosis, treatment and consultation, reduced time taken for delivery of services, improved speed and accuracy of medical insurance claims registration, improved data integrity of patient's medical records, better control of employee work schedule and the institution's overall responsiveness.

Case # 2: Ogden Clinic (http://www.nextgen.com/images/pdfs/Ogden-FCG.pdf)

Ogden Clinic is a multispecialty group practice in Utah, USA. They implemented Next Gen EMR and enterprise practice management systems in 2005. Ogden Clinic began experiencing the following process level improvements: Patient check-in process gets completed in half the time and several reporting tasks associated with the receptionist function have been reduced by half. Using point-of-care documentation templates have allowed Ogden Clinic to eliminate 95% of its transcription use. Scanning and electronic storage of documents have reduced the volume of paper work by 75%. Electronic ordering and results management have been greatly streamlined—with an electronic interface to the laboratory information system, an EKG interface, and e-prescribing capabilities saving valuable physician and support staff time. With health maintenance reminders linked to its disease management programs and a robust set of online patient education materials, Ogden Clinic automatically generates patient recall reminders on a weekly basis, alert physicians when patient interventions are overdue, and provide comprehensive clinical information tailored to each patient's condition. As a result, the organization has recorded an annual increase in revenue of $72,000 attributable to the additional health maintenance visits. Whenever a national drug is recalled, Ogden Clinic generates a list of all its patients on that medication and sends them personalized letters with instructions, providing timely care and saving staff time.

Case # 3: Northwest Diagnostic (www.healthmgttech.com)

Northwest Diagnostic is a family practice clinic in Texas, USA. They implemented the clinical charting, ambulatory care, billing, and scheduling modules of the e-MD EMR system in 2005. Viewing capabilities of EMR system resulted in an up to date availability of data and charts, better data organization and legibility. Support staff reported that they spend less time finding, pulling and filing charts. Physicians reported that they spend less time in locating information. They were able to access and modify the records as and when needed. They reported that they are able to spend more time on assessment and patient care. Coding documentation (different medical procedures have different codes) also improved. Quality of preventive care and disease management improved because of use of electronic alerts on symptoms and allergy lists. Billing procedures also dramatically improved. All these resulted in a saving of a quarter of million dollars in the very first year after implementation.

Case # 4: Cayuga Family Medicine (http://www.healthmgttech.com/archives/1106/1106bridging_gap.htm)

Cayuga Family Medicine is a New York-based low volume practice that focuses on pediatrics and obstetrics. They implemented the patient registration, appointment scheduling and medical billing modules of EMR system in 2000. Cayuga realized the following process level improvements: reduction in the transcription and billing errors, improvement in the speed and accuracy of medical insurance claims registration, data consistency of the patient's medical records and overall productivity of the physicians and front office staff.

Case # 5: Newport Heart (http://www.alteer.com)

Newport Heart is a California based cardiology unit. It implemented the medical billing, clinical charting, and patient registration modules of the EMR system. They experienced the following benefits after implementation of the EMR system: improvement in cash flows, reduction in accounts receivables by 25%, reduction in the time taken for delivery of services to patients, improved ability to inform patients about their up to date financial account status, accurate patients' records, and reduction in the paper work by 90%.

Case # 6: Public Hospitals and Polyclinics under National Health Care Group and Singapore Health Services, Singapore (http://www.zdnetasia.com/news/business/0,39047112,39189253,00.htm)

Seven public hospitals under National Health Care Group and 17 polyclinics under the Singapore Health Services share in-patient discharge summarizes including prescriptions, treatments, and allergies and out-patient records, x ray and lab reports through a centralized platform of EMR system. The hospitals and polyclinics have realized the following benefits: better coordinated care for patients moving across different providers, reduction in transcription errors, better clinical decisions with access to complete and legible clinical histories, cost savings through the avoidance of unnecessary repeat tests and investigations, 24-hour access to real time data for up-to-date results reporting, and improved data security with provision for audit trails.

In summary, we were able to identify several process level benefits from EMR adoption and use such as:

a. Improved coordination between departments in the hospital,
b. Better access to legible medical records from remote locations,
c. Increased throughput for diagnosis, treatment and consultation,
d. Increased speed and accuracy of medical insurance claims registration,
e. Improved data integrity of patient medical records,
f. Better work schedule management,
g. Improved data security and audit trails,
h. Better disease management and preventive care, and
i. Increased costs savings.

CONCLUSION

Electronic Medical Records system (EMR) is an enabling interorganizational information system for overall improvement in health care quality. In this article, various modules of EMR and the relationships between them were presented. There are several modules such as patient registration, appointment scheduling, ambulatory care, e-prescription, knowledge base management, work flow management, billing and receivables management modules. They all work synergistically to increase the value and benefits to all stakeholders.

The process level benefits of EMR systems were then examined by conducting qualitative case analysis of six organizations that had implemented EMR systems and content analysis of their Web sites. Assessment of benefits (at the process level) helps to explicate the underlying linking mechanism between EMR implementation and organizational level impacts. We were able to identify several process level benefits from EMR adoption.

While a few studies in the literature tried to examine the usefulness of EMR at organizational level, very little research has been done to examine the various components of EMR and process level benefits of EMR systems. We have set a stage for examining process level benefits of EMR systems to organizations. Researchers should further this line of research by conducting a longitudinal study involving several health care organizations and examine the process level benefits of EMR systems. Researchers could use theoretical lenses of Transaction Cost Economics, Resource Based View, and Digital Options theory to explain the process level benefits of EMR systems.

REFERENCES

Anonymous. (2007). Newport heart case study. Retrieved February 14, 2008, from http://www.alteer.com/features+benefits/case_studies/index.php

Barua, A., Kriebel, C. H., & Mukhopadyay, T. (1995). Information technologies and business value: An analytical and empirical investigation. *Information Systems Research*, *6*(1), 3–23. doi:10.1287/isre.6.1.3

Benbasat, I., Goldstein, D. K., & Mead, M. (1987). The case research strategy in studies of information systems. *MIS Quarterly*, *11*(3), 369–386. doi:10.2307/248684

Bria, W. (2006). Applied medical informatics for the chest physician: Information you can use! *Chest*, *129*, 446–452. doi:10.1378/chest.129.2.446

Davis, M. (Ed.). (2007). Foothills health information network. Retrieved February 14, 2008, from http://www.oconeememorial.org/index.cfm?PageID=72

Doyle, M. (2006). Promoting standardized nursing language using an electronic medical record system. *AORN Journal*, *83*, 1335–1347. doi:10.1016/S0001-2092(06)60147-6

First Consulting Group. (2007). Measurable benefits achieved early in EMR implementation – and growing quickly. Retrieved February 14, 2008, from http://www.nextgen.com/images/pdfs/Ogden-FCG.pdf

Gill, J. M., Ewen, E., & Nsereko, M. (2001). Impact of electronic medical record on quality of care in primary care office. *Delaware Medical Journal*, *73*(5), 187–194.

Hippisley-Cox, J., Pringle, M., Carter, R., Wynn, A., Hammersley, V., & Coupland, C. (2003). The electronic patient record in primary care – regression or progression? A cross sectional study. *British Medical Journal*, *326*, 1439–1443. doi:10.1136/bmj.326.7404.1439

Karsh, B., Beasley, J. W., & Hagenauer, M. E. (2004). Are electronic medical records associated with improved perceptions of quality of medical records, working conditions or quality of working life? *Behaviour & Information Technology*, *23*(5), 327–335. doi:10.1080/01449290410001693845

Kohn, L. T., Corrigan, J., & Donaldson, M. S. (Eds.). (2000). To err is human: Building a safer health system (1st ed.). Washington DC: National Academy Press.

Krippendorff, K. (1980). Content analysis: An introduction to its methodology. Beverly Hills, CA: Sage Publications.

Lai, E. N. (2004). Tech supplements. Retrieved February 14, 2008, from http://www.zdnetasia.com/news/business/0,39047112,39189253,00.htmLederman, R. (2005). Managing hospital databases: Can large hospitals really protect patient data? Health Informatics Journal, 11, 201-210.

Lenhart, J. G., Honess, K., Covington, D., & Johnson, K. E. (2000). An analysis of trends, perceptions, and use patterns of electronic medical records among U.S. family practice residency Ppograms. *Family Medicine*, *32*(2), 109–114.

Loehr, J. (2007). Bridging the gap. Retrieved February 14, 2008, from http://www.healthmgttech.com/archives/1106/1106bridging_gap.htm

McBride, M. (Ed.). (2007). Northwest diagnostic case study. Retrieved February 14, 2008, from www.healthmgttech.com

Miller, R. H., & Sim, I. (2004). Physicians' use of electronic medical records: Barriers and solutions. *Health Affairs*, *23*(2), 116–126. doi:10.1377/hlthaff.23.2.116

Radhakrishnan, A., Zu, X., & Grover, V. (in press). A process-oriented perspective on differential business value creation by information technology: An empirical investigation. Omega . *The International Journal of Management Science.*

Simon, S. J., & Simon, S. J. (2006). An examination of the financial feasibility of electronic medical records (EMRs): A case study of tangible and intangible benefits. *International Journal of Electronic Healthcare*, *2*, 185–197.

Singh, R., Servoss, T., Kalsman, M., Fox, C., & Singh, G. (2004). Estimating impacts on safety caused by the introduction of electronic medical records in primary care. *Informatics in Primary Care*, *12*, 235–241.

U.S. Federal Government Health Information Technology Plan. (2004). Retrieved February 14, 2008, from http://www.whitehouse.gov/infocus/technology/economic_policy200404/chap3.html

Whitten, J. L., & Bentley, L. D. (2007). Systems analysis and design methods. New York: Mc Graw Publications.

Yin, R. K. (2002). Case study research, design and method (3rd ed.). Newbury Park: Sage Publications.

KEY TERMS AND DEFINITIONS

Electronic Medical Records System: An interorganizational information system that captures the essential components of a patient's medical encounter with the medical provider, including storage and retrieval of subjective, objective patient information, assessment, and plans for patient care (Lenhart et al., 2000).

EMR Process Level Benefit: A benefit measured at the process level after 2 years of adoption and use of Electronic Medical Records System in medical institutions (adapted from Radhakrishnan et al., 2007).

Health Care Information System: An arrangement of information technology, people, data, and processes that interact to gather, process, store, and disseminate health care information (adapted from Whitten & Bentley, 2007).

This work was previously published in Encyclopedia of Healthcare Information Systems, edited by N. Wickramasinghe; E. Geisler, pp. 1085-1092, copyright 2008 by Medical Information Science Reference (an imprint of IGI Global).

Chapter 1.27

A Comparison of How Canada, England, and Denmark are Managing their Electronic Health Record Journeys

Denis Protti
University of Victoria, Canada

ABSTRACT

Healthcare is one of the world's most information-intensive industries. Every day, volumes of data are produced which, properly used, can improve clinical practice and outcomes, guide planning and resource allocation, and enhance accountability. Electronic health information is fundamental to better healthcare. There will be no significant increase in healthcare quality and efficiency without high quality, user-friendly health information compiled and delivered electronically. The growing use of information and communication technology (ICT) in the healthcare sector has introduced numerous opportunities and benefits to patients, providers and governments alike. Patients are being provided with tools to help them manage and monitor their healthcare, providers are able to seamlessly access up-to-date patient information, and governments are showing transparency to the public by reporting health data and information on their websites. There is mounting evidence that national, regional, and organizational e-health strategies are being developed and implemented worldwide. This chapter provides an overview of three different national e-health strategies, and identifies the lessons learned from the e-health strategies of Canada, England and Denmark.

DOI: 10.4018/978-1-59904-792-8.ch012

INTRODUCTION

Due to the ever increasing pressures and demands for healthcare services and the strain those services put on the economy, many nations have realized that they must develop a more sustainable, efficient and effective healthcare system. In doing this, there has been much investment in ICT. Information systems play a significant role in helping improve health outcomes and decision-making at the point of care, and the benefits don't stop there. There are a number of global themes that emerge regarding

Table 1. Global themes in health information systems

Theme	Deliverables and Challenges
Electronic Health Records (EHRs)	• Conveys clinical information • Coordinates care for particular diseases or services • "Virtual concept" reliant on the network approach • Pulls data from multiple stores
Decision Support Tools	• Supports clinician decision making at the service (planning, peer reviews) and care level (care plans, individual clinical actions) • Uses include: o Computerized Physician Order Entry (CPOE) o Computerized Nurse Order Entry (CNOE) o E-Prescribing o Formularies
Unique Patient Identifiers	• Enable EHRs to span across the continuum of care • Manages patient visits and person data
Connectivity	• Online access demands create a need for greater bandwidth • Addressing security demands in order to ensure patient information is secure
Common Standards and Minimum Data Sets	• Detailed data sets lack consensus within and across countries • Consistent and standardized reporting is lacking, worldwide
Coordination of Care in General Practice	• Growing use of more sophisticated practice management systems • Opportunities for greater functionality including clinical uses • Individual care plans are supported • Increasing number of electronic interactions • Supports the global trend to focus on primary care as the main focus of health service delivery • IT vendors are focusing more research and development budgets in this area
Telehealth	• Delivers community and home-based services remotely • Potential to provide specialist services to rural and disadvantaged communities, from a distance • Opportunity to deliver care, monitor and manage chronic conditions remotely via the internet • Devices available for home use to capture vital signs and transmit to the care provider
Consumer Involvement	• Consumers are making informed decisions • Demand for health information and knowledge • Available information should be integrated into service delivery to better involve consumers • Demand for individually tailored care
Access	• Demands on the healthcare system has resulted in various initiatives which allows consumers access to the most appropriate care provider o Call centers, knowledge bases, nurse-based telephone triage

the use of health information systems (Table 1). These themes include establishing electronic health records, developing clinical decision support tools and introducing Telehealth services to those in remote and rural areas often with a high incidence of chronic disease. Orchestrating the change from the paper-based world, to one with seamless and fluid information systems requires a great amount of coordination, time and funding and most importantly a comprehensive strategy.

The impact of the electronic health record (EHR) on patient care can be quite substantial (Infoway, 2006). Some of the potential benefits include:

- Improved communication between providers, and between providers and patients. In many countries, the flow of information has grown exponentially.
- In a number of countries, the implementation of the EHR among various professions has created momentum for working in teams. The EHR has been a catalyst for accelerating this key element of healthcare

innovation widely supported at the policy level throughout the world.

- Patient empowerment. In Denmark, people have access to their EHR. They can review information such as laboratory results and prescriptions to improve self-care—particularly important for chronic disease management. They can see which providers have viewed their records, which allows them to monitor privacy.
- Improved adherence to preventive measures. The literature suggests that electronically generated reminders for screening and follow-up increases adherence by 10% to 15%.
- Improved delivery of recommended care for various conditions. The Vanguard group, in Boston, delivered recommended care about 60% of the time in a baseline study. It improved to over 90% by combining team-based practice with the EHR.
- Nation-wide implementation of the EHR in the USA, including e-prescribing with decision support tools built in, could reduce adverse drug events by two million annually, preventing 190,000 hospitalizations.
- According to the literature, introducing the EHR into the ICU reduces ICU mortality by 46% to 68%; complications by 44% to 50%; and overall hospital mortality by 30% to 33%.
- The use of e-prescribing in Denmark has reduced the medication problem rate from 33% to 14%, and laboratory systems have reduced tube labeling errors from 18% to 2%.
- A major touted benefit of the EHR is chronic disease management (CDM). Some believe the benefits have already been demonstrated and there is consensus that the EHR is a necessary, but perhaps not sufficient, tool to improve CDM.

CANADA'S JOURNEY

Canada has an e-health strategy that is committed to accelerating the implementation of electronic health information systems in Canada. Canada Health Infoway Inc., an independent, not-for-profit organization, created in 2000, is governed by Canada's 14 federal, provincial and territorial Deputy Ministers of Health. Infoway provides leadership by establishing a strategic direction for EHR implementation in Canada in collaboration with the provinces and territories.

Canada Health Infoway recently released an updated electronic health record Solution blueprint for Canada. This blueprint is meant to be a business and technical framework defining how health information is shared "between health services providers (physicians, specialists, nurses and pharmacists) across care settings (hospitals, emergency rooms, clinics and homecare settings) and across geographical distances."

Currently, a key focus in Canada is to develop a network of interoperable electronic health record solutions across Canada, through linking clinics, hospitals, pharmacies and other points of care, in order to help increase access to healthcare services, enhance the quality of care and make the healthcare system more productive. Canada is planning on accomplishing the goals of achieving a comprehensive integrated electronic health records solution, through nine investment programs.

The main areas of interest of Canada Health Infoway are interoperable EHRs and related telehealth and applications. Priority activities are defined and funded from an allocation of $1.2 billion from the federal government. Infoway acts as a "strategic investor"and aims to build on existing work in Canadian Provinces or explore new initiatives in collaboration with other partners, whether healthcare organizations or commercial IT suppliers.

There are nine Infoway programs:

- Interoperable EHR (including privacy and security architecture and standards)
- Infostructure— (architecture, standards to ensure interoperability of systems and support reuse)
- Registries—to provide electronic identification of patients and providers and provide basis of health record system
- Telehealth Diagnostic Imaging
- Drug Information Systems—medication profiles and eventually e-prescribing
- Lab Information Systems—to view lab results
- Telehealth—particularly for rural and remote settings
- Health Surveillance
- Innovation/Adoption

The main objective is to make interoperable electronic health records available for 50% of the population by 2009. However, Canada's healthcare system still manages information with old technologies and practices, some of which literally originated in the 19th century (94% of physician visits in Canada involve paper records; most prescriptions are handwritten). The production of information has grown exponentially, but the capacity to process, analyze, and deploy it to good effect has not kept pace.

Though there has been some progress towards the EHR, it was recently reported that Canada lags significantly on use of electronic medical records in physician's offices (Schoen, 2006). An international survey of more than 6,000 doctors in seven countries found that only 23% of Canadian physicians use electronic medical records, which is the lowest percentage and far behind the 98% level in The Netherlands. Primary care doctors in Australia, the Netherlands, New Zealand and the United Kingdom have the most widespread and multifunctional systems. The majority of doctors in these countries also reported routine use of electronic prescribing and electronic access to test results. Overall, fewer than one-in-five Canadian and U.S. primary-care doctors have access to robust information systems that provide a foundation to guarantee high-quality care.

In the four countries that report widespread EMR use, about 50 to as much as 90% of doctors routinely use computerized alerts to notify themselves of possible prescribing problems, reminder systems to notify patients about preventive or follow-up care, and prompt to advise patients of test results. In contrast, less than a quarter of Canadian and U.S. doctors have computerized systems for these tasks.

Canada has five priorities in healthcare (Infoway, 2006):

1. Reduced wait times, not only in high profile areas such as hip and knee replacements and cancer care, but also in access to primary and specialty care, and underserved areas such as mental health;
2. Primary healthcare, with interdisciplinary teams providing comprehensive, convenient care with an increased emphasis on health promotion and prevention.
3. Enhanced patient safety in the community and institutions.
4. Improved quality of care, particularly for people with chronic conditions.
5. Improved efficiency and better value for money.

The EHR could contribute to addressing them provided there is full-fledged implementation across the country. As the EHR becomes richer, with more elements and connectivity, the potential impact grows. In some areas, there is already solid evidence that the benefits can be realized. In others, the logical case appears persuasive, but there is a need for stronger empirical evidence.

ENGLAND'S JOURNEY

England journey is based on building on its success in the primary care computing arena. There are currently approximately 8,900 general practices (GP) in England, of which 97% have a GP clinical computer system. All practices use their systems for NHS acute prescribing (once only) and for repeat prescribing. Exceptions to this rule are those prescriptions generated during home visits or when prescribing controlled drugs which at present by law these must be hand written. Many practices are using electronic appointment systems and an increasing number of practices scan all hospital letters, reports etc which are then attached to the individual patient record. There are estimates of up to 30% of practices running 'paper-light' systems today.

All health systems such as England's NHS depend on successful handling of vast quantities of information to function safely and effectively. The National Programme for Information Technology in the NHS (NPfIT—now referred to as Connecting for Health—CfH) is a 10-year program which presents an unprecedented opportunity to use information technology (IT) to reform the way the NHS in England uses information, and hence to improve services and the quality of patient care. The core of CfH will be the NHS Care Records Service, which will make relevant parts of a patient's clinical record available to whoever needs it to care for the patient. The national program also includes many other elements, including medical images accessible by computer, electronic transmission of prescriptions, and electronic booking of first outpatient appointments.

According to a recent National Audit Office report, in the past, individual NHS organizations procuring and maintaining their own IT systems and the procurement and development of IT within the NHS was haphazard. The Department of Health did not consider this approach to have been successful, and one of the aims of the national program has been to provide strong central direction of IT development, and increase the rate of take up of advanced IT. CfH is being delivered mainly through contracts negotiated by NHS Connecting for Health with IT service suppliers. Once systems have been developed by the suppliers, further action is needed to bring them into use, such as integrating with existing IT systems and configuring them to meet local circumstances, training staff to use them, and adapting ways of working to make the best of the solutions. Four local service providers are primarily responsible for organizing this work, but much work is needed by local NHS organizations—strategic health authorities, NHS Trusts and other providers working for the NHS, such as GPs and pharmacists.

The scope, vision and complexity of CfH is wider and more extensive than any ongoing or planned healthcare IT program in the world, and it represents the largest single IT investment in the UK to date. If successful, it will deliver important financial, patient safety and service benefits. The main implementation phase of CfH and the realization of benefits is mainly a matter for the future and it will therefore be some time before it is possible fully to assess the value for money, as this will depend on the progress made in developing and using the systems it is intended to provide.

CfH has not been without significant growing pains. An April 2006 open letter by 23 English academics to the Health Select Committee argued that the committee should be aware of the concerns of health professionals, technologists and professional organizations about the £6bn NHS National Programme for Information Technology (NPfIT). It pointed out that the NHS Confederation has said "the IT changes being proposed are individually technically feasible but they have not been integrated, so as to provide comprehensive solutions, anywhere else in the world."

The letter went on to point out that two of NPfIT's largest suppliers had issued warnings about profits in relation to their work and a third has been fined for inadequate performance.

Various independent surveys show that support from healthcare staff is not assured. Concern was expressed that concrete, objective information about NPfIT's progress is not available to external observers. Reliable sources within NPfIT have raised concerns about the technology itself. Questions which the academics felt had not been answered included: Have realistic assessments been carried out about the volumes of data and traffic that a fully functioning NPfIT will have to support across the 1000's of healthcare organizations in England; need for responsiveness, reliability, resilience and recovery under routine and full system load?

As a result of the letter and a series of other documents and accounts—particularly about privacy and confidentiality of the national care record—a shift of responsibility for NHS IM&T in England from the center to local organizations was signaled in the service's new plan for 2007-2008 which was published on December 11, 2006.

The NHS in England: the operating framework for 2007-8 was launched by the NHS chief executive, who says in his foreword: "We are devolving power from the centre to the service in many ways, not least in how we allocate money, such as the unbundling of central budgets. Some of the key enablers of service transformation, such as the delivery of information technology, will also increasingly need to be driven and owned by the service rather than from the centre so that patients can get the full benefits as quickly as possible."

Plans will be required from NHS organizations showing not only how local but national priorities will be achieved including: implementation of GP Systems of Choice; preparing for the National Summary Care Record; the completion of picture archiving and communications rollout; implementation and benefits realization for the Electronic Prescriptions Service and further exploitation of e-booking. The framework also says plans should show how organizations will carry out the deployment and benefits realization for patient administration systems and order communications and results functionality, in line with existing commitments and targets set by each SHA, in the context of existing commercial arrangements.

The broad planning local NHS organizations will be required to do is set out, though the framework says more detailed guidance will be issued shortly. All NHS providers will have to have a forward looking IM&T plan which is "core to their business, exploits fully the NPfIT opportunity and thereby demonstrates migration to the NHS Care Record Service." Primary care trusts, as commissioners, will have their own comprehensive IM&T plan and work with all providers in their local health communities to align IM&T plans and enable patient-centered service transformation. Strategic health authorities will be charged with assuring that the local NHS has the capability and resources to deliver their plans.

From 2007/08 onwards, IM&T investment and exploitation will form part of mainstream NHS planning in support of health and service priorities and reform. With the shift to a self-improving system, the new accent is on local ownership and leadership—away from the centralized approach used by CfH—driving a local IM&T agenda which also meets a defined set of national expectations and exploits the National Programme for IT (NPfIT). Some have suggested that the direction of travel is reminiscent of the 1998 national health information strategy.

DENMARK'S JOURNEY

Denmark is perhaps the most advanced nation in the world when it comes to the use of information technology in healthcare (Protti & Johansen, 2003). Virtually all Danish GPs, and as of January, 2007 (all specialists as well), use their computers to electronically send and receive clinical messages such as prescriptions, lab results, lab requests, discharge summaries, referrals, and so forth. Sixty standardized messages (up from 32 in 2002), including their "One letter solution," have been implemented in approximately 100 computer systems, including physician office systems, hospital systems, laboratory systems and pharmacy systems. The national network is used by over three quarters of the healthcare sector, altogether more than 5,000 different organisations. All hospitals, all pharmacies, all laboratories and general practices take part. As of January, 2006, all private physiotherapists (1,750 in 550 clinics) and all private dentists (2,800 in 1,600 clinics) were also connected to the network. By the end of 2006, all 240 private chiropractor clinics and all 675 private psychologists will also be part of the electronic network. The majority of specialists and all of the local authority health visitor services now participate in the electronic communication via the healthcare data network. Over 90% of the country's clinical communications in the primary sector are exchanged over Denmark's national network. This high level of connectivity means that most Danish physicians run paper-light offices.

GPs enter all medications themselves. They access a drug database that is maintained centrally by the national Danish Drug Agency. The Agency automatically updates the physician office systems every 14 days. Physicians are required to use the lowest cost drug unless a "no substitution" order is given. Most systems provide some decision support in terms of drug-drug interaction, warnings concerning pregnant patients, etc. After the physician selects the patient's pharmacy from a pull down menu, the prescription is sent electronically to the specific pharmacy. At this time, over 85% of prescriptions are sent electronically to pharmacies. All 332 pharmacies with four different IT systems are able to receive electronic prescriptions. As of 2006, all dispensed medications are in a central database which is accessible via the health portal to both physicians and patients who have a digital signature (Johansen, 2006).

Thirty-five percent of Danish hospitals have electronic patient record (EPR) systems, a figure higher than most of Western Europe. EPR penetration in Denmark is expected to rise to 100% during the next two years. Ninety-eight percent of general practitioners (GPs) and a large percentage of specialists use electronic medical record (EMR) systems—a level similar to the UK, The Netherlands, and the other Nordic countries.

MedCom, Denmark's coordinating organization for healthcare IT was founded in 1994 to address these problems. By 2002, it had developed national standards for electronic data interchange (EDI) communication and ensured their widespread adoption in primary care. MedCom is funded 50% by the Ministry of Health, 35% by the Association of County Councils, with the remainder of the funding coming from municipalities, the Danish Pharmacy Association, and other organizations. MedCom has a staff of approximately 15 and a budget of three million euros per year.

MedCom created standard EDI forms for the six principal information flows in primary care for which paper forms were used: lab orders and results; prescriptions ordered by GPs; referrals from GPs to specialists; radiology orders and results; community (home care) messages; and insurance claims submissions and reimbursements. It disseminated these standards through local projects funded by the counties. To encourage adoption, MedCom published on its Web site the number of messages sent in each county, and the progress of vendors in modifying their applications to become compliant with the standards. The main problem was that the standards were too ambiguous. Focus groups involving clinicians, IT professionals and vendors resulted in more-precise versions of the standards.

Since 2002, MedCom has:

- Formed a health data network by linking existing local and regional secure healthcare networks and the value-added network services of counties, hospitals, vendors and other organizations to a central hub via a virtual private network (VPN). The VPN is used for transferring messages, as well as for videoconferencing, conducting teledermatology, accessing digital images, and accessing the standardized extracts of patient data (SUP) system and the national portal.

- Developed a tool to convert EDI messages to XML. One of the goals is to facilitate the transition from existing administrative and clinical applications to applications based on the new EPR data model.
- Developed standards for hospital-to-hospital discharge letters, patient referrals, correspondence messages and clinical biochemistry laboratory results. MedCom paid vendors to modify their applications to incorporate these standards.
- Developed messages for GPs and hospitals to communicate with local authorities and home care providers. This is particularly important in the care of senior citizens, who are frequently transferred between hospital and home care.
- Has been certifying all supplier systems since 2000. Currently suppliers do not have to pay for certification, which entails not only messaging standards but also presentation formats, functionality, ability to change, etc. Suppliers are certified for life unless they introduce major changes (e.g., convert their operating system from DOS to Windows). There are currently 11 suppliers who support 16 different physician office systems, with the major products being either local install or through an Internet service provision. Three suppliers have 57% of the market. Overall, there are some 60 vendors with over 100 software systems using the MedCom network.

The Danish central government contributes to healthcare IT through the National Board of Health (Edwards, 2006).

The board has created a EPR data model known as the basic structure for electronic health records. The board plans to bring the data model into compliance with the health level seven (HL7) version 3 reference information model (RIM) during the next few years. The data model specifies the functionality that every EPR system in Denmark should contain. It is being used as the basis for the tenders that counties are issuing for EPR systems. The board is also completing the development of a national terminology server, including a translation of systematized nomenclature of human medicine (SNOMED) into Danish.

The purpose of the SUP project, which was designed by two counties and three vendors and was implemented by MedCom, is to make data held by Danish hospitals available to clinicians and patients across the country. SUP is currently supplied with data on 16% of the population. Three counties are contributing data. The SUP metadata model contains the data common to the main administrative and clinical applications used in Danish hospitals. Every 24 hours, the data from local applications is copied into an XML file, which is transferred to the SUP database. Clinicians can only view the data; they cannot download it into their own applications.

Once vendors adopt the EPR data model and hospitals implement upgraded EPR applications, the SUP metadata model will be updated, which is expected to enable data extracts every one to two hours. It is likely that SUP will become an EHR covering the entire country.

Since year-end 2003, Denmark has had a healthcare portal, Sundhed.dk, which is funded by the same organizations as MedCom. The portal was developed by IBM Acure and runs on an IBM WebSphere portal server, WebSphere application server and DB2 database. The portal cost 15 million euros to set up. Its annual cost is 4.5 million euros: 3 million euros for IT operations and 1.5 million euros for administration. The content is contributed by the stakeholders (principally the counties and local authorities).

The portal enables patients to:

- View their data from the SUP database (to go into effect in August 2006).
- View their medicine profiles.
- Renew prescriptions.
- View summaries of their medical histories (as of September 2005).
- View a shared care pregnancy record.
- Purchase prescription drugs from pharmacies.
- View information on medical conditions, preventive medicine, and health laws and regulations.
- Specify their organ donation preferences.
- Book appointments with GPs, view a calendar containing their appointments and set up appointment reminders.
- Have electronic consultations with GPs, which are reimbursed according to nationally agreed fees. The Danish GP association has agreed that, by year-end 2007, all GPs will offer electronic consultations.
- View a directory of healthcare organizations, with information on waiting times, quality and accessibility.

Clinicians can view the same information as patients. In addition, they can view clinical knowledge (the Cochrane Library), job listings, laboratory test results (a pilot project) and guidelines for referring patients to hospitals. The portal uses a public-key infrastructure (PKI) for security. Access by patients requires a digital signature; 650,000 have been issued to date. Patients store the digital signatures on their personal PCs and can also transfer them onto thumb drives if they wish to access the portal from another PC. There are approximately 175,000 unique patient visits to the portal per month.

Access by clinicians or pharmacies requires special security certificates. Patients can view the name of the person viewing their data, the date and time of the access, and the action taken. In theory, Danish patients have to give explicit consent each time data is shared, they are allowed to choose which clinicians can access their medical records, and they are allowed to restrict access to data on mental and sexual health. In reality, patients are encouraged not to exercise these powers. Consent to share data is requested only when the patient changes physicians or hospitals.

Studies have concluded that MedCom has produced financial benefits (Gartner). A cost-benefit analysis conducted in 2006 by the market research firm Empirica estimated that the cumulative present value cost of MedCom prior to year-end 2005 was 536 million euros, and the benefit was 872 million euros. Empirica estimated that a typical GP, serving 1,300 patients, saves 30 hours per week of secretarial work by using the MedCom standards.

Higher quality and higher throughput by individual GPs due to the use of EMRs and electronic communication have been shown. On average, GPs have experienced a 20% increase in number of consultations after beginning use of EMRs and electronic communications. Other outcomes include reduced cost of medications and a lower mortality rate due cervical cancer. There are less smear samples and a reduction in cervical cancer (62 in 1988 down to 18 in 2004) and in deaths (29 in 1988 down to 12 in 2001).

Though there is little hard evidence of clinical benefits, soft evidence includes more effective communications (clear, accurate, complete and consistent), more-efficient communications (rapid and lower-cost), and more widespread communications. GPs and hospitals spend less on administrative processing and get reimbursed faster. Local authorities spend less on handling transfers of patients between hospital and home care. Patients benefit from more-efficient delivery of health services, better and more rapid communication of patient data, and access to information about their health.

LESSONS LEARNED

Canada embarked on its particular EHR journey for a number of reasons. One was because at the time when Canada started with EHRs there was not a proliferation of EMRs in doctors' offices. Since healthcare is a provincial responsibility, moving that agenda forward is based on the provinces negotiating with their doctors to install computers in their offices. Secondly, national statistics suggested that the system errors, the adverse effects occur in hospitals, in emergency departments. Infoway wanted to make medication history, lab results and diagnostic imaging data available at that front line.

Lesson learned from the Canadian journey include:

- Secured funding from the federal government
- Facilitated unprecedented federal/ provincial/territorial cooperation
- Enabled a broad language of acceptance around the need for and expected benefits of EHRs
- Established standards
- Secured some early implementation successes (e.g., registries)
- Achieved savings from national procurement initiatives

Despite the investments of funding, planning, goodwill and achievements to date, some feel that the current process for building an electronic infrastructure for the Canadian healthcare system faces a very real danger of delivering a fragmented system that may provide less value to patients in terms of providing better care, and alienates the majority of physicians expected to embrace these new tools (Pascal, 2006). Pascal argues that without serious re-evaluation of our investment priorities and the timing of those investments, as well as how best to involve and support frontline healthcare workers—especially physicians—in meaningful ways throughout this process, Canada is at risk falling far short of our goal of improving healthcare outcomes through the effective application of ICT. He argues that the current approach is seriously impairing the achievement of an adequate return on value (ROV—return on value is the assessment of quantitative and qualitative costs and benefits from IT investments in the healthcare sector; ROV is richer than ROI which only deals with the quantification side of the equation).

According to Pascal (2006), as Canada Health Infoway, provincial and regional jurisdictions go about their work concentrating on the acute sector; there is growing concern within the medical community about how the process is unfolding without their involvement. The greatest gains in healthcare outcomes occur in the community care as over 80% of care originates and is delivered in community settings. Pascal questions why the concentration on the construction of large data bases when physicians and other healthcare workers have little or no connectivity to neither this information, nor the electronic capabilities in their offices to capture or display it? One of the goals of the Canada Infoway e-health strategy is was to have the right information, at the right place, with the right provider, at the right time to provide the best care possible. To do this there has to be connectivity between points of care and the necessary technologies available at them when the encounter occurs. The majority of health information that will make up an EHR or that will be shared among providers to support the care of a patient will be generated at the community level and captured in physician's EMRs.

The lessons learned from England were recently addressed by the British Computer Society who suggested that in order for the national program to succeed the following changes are required:

- Provide a business context for CfH owned at national and local level

- Focus on local implementations at Trust and provider unit level, for example, hospitals, diagnostic and treatment centers, community and mental health trusts, and practices. Providing specialty, service-specific and niche systems will encourage clinical involvement and give quicker benefits
- Persuade local NHS management that informatics is an essential part of business solutions and service transformation. Provide explicit additional funds for business change and service transformation. Embed informatics in trust business targets with realistic target dates.
- Adopt a truly patient-centered approach at the local health community level.
- The strategy should be evolutionary, building on what presently works and encouraging convergence to standards over time, rather than revolutionary.
- Given a heterogeneous set of systems, there needs to be a greater emphasis on standards to enable systems to interoperate effectively, rather than focusing on relatively few monolithic systems.
- Establish basic informatics elements that are standard across the UK to enable coherent treatment of patients irrespective of their movement across home country borders. Ensure that other facets of the English strategy support this coherence.
- Fully implement GP system choice at practice level.
- There needs to be an accreditation process for all new and existing systems, both against the chosen standards and functionality requirements that does not stifle innovation.
- Revisit and reallocate roles and responsibilities of the NHS at each level, NHS CFH nationally and locally, and system suppliers.
- Transform NHS CFH into an open partnership with NHS management, users, the informatics community, suppliers, patients and their careers that is based on trust and respect.
- There are major issues about the sharing of electronic patient data which need to be resolved whatever the shape of future informatics in the NHS. These must not be hijacked by technical issues, and informed patient consent should be paramount.
- Information sharing between care professionals should initially be by messaging using the Spine TMS service pending further work on information governance and the National Care Record Service.
- Clearly define what the NHS Care Record Service (NHS CRS) is. A virtual service offering views of the distributed records available for a patient would seem appropriate.
- Put implementation of the personal spine information system (PSIS) on hold.
- Consider developing the equivalent of the Scottish Emergency Care Summary. General practice systems could provide this on demand.
- The clinical professions, NHS management and informaticians should collaborate to provide clear and comprehensive guidance for all sectors on good informatics practices, such as record keeping and information management—clinical and other—and embed this in undergraduate and post-graduate training. The NHS should facilitate the take-up of this guidance.
- More appropriately skilled/qualified staff is likely to be needed. The approximate volumes need to be agreed, and their supply enabled. The process of professionalizing informatics staff should continue.
- Data quality is critical to reaping the benefits of the raised investment in IT. The improvement of general practice patient data across England has been the subject of work for some years. The same needs

happen in all care sectors, including private and voluntary care providers, and to be extended to data other than patient data.

The lessons learned from Denmark are many and include:

- Support to adopt MedCom standards is paid for by counties. Project coordinators at hospitals involve staff in determining the data to be communicated electronically and develop new procedures for handling electronic messages. Data consultants, paid for by the counties, train physicians and their staff on how to use electronic communications. Physicians are paid to help hospitals communicate better with physician practices.
- Precise standards. MedCom did not just create standards; it worked with clinicians to define the precise content of the standards. This process, though time-consuming, resulted in more-accurate communications and was critical in educating clinicians about the value of IT. Vendors are actively involved as well in setting standards.
- Peer pressure through public monitoring of participation. The MedCom Web site displayed a running total of electronic messages sent, participating counties and compliant vendors.
- Gradual approach with realistic time frames. There is an acceptance by all parties that the adoption of electronic communication takes many years and should not be rushed. Danes start simple and keep it as simple as possible. It is tempting to take on many projects at once, but increasing the level of complexity does not bring a corresponding increase in benefits.
- Financial incentives to physicians to adopt EMR systems. Physicians in Denmark are independent contractors who make independent decisions about IT. Physicians who adopted EMR systems and used the MedCom standards received faster reimbursement.
- Incentives to vendors. No one requires healthcare organizations to use a particular vendor. Counties encourage vendors to upgrade their applications to the MedCom standards by committing to purchase the upgraded applications.
- Culture of consensus. MedCom is funded by many different stakeholders and is viewed as an impartial organization. There is an appropriate balance between central coordination and local leadership
- Project-based approach. Approximately half of MedCom's budget is spent on permanent employees and overhead. The rest is devoted to projects. MedCom believes that this approach has given it more flexibility.
- The Danish Act on Processing of Personal Data (July 2000) was amended in 2004 to permit physicians to have access to medication data. Prior to the change, it was against the law to have access to medication profiles without patients' consent. In terms of patient consent, the current legislation is based on an 'opt-in' model which means that the patient has to give his or her verbally or written consent to let a health professional have access to this/her data. Danish law forbids the interconnection of IT systems across sectors (e.g., health and taxation).

CONCLUSION

No healthcare jurisdiction, other than perhaps the Veteran's Administration in the United States, has achieved a fully automated, comprehensive EHR for its entire population. Hence there are no definitively proven strategies for problem-free implementation. However, a number of insights are beginning to emerge from the countries leading the way, including:

- The transition period is invariably difficult. The initial preferences of users (e.g., text-based rather than structured data entry) may change over time. Flexibility is therefore essential.
- Moving to an EHR in its fullest form is not just a technical innovation; it is a cultural transformation. Change management is vital, and failure to build in processes for effecting the transformation will reduce both uptake and impact. Providers and managers need to complete the transition from resistance to electronic information (historical position) to acceptance (current position) to addiction (cannot function without it).
- Implementation takes time, but can be accelerated once adoption and proven successes have reached a critical mass, or tipping point. At these stages, policy can drive faster change, for example, by making certain resources available only through electronic portals.
- The data elements are the core of any system, and spending time and resources on standardizing definitions and usage will go a long way toward creating information systems that yield valid and reliable measures of quality and performance.
- There will be far greater acceptance of provider-level information technology (IT) if workflow is modified accordingly to gain improvements.
- Creating secure networks for communicating information in any form has proven to be hugely appealing to providers in almost every country. E-mail use grows very rapidly and is an effective vehicle for introducing providers to the world of electronic information.
- It is very important to structure contracts so that risks are appropriately shared, and purchasers do not pay for systems that do not work. The National Health Service (NHS) in England has taken a firm stance, and while it incurred delays because it changed a principal vendor, it did not take a huge financial hit.
- Leadership at all levels—including the very top—is crucial. Clinician leadership is essential but cannot be effective in isolation.
- Helping family doctors use the data generated by the EHR to analyze and improve their own practices will increase uptake. In Denmark, the counties fund data consultants who visit each practice 1-2 times per year to troubleshoot and help produce usable quality-oriented information on treatment patterns, and so forth.
- If providers perceive “early wins” in the process, they will be more likely to invest their own money and agree to standards.
- Some strategies to enhance adoption among providers include clinical stories, peer-to-peer training, demonstration clinics, mentorship, and protected time.

As stated in the Infoway findings at Montebello, the EHR by itself cannot guarantee improved performance. The culture must also change, and all health system stakeholders, including users of services, must be inclined and trained to convert the potential of health information into concrete improvements in quality and efficiency. The benefits of the EHR grow over time as providers in particular exploit its potential to enhance communications, improve safety and quality by using decision support tools, expand the network of trusted colleagues, and generate valid performance measures and comparisons. In other words, however indifferent the initial reaction and despite the inevitable pain of the transition phase, over time the human and capital investment generates a high rate of return. No one ever goes back to paper world once exposed to an EHR.

FUTURE RESEARCH

A common frustration in all nations is determining the true cost of information technology in healthcare. One of the problems is that there is little consistency across healthcare organizations as to what is to be included in the IT domain—let alone the information management (IM) domain. As part of a course taught at the University of Victoria, 28 Canadian healthcare CIOs were interviewed and asked to describe the departments they were responsible for. The survey found that the CIOs were heading divisions that had 17 different names, with 'information management' leading the way—used in four sites. To say that our Canadian healthcare CIOs are responsible for a diverse set of departments would be an understatement. The areas of responsibility range from the usual IM&T areas to others areas such as networks, health records, decision support, telecommunications, biomedical engineering services, switchboard and information desk, library services, privacy, and so forth. The areas that the CIOs were responsible for generated a list that was two pages long! Little wonder it is difficult to find a common set of measurements as what the IT investment really is.

The conundrum of measuring the IT function is that:

- Efficiency (doing things right) is easier to measure than effectiveness (doing the right things)
- Since effectiveness ("doing the right things") and innovation ("doing new things") can not be readily quantified in terms of traditional outputs, improvements are not usually reflected in economic efficiency statistics
- New systems are intended to change difficult to measure actions
- Strategic systems elude measurement
- Infrastructure investments cannot be cost justified on a ROI basis

As with any infrastructure, IT infrastructure does not provide direct business performance. Rather it enables other systems that do yield business benefits. ICT infrastructure is strikingly similar to other public infrastructures such as roads, hospitals, sewers, schools, etc. They are all long term and require large investments. They enable business activity by users that would otherwise not be economically feasible. They are difficult to cost-justify in advance as well as to show benefits in hindsight. They require a delicate investment balance—too little investment leads to duplication, incompatibility, and suboptimal use; while too much discourages user investment and involvement and may result in unused capacity.

Further research is required to determine whether or not ICT in healthcare, i.e. the EHR, is very much about infrastructure. If so, a new way of thinking of the investment and the return on investment is needed.

REFERENCES

Edwards, J. (2006). *Case study: Denmark's achievements with healthcare information exchange*. Gartner Industry Research.

Infoway. (2006). *Beyond good intentions: Accelerating the electronic health record in Canada*. Canada Health Infoway Montebello Policy Conference.

Johansen, I. (2006). *What makes a high performance health care system and how do we get there?* Paper presented at the Commonwealth Fund. Washington, DC.

NHS. (2006*). The NHS in England: The operating framework for 2007/08. Guidance on preparation of local IM&T plans*. Department of Health.

Pascal, B. (2006). I*nvestment in health IT: Heading down the wrong road? HCIM&C*, *XV*(1), 6–7.

Protti, D. J., & Johansen, I. (2003). Further lessons from Denmark about computer systems in physician offices. *Electronic Healthcare*, *2*(2), 36–43.

Schoen, C., Osborn, R., Huynh, P. T., Doty, M., Peugh, J., & Zapert, K. (2006). On the front lines of primary care doctors office systems, experiences, and views in seven countries. *Health Affairs*, Web Exclusive, P. w555, 2.

ADDITIONAL READINGS

Adair, C., Simpson, E., & Casebeer, A. L. (2006). Performance measurement in healthcare. *Healthcare Policy,2*(1)

Anderson, A., Vimarlund, V., & Timpka, T. (2002). Management demands on information and communication technology in process-oriented health-care organizations. *Journal of Management in Medicine*, 159–169. doi:10.1108/02689230210434907

Brigl, B., Ammenwerth, E., Dujat, C., Gräber, A., Große, A., Jostes, C., & Winter, A. (2005). Preparing strategic information management plans for hospitals: A practical guideline; SIM plans for hospitals: a guideline. *International Journal of Medical Informatics*, *74*(1), 51–65. doi:10.1016/j.ijmedinf.2004.09.002

Carr, N. G. (2003, May). IT doesn't matter. *Harvard Business Review*, *81*(5), 41–49.

Clark, F.C., & Kimmerly, W. (2002). Strong IT governance: Don't even think about not doing it! *HIMSS Proceedings, Session 28.*

Dario, A, Giuse, K., & Kuhn, A. Health information system challenged: The Heidelberg conference and the future. *International Journal of Medical Informatics*, 105-114.

Deloitte. (2003). Clinical transformation: Cross-industry lessons for health care. Deloitte Research.

DIRAYA. (2006). Diraya—More than a medical record. Servizio Andaluz de Salud.

Dufner, D. (2002). Can private sector strategic information systems planning techniques work for the public sector? *Communications of the Association for Information Systems*, *8*, 413–431.

Edwards, J. (2006). Case study: Denmark's achievements with healthcare information exchange. Gartner Publications.

Feld, C.S., & Stoddard, D.B. (2004). Getting IT right. *Harvard Business Review, February.*

Gibson, M. (2007).Using technology to improve patient care—The POSP experience. ITCH 2007 Presentation. February.

Glaser, J. (2006). Information technology strategy: Three misconceptions. *Journal of Healthcare Information Management*, *20*(4).

Grimson, J. (2001). Delivering the electronic healthcare record for the 21st century. *International Journal of Law and Medicine*, 111-127.

Gunasekaran, S., & Garets, D. E. (2003). Business value of IT: The strategic IM&T planning process. *Journal of Healthcare Information Management*, *17*(1), 31.

Healthcare Information and Management Systems Society. (2000). The 11th Annual HIMSS Leadership Survey Sponsored by IBM: Trends in Healthcare Information and Technology Final Report. June 2000, [http://www2.himss.org/survey/2000/2000Final.pdf].

Leung, G., Yu, P., Wong, I., Johnston, J., & Tin, K. (2003). Incentives and barriers that influence clinical computerization on Hong Kong: A population-based physician survey. *Journal of the American Medical Informatics Association*, 201–211. doi:10.1197/jamia.M1202

Luftman, J. (1999). Enablers and inhibitors of business-IT alignment. *Communications of the Association for Information Systems*, *1*, 11.

McAfee, A. (2006). Mastering the three worlds of information technology. *Harvard Business Review*, 141.

McConnell, H. (2004). International efforts in implementing national health information infrastructure and electronic health records (pp. 33-40). UK: World Hospitals and Health Services, The Federation.

Protti, D. (2005). The benefits of a single 'national' health record has been demonstrated. http://www.npfit.nhs.uk/worldview/ March

Rippen, J. (2003). Building support for health information technologies. *Studies in health technology and informatics* (pp. 103-108). Netherlands: IOS Press.

Sanders, D. (2002). Designing, developing, and supporting an enterprise data warehouse (EDW) in healthcare. *Intermountain Healthcare*.

Terry, N. (2004). Electronic health records: International structural and legal perspectives. *International Journal of Law and Medicine*, 26-39.

United States Government Accountability Office. (2004). HHS's efforts to promote health information technology and legal barriers to its adoption. Government Accountability Office, United States, pp.12. Retrieved August 13, 2004, from http://www.gao.gov/new.items/d04991r.pdf

Wood, J., & Aceves, R. (2005). Five steps to electronic health record success. *Healthcare Financial Management*, 56–61.

This work was previously published in Human, Social, and Organizational Aspects of Health Information Systems, edited by A. Kushniruk; E. Borycki, pp. 203-218, copyright 2008 by Information Science Reference (an imprint of IGI Global).

Chapter 1.28

Electronic Oral Health Records in Practice and Research

Amit Chattopadhyay
University of Kentucky, USA

Tiago Coelho de Souza
University of Kentucky, USA

Oscar Arevalo
University of Kentucky, USA

ABSTRACT

Electronic Oral Health Records (EOHRs) contains all personal health information belonging to an individual and is entered and accessed electronically by healthcare providers over the person's lifetime. This chapter presents a systematic review about EOHRs, describes the current status of availability of EOHR systems, benefits and barriers for implementation and EOHR usage in clinical, public health and research settings to pave the way for their rapid deployment. The chapter draws the scenario of how a fully integrated EOHR system would work and discuss the requirements for computer resources, connectivity issues, data security, legal framework within which a fully integrated EOHR may be accessed for real time data retrieval in service of good patient care practices. This chapter also describes the need for defining required criteria to establish research and routine clinical EOHR and how their differences may impact utilization and research opportunities to establish practice-based research networks.

INTRODUCTION

In 2003, Sittig, Kirshner and Maupomé (Sittig et al.2003) described an informatics-oriented, future-patient care scenario and identified key functions, applications, or technologies in the field of dental informatics. The scenario envisioned a completely paper-less series of interaction between a patient, his/her dentist, and several specialists starting from her initial presentation to completion of a series of procedures and scheduling periodic recall leading to an "ideal" treatment experience. It would be naive to think that such a system will not happen – its fundamentals are already in place. Such a system

DOI: 10.4018/978-1-60566-292-3.ch013

does not require technological marvels, but only needs proper integration of technologies that are in existence for some time. Central to this variety of tasks and sub-tasks in the oral health care system is the patient's health record.

Traditionally, patient information ranging from clinical history to research results has been stored in hard copy format all around the world. Such a storage system demands ever increasing space and is prone to easy destruction requiring great security systems for its physical existence and control of privacy of the information. Such a system also poses difficulty in duplication of data when needed, availability of real-time updated patient information over space and time, and poses even greater difficulty in organizing and aggregating the data for analyses. With the advent of computerized information processing and ever increasing cheap computer disk space and memory, it has become imperative to use this easily available resource to organize health records of patients in an easily retrievable manner in digitized format called electronic health records (EHRs).

EHRs digitize the contained information becoming a database that allows easy access to the information from individual EHRs, or in an aggregated manner. Development of electronic records for oral health requires substantial departures from standard EHRs because several specialty-specific nuances need to be incorporated to appropriately address the needs and maximize the benefits for patients, researchers, practitioners and academicians. Although EHRs have come into existence in routine medical care facilities, their adoption has been slow for a variety of reasons. Similarly, although development and incorporation of electronic oral health records (EOHRs) in day to day clinical practice has been anticipated, forecast and urged for long (Green 1996, Greenwood 1997, Miller 1995, Rada 1995, Schleyer 1995, Schleyer et al. 2001, 2003, Snyder 1995, Walther 1998), their adoption has been still slower. To respond proactively to the digital transformation of oral health care, dentists must become familiar with technologies and concepts (Umar 2002a, 2002b). They must learn what new information technology can do for them and their patients and then develop creative applications that promote the profession and their approaches to care (Bauer & Brown 2001).

WHAT IS EOHR?

Terminology of EHRs have undergone several changes and currently several terms are still used to represent EHRs. Terms such as: automated medical record (AMR), clinical data repository (CDR), computerized medical record (CMR), computerized patient record (CPR), computer-based patient record system (CPRS), electronic health record (EHR), electronic medical record (EMR), electronic patient record (EPR), lifetime data repository (LDR), virtual health record (VHR), virtual patient record (VPR) are some of the terms that have used interchangeably for EHRs. In dentistry, these systems have been variously referred to as: "electronic dental records", "dental electronic records", "electronic dental patient records", "electronic patient record system", "computer-based patient record", and "dental EHR". However, the term EOHR is more comprehensive compared to and is frequently being used universally – therefore, we resolved to use this term.

In general, EOHR is an electronic repository of patients oral health related information in form of a database at the back-end. Therefore EOHR contains a wide array of information (Heid et al.2002) including:

- Patient demographics
- Practitioner characterization
- Immunizations
- Health history
- Health conditions/ problems
- Examinations and findings

- Treatment plans/ clinical orders
- Diagnostic observations
- Radiographs, laboratory data and other investigation reports
- Prescribed medications
- All therapeutic interventions
- Hospital admissions and attendances
- Scheduled events
- Patient encounters

EOHR, therefore "contains all personal health information belonging to an individual and is entered and accessed electronically by healthcare providers over the person's lifetime. EOHR extends beyond acute inpatient situations including all ambulatory care settings at which the patient receives care. Ideally it should reflect the entire health history of an individual across his or her lifetime including data from multiple providers from a variety of healthcare settings, primarily to support continuing, efficient, and quality healthcare." (WHO, 2006) EOHRs must also continue to meet legal, confidentiality, and retention requirements of the patient, the attending health professional and the healthcare institution/ country

The Status of EOHRs

Currently, the use of EHRs and EOHRs and their outcomes are still considered as scientifically reportable events and clear quality assurance guidelines are derived from the HIPAA in the US.

EOHRs are slowly being recognized as the cornerstone of data storing and management on clinical, public health and research settings all over the world although the main thrust of evolving workable EOHRs has remained in the developing world, especially Canada, the United States, United Kingdom, Germany, Australia and New Zealand. EOHR development and adoption are also being reported from the developing countries such as Argentina, Brazil, China, Hong Kong, India, Indonesia, Korea, Malaysia, Singapore, Taiwan, and Thailand. In general, the world over, the introduction of EHR "seems overwhelming and almost out of reach to many healthcare providers and administrators as well as medical record/health information managers" (WHO, 2006).

The US Department of Health and Human Services (DHHS) took the lead in developing a National Health Information Infrastructure (NHII) which is a voluntary initiative aiming at improving "the effectiveness, efficiency and overall quality of health and health care in the United States". This infrastructure has been conceived as "a comprehensive knowledge-based network of interoperable systems of clinical, public health, and personal health information that would improve decision-making by making health information available when and where it is needed" (DHHS 2004) NHII integrates various aspects of individual health, health care, and public health such as: technologies, standards, applications, systems, values, and laws. The central focus of NHII is to implement computer-based patient records for most Americans, connect personal health information with other clinical and public health information, and enable different types of care providers to access computer-based patient records.

USDHHS pointed out categorically that the NHII is not a centralized database of medical records or a government regulation. The NHII integrates the "'lessons-learned' from other National systems (Canada, United Kingdom, and Australia) and ongoing projects". The NHII has three defined stages with outlined timelines: 1) development of leadership (2-years); 2) building collaboration between stake holders (5-years); and 3) Developing and implementing the infrastructure in all relevant public and private sectors (10-years – final target year: 2014) (USDHHS 2004).

Development of the NHII begot the question: Should dentistry be part of the National Health Information Infrastructure? (Schleyer et al. 2004b). The authors pointed out that the advantages of NNHII including "transparency of health information across health care providers, potentially increased involvement of patients in their care, better clinical decision making through connecting patient-specific information with the best clinical evidence, increased efficiency, enhanced bioterrorism defense and potential cost savings" and argued for integration of Dentistry into the NHII (Schleyer et al. 2004b).

EOHR: BENEFITS

EOHRs provide immense benefits in storage, retrieval, and utilization of data and are a key component of establishing efficient and effective evidence based clinical practices. EOHR help to save time and money by reducing paper work, duplicate laboratory and radiologic testing and eliminating the need for dictating services, reducing transcribing errors. In general, EOHRs:

- Improve the accuracy, precision and quality of data recorded in a health record and reduce errors in data recording
- Enhance access to patients' healthcare information by clinicians, researchers and public health authorities and increasing the ability to share data and facilitating continuity of care.
- Improve the quality of care as a result of having health information immediately available at all times facilitating inter-consulting among health care providers.
- Improve the efficiency of the health care delivery system.
- Contain healthcare costs

Access to Clinical Data, Medical Information and Population Data

Without an up-to-date record, it often becomes difficult to provide time high-quality care. Clinical dentistry has a need for complete current data on patients including medical history, radiological, laboratory, patient's drug sensitivity, resistances and allergies. Often such data may be present in different physical locations across clinics and centers which make difficult to procure and may lead to repeated procedures and testing. EOHRs allow available data to be accessed easily, even from distant locations in a comprehensive manner at any time of the day. This increases the efficiency of medical care and also allows speedy resolution to several issues by bypassing logistic problems related to manual chart retrieval and storage problems. Because EOHRs can be easily duplicated, it is also possible for more than one clinician to access the records at different places simultaneously. At the same time, integrating technological advances such as tele-dentistry into the system allows for quick conferences between multiple clinicians, laboratory staff, administrators and healthcare/ insurance managers.

Evidence based practice demands ready knowledge about recent advances. EOHRs address this issue by allowing the presentation of current medical findings which can be incorporated both actively and passively. Using EOHRs, practitioners can easily integrate references and cross-checks by incorporating guidelines, protocols, recommendations, clinical notes, directions at the point of care efficiently and effectively. EOHRs may also incorporate "built-in rules, alerts, or reminders that act to remind clinicians about care that is due for patients, both for preventive care and for chronic disease management. In more advanced systems, these reminders may allow for resolution of the issue at the point of care, allowing a clinician to resolve the issue from within the alert itself." (Cusack, 2008)

EOHRs can add functionality to track population data and parameters, incorporate flags to schedule and recall patients for preventive care, follow-up patients with a set of risk factors. The clinician can easily not just track laboratory, pathology, radiologic tests, but can also incorporate automatic flagging and alerts for abnormal results. Use of EOHRs eliminates the need for dictation and use of transcribing services. This eliminates a source of errors resulting from medical transcription errors.

Improvement in Patient Safety and Quality of Care

The Institute of Medicine's (IOM) report *To Err is Human* (IOM 2000) estimated that up to 98,000 patients were dying each year in the United States because of medical errors. A subsequent report suggested that the IOM's figure be an underestimate and the true number may be as high as 225,000 a year (Healthgrades 2004). Medical errors have been reported in dentistry resulting from procedural, diagnostic, dispensing, prescription and other processes (Pontes et al.2008, Ogunbodede et al.2005, Kim 2004, Bergenholtz et al.2004, Kim 2004, Krol et al.2002, Vaubert et al.1999, Oakley & Brunette 2002).

EOHRs with inbuilt rules, alerts, stops, range checks can go a long way in preventing a large proportion of these errors and maximize patient safety. It has been reported that even achieving a 10% improvement in quality care measures for the population served by small offices could have a substantial effect on public health (Baron, 2007) and EHRs contribute substantially to this improvement.

For example, in a pilot study at the University of Washington, a diabetes care module was developed, and the feasibility of allowing patients with type 2 diabetes to co-manage their disease from home using institutional EHR and web access by the patients in which one newly diagnosed patient was started on an oral hypoglycemic, underwent two upward dose adjustments, and achieved control by reducing HbA1c from 8.0% to 6.1% (Goldberg et al.2003). Similarly, several recent studies have reported the use of EOHRs to successfully assess health risk and improve oral health care quality and dental education. (Atkinson 2002, Delany 2004, Delrose 2000, Finkeissen et al.2002, Fouad & Burleson 2003, Freydberg 2001, Reis-Schmidt 2000)

Clinical Quality Assurance and Education Improvement

EOHRs play a major role in dental educational institutions in terms of improving student and patient experience, quality assurance, improving quality of education, and inculcating principles of evidence based practices among dental students and residents.

The international development and deployment of an electronic modularized dental curriculum is central to the development of an electronic engine to be used for the effective management of dental education. This will ensure continuity in high quality of care across all boundaries, through the continuous updating of its content and linkages to contemporary resources and databases. An electronic engine to be used for the effective management of dental education in a comprehensive dental school/hospital setting is at the core of an international 'virtual' dental education institution. The issue of policy development necessary to ensure consistency, quality and management for an electronic engine is at the very centre of: a) systems management and system databases; b) records of students, patients and personnel; and c) financial records.(Eplee et al.2002)

For example, in a recent study, Shelly et al.(2007) evaluated the use of an EOHR system to assess quality of care in an academic dental institution. Their primary outcome of interest was the timeliness and completeness of restorative care following completion of nonsurgical root canal therapy. They were quickly able to query the system and develop a report assessing permanent restoration, teeth build-ups, complete coverage restorations and were able to assess if patients were receiving recommended treatment. They were able to use EOHR "to objectively and efficiently assess one aspect of quality of care in a dental school environment" and found the use of EOHR to help in clinical assessment and quality assurance.

Minimizing Medication Errors

The Agency for Healthcare Research and Quality (AHRQ) in the United States has defined error as an act of commission (doing something wrong) or omission (failing to do the right thing) that leads to an undesirable outcome or significant potential for such an outcome. Medication errors may or may not cause harm to the patient. Such errors include any errors in dose, route, frequency, and drug choice (IOM 2000, Cusack 2008) that may due to prescribing multiple drugs of similar class, or due to drug-drug, and other possible interactions. Adverse drug events (ADE) may or may not involve medication errors, but may be avoidable if a patient has previous history of similar or related events. ADEs need to be tracked irrespective of whether they occur due to medication error or not.

EOHRs, when linked to electronic prescription systems and drug checking software, can reduce ADE and medication errors by alerting the clinician of such possibilities (for example through a pop-up message about ADE's and drug interactions, related to medications being prescribed, and by cross checking prescriptions against patient history, laboratory test results and other prescribed medications). One study found that some 21% of the prescriptions had errors (Shaughnessy & Nickel 1989). EOHRs also minimize errors resulting from legibility of prescriptions and prevent difficulties resulting from lost/ mutilated/ forgotten prescriptions and fraudulently prepared prescriptions. Drug dosing calculations based on patient's age and weight linked with updated information on liver, renal and other patho-physiological conditions can reduce dosing errors by calculating correct dosages, and modifying those in real-time on an as per need basis.

ADOPTION OF EOHRS IN CLINICAL SETTINGS

The fact that electronic systems, especially computers in dental clinical offices could revolutionize clinical management and practice was recognized very early. The earliest article we found that dealt with electronic data processing in the storage and retrieval of dental patient file information was published in 1967. (MacGregor & Halabisky 1967) With the advent of personal computers, their role in clinical dentistry was envisioned quickly and several articles predicted various scenarios of automated clinical practice. (Green 1996, Greenwood et al. 1997. Miller 1995)

A British study noted that despite the advantages of using computerized systems, many dental practices were only using them to a limited extent. (John et al. 2003) In a study about the adoption, utilization and attitudes toward clinical computing Schleyer et al.(2006) surveyed 256 randomly selected general dentists in the US using a 39-item interview questionnaire. These dentists were selected from among 1159 because they met the eligibility criteria of having computers at chairside. Among these, only 102 (39.8%) could be interviewed. The authors found that 1.8% of the dentists were working in a completely paperless environment. "Auxiliary personnel, such as dental assistants and hygienists, entered most data. Respondents adopted clinical computing to improve office efficiency and operations, support diagnosis and treatment, and enhance patient communication and perception. Barriers included insufficient operational reliability, program limitations, a steep learning curve, cost, and infection control issues." (Schleyer et al.2006)

... general dentistry has become increasingly computerized in the past 20 years ... the proportion of all dental offices (generalists and specialists) with computers has increased from 11% in 1984 to over 85% in 2000. According to data from the Dental Products Report (DPR), a dental trade

publication, the adoption of computers in treatment rooms follows a similar curve with a time lag of approximately 13 to 15 years. The 2004 Survey on computer/ internet usage by the DPR found that 30% of all general dentists used computers in the operatory [an operatory is a treatment room or bay equipped with a dental chair] (Goff 2004). Respondents' primary uses for computers at chairside included scheduling (77.9%), treatment planning (63.9%), patient education (60.7%), hard tissue charting (58.2%), and periodontal charting (54.1%). (Schleyer et al.2006)

Implementing clinical computing in a dental office is a difficult undertaking for a number of reasons. Most dental offices are small (75.3% of all dentists work in a solo practice) (ADA 2003) and thus cannot spend large amounts of capital on information technology (IT). Limited personnel resources require that most dentists outsource the installation and maintenance of the IT infrastructure to a vendor or consultant. Dental computer applications are complex because they must integrate and maintain structured data (such as intraoral findings, treatment plans, and the medical/dental history), free text (such as progress notes), images (such as radiographs and photographs), and three-dimensional models. (Eisner et al.1993) On a small scale, these systems integrate the functions that are typically found in medical software applications for registration, admission, discharge, and transfer; laboratory results; picture archiving and communications; computer-based patient records (CPRs); and billing and insurance processing. Currently, different companies supply the necessary software and hardware components, which makes integration a significant challenge for end users (Schleyler 2004a) … future research must address usefulness and ease of use, workflow support, infection control, integration, and implementation issues." (Schleyer et al.2006)

A study conducted by Flores-Mir reported on the perceptions of Canadian dentists. Using an anonymous self-administered survey by mail to a stratified random sample of 1,096 Canadian dentists (283 were finally available for analysis), the study found: the "usefulness of digital technologies in improving dental practice and resolving practice issues; to determine dentists' willingness to use digital and electronic technologies; to determine perceived obstacles to the use of digital and electronic technologies in dental offices; and to determine dentists' attitudes toward Internet privacy issues." (Flores-Mir et al. 2006)

Diffusion of innovation is the process by which an innovation is communicated through certain channels over time among the members of a social system (Rogers 2003). Depending upon whether people innovate or adopt innovation, they can be divided into: innovators, early adopters, secondary adopters, tertiary adopters, quaternary adopters, and laggards. Innovators are very few and only a small number of people are early adopters. Most people fall under "secondary, tertiary and quaternary adopters" depending upon how quickly they adopt the innovation. Laggards are the most skeptical people who are the last to adopt the innovation. In relation to EOHRs, at this time, it seems that in the US, early adopters have appeared and are incorporating EOHRs in their dental clinical environment.

EOHRs have started to make inroads into dental clinics and institutions slowly – though EOHRs are being increasingly adopted by dental professionals, the adoption rate is slow as is evident from the findings of the studies described above. EOHRs may be viewed as innovations and adoption of innovations takes time because adoption of EOHRs requires behavioral modification on part of dental professionals. Behavior changes are slow and acceptance and adoption of innovations occur through processes known as "diffusion of innovation". In relation to EOHRs, at this time, it seems that in the US, early adopters have appeared and are incorporating EOHRs in their dental clinical environment.

Commercial EOHR systems are critical to universal adoption of EOHRs across the world because the development of these systems represent good business opportunities for private investors. Larger scale adoption of EOHRs will require settling of the commercial EOHR offerings. Currently there are several major technical problems facing the developers of EOHR programs which may prevent quick adoption of EOHR by most of the dental community.

EOHR: PROBLEMS, PITFALLS AND BARRIERS

The interest in implementing EHR is similar in developing and developed countries as are the key issues, challenges and barriers (WHO 2006). Different countries and Institutions within countries are at different stages of implementation of EOHRs. While some countries are in the planning stage, others have implemented pilot projects, and some have implemented functional systems and are progressing to large-scale deployment and development of nationally integrated systems. Slow adoption of EOHRs has been attributed to several factors such as: clinician resistance, high costs, skepticism about return on investment, misaligned incentives, and technical issues related to their compatibility with query systems and larger back-end database systems. Anecdotal evidence suggests that EOHRs do not represent clinical information with the same degree of completeness and fidelity as paper records. These issues, challenges and barriers may be summarized into the following points.

- Resistance to change on part of healthcare providers
- Lack of standard terminology
- Issues related to clinical data entry
- Data coding issues and lack of skill in using disease classification systems
- Concerns about the correct software choice
- Issues related to integration of EOHR software with existing database systems
- High costs of hardware and software
- Data security, privacy and confidentiality issues
- Resistance to computer technology
- Lack of computer literacy and need for relearning and updating skills
- Concern about availability/ retrieval and accuracy of information in a timely manner
- Quality of electronic healthcare information and accuracy of data entries
- Issues related to space requirement and other associated logistics
- Involvement of clinicians and hospital administrators

Dealing barriers in implementing EOHRs require deft management of all or some of the points mentioned above. We approached a clinic manager of an academic institution in the US who described his experience in implementing EOHRs in an academic institution. He responded:

The initial function of the clinical management system (CMS) was for keeping accurate track of patients, procedures and billing. The CMS had 7 or 8 components, one of which was the EOHR. To make use of the EOHR it was necessary to implement the major pieces of the CMS which feed into the EOHR. A major concern for implementation was the significant dollar investment. The initial investment can be hundreds of thousands of dollars and then the yearly maintenance fees in addition to licensing for users although some software is based on having blocks like 1-25, 25-50, 100+, etc. Although there is basic software that works well in private practice, in that particular academic institution we were charged to implement an enterprise CMS for the network offices that would eventually go into the dental school. (Sullivan 2008).

Data Related Barriers

Lack of uniform standard data format and record content across clinical facilities is a major limitation for implementation of EOHR. Practitioners use different record formats, and even those using the same format may not collect data uniformly. This factor limits the integration of data among clinical facilities and health care organizations. This issue is compounded because different commercial EOHR systems use different formats and different technical specifications for the data. Technical data related barriers include:

- Different data formats and specifications used by different EOHRs.
- Lack of diagnostic codes impedes linking of diagnostic, treatment and claims data sets
- Adoption of ICD systems or procedure codes is not uniform and a variety of terminology exists to describe diagnoses, treatment and procedures
- Lack of universal identifiers (in several settings).

The dental profession should develop a more common record with standard diagnostic codes and clinical outcome measures to make the EOHR more useful for clinical research and improve the quality of care (Atkinson et al.2002). Bailit (2003) has pointed out the problem of inaccurate and non-specific diagnoses found in dental charts:

... the nomenclature used to describe dental diseases and treatments. For example, stating that the patient has periodontal disease means little, since this is a very broad term and does not describe the location, severity, or type of periodontal disease. Further, there is considerable subjectivity in how different dentists use this term. This means that periodontal disease may mean one thing in one practice but something different in another practice. Of course, this problem is not unique to dentistry, but it is a problem for researchers trying to use record data to understand why some patients are receiving certain services.

Data charting: Charting of dental data is a tedious and time consuming process. Therefore for those who are used to manual charting, the transition to electronic format involves re-learning the entire process and re-orienting to a new process. Flipping through paper is different from clicking through tabs. Similarly, the orientation of data fields in paper formats and EOHR are substantially different in structure.

A typical scenario leading to frustration out of technical issues not easily resolvable by the data entry operator or similar end user that occurs with EHR was recently reported by Baron (2007):

Unfortunately, our electronic signature did not transfer the contents of that document to the chart as data that a computer could conveniently manipulate. For that to happen, data must be entered into the chart in a structured format… An EHR is a large, highly structured database. Because patients do not usually present themselves or their histories in a structured data format, EHR users must translate what they hear or read into a format that the computer can use... Although much information can be readily translated (for example, medication data), some of it cannot (for example, recording for preserving the patient's voice). Electronic interfaces can automatically import certain data, such as quantitative laboratory results, into the chart in a structured format. However, interfaces may not be reliably available for many clinical data."

However, data retrieved from EOHRs although present in electronic form, give rise to several issues. Most EOHRs export data elements in Excel format. This limits the analytical functionality of the data to those functions that may be easily performed in Excel. However to maximize analytical yield, specialized statistical software need to be used. Transferring data from Excel to formats suitable for statistical software requires thorough checking of the Excel spreadsheets for appropriate marking of missing data, correct formatting of date and data fields etc., a process generally called as "data cleanup". Data clean up preparation of data elements and formats for proper use in statistical analytical software consumes a large amount of data analyst's time, apart from being a tedious process. Most of the times, analysts involved in cleaning of such data annotate their data clean-up outputs with a "the best that I could do". Anecdotal data suggests that in a study, some 90-95% of the total time is taken up in data cleaning whereas the actual analysis takes only 5% of the time. Our experience at the University of Kentucky has also been along similar lines. Furthermore, the data cleanup process cannot be automated because of non-standard terminology, data fields, varying formats and filters and variables across different EOHR programs. If multiple formats are to be accommodated in an analysis of data aggregated from different sources, the enormous data cleanup time required may even prohibit the conduct of the analysis.

In order to obtain greater harmony across EOHRs and make these systems better than paper records, the question to be asked is: what information should be contained in EOHRs, and in what format should those be inputted, retained and exported? A recent qualitative study reported an attempt to develop a basic content model for clinical information in paper-based records and examine its degree of coverage by commercially available EOHRs. (Schleyer et al.2007) The general conclusions from the study were revealing:

- Although dental records contain a relatively large number of fields, there is little agreement on what those fields should be.
- A complied list of dental record elements aggregated across different paper record formats contained more data elements than any EOHR system (70% of the elements were present in EOHR).
- Dental schools' records covered slightly more categories dentists' and vendors' records.
- Dental schools use more comprehensive medical history forms.
- There was a relatively high level of agreement on categories among paper-based and computer-based record formats.
- This agreement did not extend to data fields – only 57% of the data fields occurring in five or more paper records were contained in more than two EOHRs.
- Limitations in information representation in EOHRs were evident in charting hard tissue and periodontal findings, and procedures.
- Dedicated fields associated with developing problem lists or making diagnoses were absent in EOHRs
- Information coverage in EOHRs were more limited that paper formats

EOHRs contain lesser information and provide limited scope for covering clinical information that clinicians' may wish to add. Furthermore, data fields/ elements in EOHRs are grouped differently than paper formats which may lead to clinician's resistance in using EOHRs. Extensive navigation requirements in EOHRs through routines that may be perceived as counterintuitive may also be a limiting factor in clinician's resistance in using EOHRs. This suggests that the front-end interface of EOHR may need major modifications and redesigning to improve clinician compliance with using EOHRs on regular basis.

Data Entry Issues

Anecdotal data suggests some uneasiness in using a chair side computer for clinical data entry as it leads to breaks in the "rhythm" of clinical work. Infection control issues have also been raised by some clinicians. One alternative could be to record the data in paper and then input it into the EOHR.

However, such a mechanism leads to repetitive work, increases costs and is time consuming. An alternative to have dedicated personnel for direct data entry as the clinician dictates is expensive and has the potential for transcription entry errors. As an alternative to these methods, voice activated direct data entry systems have drawn considerable attention as an ideal mechanism for data entry. Therefore, the possibility of a voice activated data entry system integrated with an EOHR system could be a perfect solution to popularize adoption of EOHRs.

Speech recognition in voice activated systems allows clinicians a hands-free option for interacting with computers, which is important for dentists who have difficulty using a keyboard and a mouse while working with patients. While roughly 13% of all general dentists with computers at chairside use speech recognition for data entry, 16% have tried and discontinued using this technology. (Yuhaniak et al.2007) Voice-activated modules are available for most leading EOHRs. “Improvements in speech recognition and microphone technology have helped voice-activated charting and clinical note dictation become more accurate, faster and easier to carry out than previously possible.” (Drevenstedt et al.2005).

It has been suggested that with improvement of technology, voice activation will become a mainstream part of dental computer technology. Currently speech functionality faces several hurdles. It has been suggested that instead of being intuitive, speech functionality is directly comparable to using a mouse and the available systems require memorizing an enormous amount of specific terminology opposed to using natural language. “Overall, limited speech functionality reduces the ability of clinicians to interact directly with the computer during clinical care. This can hinder the benefits of electronic patient records and clinical decision support systems.” (Yuhaniak et al.2007)

In an attempt to solve these issues, a recent study reported the analysis of structured data entry for dentistry using an interactive dental cross (DentCross component). This component is a graphic part of dental documentation connected to an EOHR. In conjunction with an automatic speech recognition system, based on a statistical approach, the speaker-independent (DentVoice component) made the data entry easier and faster. The study showed the practical ability of the DentCross component to deliver a real service to dental care and the ability to support the identification of a person in forensic dentistry. (Zvarova 2008)

Another recent study from the European Center for Medical Informatics, Statistics and Epidemiology at Prague in the Czech Republic (EuroMISE Centre) also reported encouraging results in voice activated EOHR technology using DentCross and DentVoice components (Nagy 2008). This study reported that “the junction of voice control and graphical representation of dental arch makes hand-busy activities in dental praxis easier, quicker and more comfortable.” It is anticipated that these advancements will lead to better quality of the data stored in a structured form in dental EOHRs.

Security Issues and Health Information Protection

Security of data, when in storage or when transported/ transmitted via electronic medium, has been a major concern with patients, administrators, and governments. Personal information privacy issues have been regulated strongly in developed countries. The European Commission (1995) through the Directive 95/46/EC protected right to privacy of individuals with regard to the processing of personal data and transfer of data. Protection of electronic storage of clinical records was mandated in Japan through the directive number HPB No. 517 (Director-General HPB Japan 1999). Although the HPB No. 57 regulated data storage, these directives fell short of complete privacy of data:

These criteria must be followed when storing clinical records in electronic form, but do not need to be followed when using the information from the clinical records. However, an individual medical facility must pay attention to ensure the proper utilization of information from clinical records stored in various systems (i.e. source-input system, new and old systems). (Director-General HPB Japan 1999)

Because EOHRs deal with personally identifiable information and the nature of information is personal and private for the patient, the importance of maintaining privacy, security and confidentiality is paramount. To protect personal health information (PHI), measures are being taken at different level of social organization dealing with PHI – policy, judicial-legal, administrative, personnel and software levels. This issue has become more important due to the potential security breaches in databases that are reported in the media regularly and frequently. Data security is a major concern because of the potential for great harm that stolen data may cause in the hands of unscrupulous elements.

Computer-based, electronic dental record keeping involves complex issues of patient privacy and the dental practitioner's ethical duty of confidentiality… Authenticating the electronic record in terms of ensuring its reliability and accuracy is essential in order to protect its admissibility as evidence in legal actions. Security systems must be carefully planned to limit access and provide for back-up and storage of dental records. Carefully planned security systems protect the patient from disclosure without the patient's consent and also protect the practitioner from the liability that would arise from such disclosure. Human errors account for the majority of data security problems. Personnel security is assured through pre-employment screening, employment contracts, policies, and staff education. Contracts for health information systems should include provisions for indemnification and ensure the confidentiality of the system by the vendor. (Szekely 1996)

The lead in assuring security of PHI was taken by the US with the enactment of the Health Insurance Portability and Accountability Act (HIPAA) that was enacted by the U.S. Congress in 1996 under the Clinton Administration. It is also known as the Kennedy-Kassebaum Act. Title I of HIPAA protects health insurance coverage for workers and their families when they change or lose their jobs. Title II of HIPAA, known as the Administrative Simplification provisions, requires the establishment of national standards for electronic health care transactions and national identifiers for providers, health insurance plans, and employers. (USDHHS 2008, ADA 2005) HIPAA requires PHI to have administrative, physical and technical safeguards. A primary goal of HIPAA is to maintain confidentiality of an individual's identifiable health information if it is transmitted by electronic means for administrative purposes. (USDHHS 2001, Pai & Zimmerman 2002) The phrase, "identifiable health information," means the information itself can be directly or indirectly linked to a person. Another goal of HIPAA is the establishment of commonality of the format used for administrative "transactions."(Chasteen et al.2003a, 2003b)

The HIPAA privacy rule is designed to protect a patient's personal health information from being accessed by an unauthorized person. It mandates the creation of a format to be used by healthcare entities such as a dental clinic/ office/ hospital which transmit health information electronically to protect the confidentiality and security of health information by setting and enforcing standards. (Walker 2002) "The security regulations contain standards with both 'required' implementation specifications and 'addressable' implementation specifications. The security regulations require covered entities to adopt administrative, physical and technical safeguards to protect electronic protected health information." (Sfikas 2003) Some functions covered under HIPAA include: enrolment, claims (encounters, status, payments, and attachments), referrals, eligibility verification, premium billing, and first report of injury or compensation. All EOHR systems therefore are required to confirm to HIPAA mandates, and to modifications of regulations specific to the countries where those are used. (Day 2000, 2001) It is expected that other countries will develop their own regulations by adapting existing regulations from European Union, Japan and USA.

Impact on Workflow

Impact of EHR on workflow in terms of slowing down clinical work has been known to contribute to clinician resistance in using EHRs (Dansky et al.1999). Clinicians were concerned that a negative impact on workflow would reduce productivity. However, EHRs require re-learning and adapting to a new paradigm of data entry, and the learning-curve integrated in this need to re-learn may be the bottleneck for the workflow impact. It has been shown that once clinicians learn the EHR processes, their workflow and productivity return to normal in 30 days (Krall 1995).

It has been suggested that the possible slowdown in workflow with an EHR may be mitigated by using templates and forms. However, prior to implementing an EHR, paper templates should be created around all commonly seen diagnoses follow-up (Cusack 2008) and electronic templates should be adequately tested against those as has been reported by Schleyer et al.(2007). Thereafter, the electronic templates should be modified for comprehensive coverage, smooth navigation and ease of use in a busy clinical facility.

ESTABLISHING EOHR AND TRANSFORMING FROM PAPER RECORDS TO ELECTRONIC RECORDS

With the massive growth in computer technology and exponentially reducing digital storage space costs, implementing EOHRs is not really a choice anymore, but a necessity. An EOHR has become a priority in many countries, including the UK (Reynolds et al. 2008).

> *In the last several years, dentistry has crossed over into the new frontier of electronic dentistry. It has embraced such developments as computer programs for producing digital radiographs and photographs, as well as digital programs that enhance these images, store and organize them into a retrievable "chart-like" fashion, and transmit them via the Internet. In Europe, I saw patients with an electronic "health card." This credit card-sized CD can carry all the information on a patient's written charts, results of laboratory tests, radiographic/imaging information and more. It is expected that the mobile phone will be an alternate vehicle for patient records, and that these records will be accessed with a password security system. This will allow patients to carry their records from location to location. Certainly, the dental implications of such seemingly advanced processes are evident. The expression, 'The future is now,' was never truer. (Schutze 2001)*

One of the key problems faced by any institution or clinical facility when converting from a paper-based/ manual health record system to EOHR is the planning of such a transition because the change reflects a paradigm shift in the way daily work is done. When instituting any major large-scale change, it is generally necessary to establish an Executive committee or hire a consultant knowledgeable in EOHR. These individuals must be integrated from the first day of planning and retained until the transition is completed.

WHO has developed a step-by-step manual to guide implementation of EHRs in developing countries (WHO 2006). The WHO guide reviews current health record systems and policies related to medical records practice. Thereafter it provides a sequential guidance to every aspect of setting up EHRs: planning for the introduction of an EHR; developing an implementation plan; factors to be considered when developing an EHR implementation plan; and finally points out the issues and challenges, providing reasonable solutions. This document is downloadable freely from WHO web site [http://www.wpro.who.int/publications/PUB_9290612177.htm] and is a very useful guide to anyone anywhere wanting to set up an EOHR system.

In order to implement electronic technology dependent methods, some key safeguards are necessary to ensure proper functioning. The basic general needed safeguards for EOHRs include existence of:

- Regular, reliable and efficient back-up system and protocol
- Electrical system emergency preparedness protocol and disaster-recovery protocol for EOHR
- Efficient, practical and easy to use security for work stations and servers and data
- Control over who is able to access the data and a system for data de-identification of data when accessed by individuals who do not need to know the patients' identity
- Mechanism to identify who accesses and/or modifies the data.

In the early 1990's the American Dental Association (ADA) published the monograph "The Computer-based Oral Health Record," to describe a specific EOHR that complements the EHR used for general healthcare. Subsequently, the ADA established a Standards Committee for Dental Informatics (SCDI) that promoted the application of information and various computerized technology. (Heid et al.2002) In 2001, the SCDI developed American National Standards Institute/ADA Specification 1000: Standard Clinical Data Architecture (ADA 2006) outlining the Structure and Content of an Electronic Health Record and is the first ANSI standard that defines the fundamental data structures used to create patient health records. The standard promotes the sharing of like data between dentists, physicians, and hospitals (Harrell et al. 2005). "This is a blueprint from which commercial vendors are encouraged to build uniform health records in interoperable practice management systems to prevent incompatibility problems between vendor systems. The SCDI is preparing an informational report called "Practitioner's Guide to Electronic Dental Records" to specify the capabilities of computer-based dental record systems." (Hamilton 2005) The ADA Technical Report No. 1004 provides a checklist of features and functions helps the dentist determine specific requirements and their priorities. "Characteristics of specific systems are then compared to these specific needs to rank the available choices. The report has also been updated to reflect increasing sophistication in the industry such as the charting interface of the clinical workstation. This specification will also be updated to reflect the growth of web-based systems and dental specialty requirements." (ADA 2004)

Supported by the ADA, orthodontic oriented solutions are being developed to send patient information to colleagues allowing practitioners to share the same patient record across different software programs by solving technical incompatibilities. (Magni et al. 2007) These orthodontic EOHRs aim to establish a seamless interchange of data between software programs and to create a standard for electronic orthodontic patient records.

EOHR SYSTEMS IN THE MARKET

Several EOHR systems are available in the market around the world, but most developers are in the US – most systems are commercial although few are freeware. Several notable systems are being developed by firms based in Canada, France, Germany, New Zealand, and elsewhere. Table 1 provides a list of commercially available and freeware EOHR systems along with the web addresses of the firms that are involved in developing those programs. Different EOHR programs work differently and comparative studies are rare. Only one comparative analysis has been published so far which found that commonly mentioned strengths of the software applications included easy to use/learn, scheduling, integration and flexibility, whereas common weaknesses included complexity, and integration issues. (Schleyer et al.2006)

The market-share of different programs varies. A study published in the United States found that the top five systems in terms of market share were Dentrix (26.2%) and Easy Dental (9.8%) (both from Dentrix Dental Systems, American Fork, UT), SoftDent (15.0%) and PracticeWorks (7.9%) (both from Kodak Corp., Rochester, NY), and EagleSoft (11.0%) (Patterson Dental, St. Paul, MN). (Clinical Research Associates, 2003 cited in Schleyer et al.2006) Anecdotal data suggests that in the US dental schools, AxiUm is commonly used system with EOHR software.

The main features included in the EOHR systems available in the market are: (a) appointment management, (b) clinical charting, (c) employees management, (d) financial management,(e) generation of presentations, (f) image interface, (g) insurance management, (h) laboratory tracking, (i) marketing management, (j) patient & family information, k) practice paperless, (l) prescription writing, m) reports tool, n) software integration, (o) touch screen, (p) treatment plan, and (q) 3D feature. Pricing of different commercial software vary substantially. Some have no up-front cost where one does not have to purchase the software *per se* but has to pay a monthly or annual fee for use the product (license). Others use a more traditional mechanism which one purchases at a one-time cost. Still others ask for payments of different services, such as support, maintenance or updates.

EOHRS IN RESEARCH AND PUBLIC HEALTH

EOHRs in Practice Based Research

Practice Based Research Networks (PBRNs) are teams of practicing dentists who investigate "everyday" issues in the delivery of oral healthcare with greater scientific rigor (NIDCR 2008).

In March of 2005, the US National Institute of Dental and Craniofacial Research (NIDCR) announced it has awarded three grants, totaling $75 million that establish regional "practice-based" research networks (PBRN) to investigate with greater scientific rigor "everyday" issues in the delivery of oral healthcare. (NIDCR 2008) The goal of PBRNs is to encourage practicing dentists and hygienists to propose and conduct each clinical study in close collaboration with their network colleagues. The general idea of developing the PBRNs is to address practical, real-world issues and generate data that will be of immediate interest to practitioners and their patients. (NIDCR 2008) Recently, a group of dental practitioners participating in the PBRN effort wrote about their perspective calling the effort to be a "win-win for private-practice dentists and the future of dentistry". (Veitz-Keenan 2007) Although not enough data is available at this moment about success or utility of PBRNs in dentistry, such networks have been in existence in medical research for over two decades; they have generally been successful (Moskowitz 2007) and have resulted in significant clinical protocol changes. (Chattopadhyay et al. 2008)

Table 1. Comprehensive list of EOHRs available in the market (in alphabetical order)

No.	Software name	Company	Country	Website
1	ABELDent	ABELSoft Corporation	Canada	www.abeldent.com
2	ACE Dental	American Computer Exchange	USA	www.ace-dental.com
3	AD2000	CLG	Canada	www.ad2000.info
4	Ad.I.C.O	Software Odontólogo	Argentina	www.software-odontologo.com.ar
5	ADSTRA Management	ADSTRA Systems Inc.	Canada	www.adstra.com
6	AlphaDent	AlphaDent	USA	www.alphadent.com
7	AltaPoint Dental	AltaPoint Data Systems, LLC	USA	www.altapoint.com
8	Apollonia	Procedia GmbH	Germany	www.procedia.de
9	AxiUm	Exan Enterprise	Canada	www.exanacademic.com
10	BioDente	BioManager	Brazil	www.biomanager.com.br
11	Bridge-IT	Fusion Software Ltd.	United Kingdom	www.fusionsoftwareuk.co.uk
12	CDM	CamSight Co., Inc.	USA	www.camsight.com
13	Ciraden	Ciraden, Inc.	USA	www.ciraden.com
14	ClearDent	Prococious Technology Inc.	Canada	www.cleardent.com
15	Curve DMS	Curve Dental	Canada	www.curvedental.com
16	DAISY	Dentist Management Corp.	USA	www.daisydental.com
17	Data Team DDS	Data Team Corporation	USA	www.datateamdds.com
18	Datacon	Datacon Dental Systems	USA	www.datacondental.com
19	DDS Works	DDS Works	USA	www.ddsworks.com
20	DentaGrama	DentaGrama	Colombia	www.dentagrama.com
21	Dental 2000	Complete Systems, Inc.	USA	www.completesys.com
22	Dental Business	BioManager	Brazil	www.biomanager.com.br
23	Dental Clinic	Codegroup	Serbia & Montenegro	www.codegroup.co.yu
24	Dental Clinic	Dental Clinic	Brazil	www.dentalclinic.com.br
25	Dental-Exec	DSN Software, Inc.	USA	www.dentalexec.com
26	Dental 4 Windows	Centaur Software Development	Australia	www.centaursoftware.com.au
27	Dentalis	Dentalis Software	Brazil	www.dentalis.com.br
28	DentalManager	Larix Dental Concepts	Netherland	www.larixtechnology.nl
29	DentalMate	MDC Services, Inc.	USA	www.dentalmate.com
30	Dental Office	Rh ! Software Ltda.	Brazil	www.dentaloffice.com.br
31	Dental Office Manager Studio	Applied Computer Concepts	USA	www.dom2.com
32	DentalPro	Random Information Systems	USA	www.dentalprosoftware.com
33	Dentalpro	Prodoctor Software Ltda.	Brazil	www.dentalpro.com.br
34	Dental System	Dialog Medical Systems, Inc.	Canada	www.dialogmedsys.com
35	DentalVision	Henry Schein, Inc.	USA	www.discusdentalsoftware.com
36	DentalVox Plus	Softart	Colombia	www.dentalvox.org
37	DentalWare	OptiMicro Technologies, Inc.	Canada	www.dentalware.com
38	DentalWriter	Nierman Practice Management	USA	www.dentalwriter.com
39	Dentech	Softech, Inc.	USA	www.dentech.com

Table 1, continued

No.	Software name	Company	Country	Website
40	Denticon	Planet DDS, Inc.	USA	www.planetdds.com
41	DentiLogic	DentiLogic	Argentina	www.dentilogic.com
42	DentiMax	DentiMax	USA	www.dentimax.com
43	Dentisoft Office	Dentisoft Technologies, Inc.	USA	www.dentisoft.com
44	Dentista Pro	Logicroutes, Inc.	Philippines	www.logicroutes.com
45	Dentitek	Progitek dev, Inc.	Canada	www.progitek.ca
46	DentoNovo	NovoLogik, Inc.	Canada	www.novologik.com

Successful PBRN activity requires that the PBRNs are linked group of clinical practices that can pool their data and resources to conduct research. Such data sharing will be possible only through coordinated use of compatible and standardized EOHR systems that allow data sharing and analyses. Similarly, administrative databases are also reservoirs of wealth of information that contribute greatly to develop workable health improvement policies. Several studies demonstrated the benefit of linking the service data to patient or provider characteristic through EOHRs. (Leake, Werneck 2005) The success of PBRNs depends upon active participation of dental practitioners who must use computers and EOHRs. As noted earlier, adoption of computerization among dentists have been slow. Training and follow-up support may encourage dental practice teams to develop more positive attitudes towards computerization and encourage them to use computers more extensively in clinical practice. (John et al. 2003)

EOHRs in Dental Public Health

Public health policies are usually based on analyses of data collected over a long period of time which also requires time for analyses. This creates a large time lag between the origin of the data and development and enactment of policies by when the nature of oral health realities may have changed. Use of EOHRs in PBRNs, public health settings and in other relevant clinical examination based surveys can help speed up the process and reduce the time between data collection and publication of analytical results from the survey thereby making policy making in "real time" possible - use of EOHRs can help

A recent report discussed and identified important design, implementation, and methodological issues with current EHR systems and their role in public health (Kukafka et al.2007). The authors suggested that "in order to support public health's traditional focus on preventive health and socio-behavioral factors, EHR data models would need to be expanded to incorporate environmental, psychosocial, and other non-medical data elements, and workflow would have to be examined to determine the optimal way of collecting these data." They also argue that redesigning EHR systems to support public health offers benefits not only to the public health system but also to consumers, health-care institutions, and individual providers. Although the need of immediate real time data in oral health surveillance is not as urgent as in surveillance for bioterrorism (biosurveillance), the characteristics and issues involved in data transmission from EOHRs in remote areas are the same as for biosurveillance.

Biosurveillance requires near-real-time event monitoring to enable early event detection and rapid response (Ventres et al.2000). The US Healthcare Information Technology Standards Panel's Biosurveillance Technical Committee has

> *done extensive work on standards and interoperability issues for biosurveillance, employing a use case that involves transmitting ambulatory care, emergency department visit, utilization, and lab results data in standardized and anonymized format to public health agencies within one day. Steps in biosurveillance data transfer will include identifying relevant information, aggregating data, and anonymizing it, formatting it to public health specifications, identifying the relevant public health agencies, transmitting the data to them, and logging all transactions. Data could be sent data directly from individual health-care organizations, through some intermediary networked organization, or through a combination of models. Importantly, this standards project is being harmonized with that of the EHR. The Biosurveillance Technical Committee has published extensive reports (BTC 2006a, 2006b) on standards needed to support this goal, as well as on remaining interoperability issues. (Kukafka et al.2007).*

It has been suggested that guidance on what data elements to include may be gleaned from the Chronic Care Model (Wagner 1998) developed to reformulate healthcare from an acute care model in managing chronic diseases into a public health model.

One idea for use of EOHRs in public health setting is to use them in mobile devices so that data collection and transfer can be speeded up from remote areas. “No ideal customisable mobile digital solution currently exists but evidence from general healthcare use suggests that there are valuable features that can aid the general dental practitioners such as personal management and point of source assistance” (Reynolds et al.2008). Wireless personal digital assistants (PDA) together with data secure transmission of digital clinical information could be used in order to assist in disaster victim identification in areas where GSM cellular networks are available (Salo et al.2007). An experiment in the state of New York used PDAs for data collection in remote areas, but the program witnessed several transmission and integration problems inhibiting effective use of PDAs for such activities in oral health surveillance (Kumar 2008).

However, wireless transmission of records has recently been successfully adopted in orthodontic clinics.

> *Wireless cellular broadband technology currently transmits data at speeds that only wired broadband connections were capable of until now. By using high-speed data access protocols such as evolution data optimized (EV-DO) or enhanced data rate for global system for mobile communications evolution (EDGE), gaining access to patient data in an orthodontic office remotely has become a relatively simple task. Affordable and convenient cellular broadband networks allow the orthodontist to remotely access schedules, and update, review, add, or modify data virtually from anywhere. Newer generation wireless broadband technologies have made the virtual office a reality. (Mupparapu 2007)*

Further enhancement of use of technological advancements will make it possible to use remote area data collection and their real time availability in analytical centers possible through the use of EOHRs that are adaptable to mobile data collection instruments such as PDAs and other hand held devices.

EOHR Input in Research Data

Data needs for oral health related clinical and public health research, especially when integrated with etiological research and basic science information are special. For example, the scientific methods require minimizing within- and between-examiner variability, highly accurate, and precise, regular periodic unbiased measurements and a battery of biologic measurements along with detailed disease and exposure measurements that may be out of scope of routine clinical EOHRs. However, clinicians involved in PBRNs would need to have access to such detailed parts of EOHRs for the purpose of research.

A general understanding of the measurement of dental diseases can help practitioners in the process of assessing the patient's future risk of disease. More importantly, as clinical studies shift from the traditional academic setting to practice-based networks, practitioners might play a more significant role in research. An important issue in oral health disease management in the future will be the standardization of clinical criteria and the development of alternative mechanisms of data collection for epidemiologic purposes. (Chattopadhyay et al.2008)

To incorporate such standardization requirements may need substantial expansion of EOHRs which might make them prohibitively expensive or difficult to deploy in clinical settings. "It is not possible to extend the EHR data model to capture the entire host of factors, but an EHR's data model should represent those data elements that are known to contribute to the disease process in order to provide decision support and/or data transfer" to research centers on an as-per-need basis (Kukafka et al.2007).

It is however possible to develop modular EOHRs where clinical, practice, public health and research needs could be addressed by designing separate modules that can be appended to a core EOHR leading to an integrated database that can be as comprehensive as the need be, and yet deployed in smaller modules. Such a modular system can also be integrated with a clinical decision support system. (Benn et al.2000) A modular approach would enhance the scope of using EOHR system for a variety of activities beyond routine clinical work. For example, a public health EOHR modules would allow "high-quality population-level research by improving data quality, pooling it, and making it available for analysis through traditional epidemiological or data-mining methods' (Kukafka et al.2007); allow modification and redesign large surveys; expand scope of the type and depth of data collected from individuals; improve recruitment for clinical trials.

ESTABLISHING A PAPERLESS DENTAL OFFICE

The vision of a completely paperless office has the EOHR at its center, and needs several technologies to be integrated into a seamless working whole from which all benefits of EOHR can be utilized to maximum by clinicians, researchers, academicians and public health professionals and policy makers. Apparently there is a gap in the direction of research and implementation of an obviously needed system that would be conducive for modern methods of health information storage, retrieval and usage. Furthermore, implementation of EOHR is lagging way behind the available hardware and software resources for implementing EOHR. At the same time, it seems that the need for dental research databases and routine clinical use databases will have different sets of requirements to maximize analytical outputs from EOHR.

To make paperless offices possible will require researchers and dental professionals to address multiple grand challenges… The following applications, processes, and technologies would need to be designed, developed, and implemented:

1. A system could profile patient risk for specific chronic oral disease status
2. A population-based system could assess the likelihood of successful outcomes for dental treatments such as implants, periodontal surgery, prostheses, amalgam, plastic, cast, and ceramic restorations.
3. 3-D image manipulation and simulation systems could illustrate the effect on the current patient's appearance of specific proposed procedures,

4. An automated treatment planning system for all dental diagnoses could be used by clinicians (evidence-based guidelines for dental diseases and conditions, multiple semi-edentulous conditions, and malocclusions).
5. A decision aid for patients would help them learn about all personally relevant and applicable dental treatment options. Such a support system would also help patients in a decision making process that would lead to a value-based choice among the various alternatives.
6. Procedures and processes would be needed to capture and analyze digital images progressively over time to track hard-tissue changes.
7. Nano-robots would be used intra-orally to monitor and transmit information on various markers of oral health status, such as salivary pH fluctuations and long-term trends, degree of mineralization shifts at certain index tooth surfaces, salivary enzyme and bacteriologic make-up changes over time, and information about crevicular fluid flow and composition.
8. *Computer-based simulations could incorporate haptic feedback and thus allow students to develop and enhance their fine motor skills.* (Sittig et al.2003)

To attain this scenario, the following challenges that must be addressed:

1. To develop a knowledge-based ontology of dental concepts from which one could extract a standardized controlled clinical terminology to describe dental signs, symptoms, conditions, diseases, and treatments (i.e., procedures, methods, techniques, materials, and devices).
2. To develop an evidence base of etiology, diagnosis, prevention, treatment, and treatment outcomes (including materials, methods, techniques, and usage) for a large proportion of dental patients and dental practices.
3. To develop a comprehensive electronic oral health record that is seamlessly integrated into the automated medical record. Such
4. To develop a nationwide oral health database that contains basic patient-level diagnostic, treatment, and outcome data linked to a nationwide medical database
5. To automate data capture, integration, and synthesis to create real-time, knowledge-based, clinical monitoring systems based on both continuously and intermittently available analog and digital data.
6. *To develop learner-centered educational systems that select a learning goal, evaluate the student's abilities, and determine the individual learning style* (Sittig et al.2003)

CONCLUSION

Adoption of EOHR offers multiple benefits for clinical practitioners, academicians and researchers including ready access to patients' information, decreased medical errors, ability to share information with providers and health care organizations, collection of data for research purposes, etc. EOHRs must also balance the need to be integrated with EHRs although any EOHR system cannot be subordinate to, or a subset of, an EHR. From a public perspective, EOHR could result in improved oral health outcomes and reduced health care expenditures. While much progress has been made several challenges remain to be overcome. Integration of EOHR has been slow because it represents re-engineering current practices and processes, dealing with technical difficulties and data safety issues, which many perceive outweigh the benefits. However, as government and health care systems strive for improved efficiency and quality, the refinement of EOHR and wide adoption in dentistry seems to be where the future lies.

REFERENCES

ADA. (2003). American Dental Association Survey Center. *Survey of dental practice.* Chicago: American Dental Association.

ADA. (2004). *ADA Specification 1004 Computer Software Performance for Dental Practice Software.* [www page]. URL http://www.ada.org/prof/resources/standards/informatics_reports.asp

ADA. (2005). *Health Insurance Portability and Accountability Act (HIPAA) [www page].* URL http://www.ada.org/prof/resources/topics/hipaa/index.asp

ADA. (2006). *ADA Specification 1000: Standard Clinical Architecture for the Structure and Content for the Electronic Health Record*. [www page]. URL http://www.ada.org/prof/resources/standards/informatics_reports.asp

Atkinson, J. C., Zelle, G. G., & Shah, C. (2002). Electronic patient records for dental school clinics: More than paperless systems. *Journal of Dental Education*, *66*, 634–642.

Bailit, H. L. (2003). Health services research. *Advances in Dental Research*, *17*, 82–85. doi:10.1177/154407370301700119

Baron, R. J. (2007). Quality improvement with an electronic health record: Achievable, but not automatic. *Annals of Internal Medicine*, *147*, 549–552.

Bauer, J. C., & Brown, W. T. (2001). The digital transformation of oral health care: Teledentistry and electronic commerce. *The Journal of the American Dental Association*, *32*, 204–209.

Benn, D. K., Kostewicz, S. H., Dankel, D. D., Segal, R., Schmidt, S. O., & Chardon, Z. (2000). Designing an electronic patient record with multiple real time decision support modules for managing diseases. *Proc AMIA Symp, 1168.*

Bergenholtz, G., & Spångberg, L. (2004). Controversies in endodontics. *Crit Rev Oral Biol Med, 1, 15*(2), 99-114.

Biosurveillance Technical Committee (BTC). (2006a). *Standards gap and overlap analysis biosurveillance use case: visit, utilization, and lab results data.* In: Office of the National Health Information Technology Coordinator, (Ed.), Evaluation of Standards Harmonization Process for HIT: Healthcare Information Technology Standards Panel.

Biosurveillance Technical Committee (BTC). (2006b). *Selected standards*. In: Office of the National Health Information Technology Coordinator, editor. Evaluation of Standards Harmonization Process for HIT: Healthcare Information Technology Standards Panel.

Chasteen, J. E., Murphy, G., Forrey, A., & Heid, D. (2003). The Health Insurance Portability & Accountability Act and the practice of dentistry in the United States: Electronic transactions. *The Journal of Contemporary Dental Practice*, *4*(4), 108–120.

Chattopadhyay, A., Arevalo, O., & Sohn, W. (2008). Understanding measurement of dental diseases and research participation in practice set-up. *Dental Clinics of North America*, *52*(2), 367–386. doi:10.1016/j.cden.2007.12.005

Cusack, C. M. (2008). Electronic health records and electronic prescribing: Promise and pitfalls. [ix.]. *Obstetrics and Gynecology Clinics of North America*, *35*(1), 63–79. doi:10.1016/j.ogc.2007.12.010

Dansky, K. H., Gamm, L. D., Vasey, J. J., & Barsukiewicz, C. K. (1999). Electronic medical records: Are physicians ready? [discussion: 454–5]. *Journal of Healthcare Management*, *44*, 440–454.

Day, J. (2000). Cyberinfo: Privacy and personal health data in cyberspace. *The Journal of Contemporary Dental Practice*, *1*, 1–6.

Day, J. (2001) Privacy and personal health data in cyberspace: The role and responsibility of healthcare professionals. *J Contemp Dent Pract, 1*(2), 02-06.

Delany, J. (2004). Riding the wave of the future. Electronic patient charting debuts in student clinic. *The Penn Dental Journal*, 2–5.

Delrose, D. E., & Steinberg, R. W. (2000). The clinical significance of the digital patient record. *The Journal of the American Dental Association*, *131*, 57S–60S.

DHHS. (U.S. Department of Health and Human Services) (2001). *HIPAA Administrative Simplification, Proposed Security Rule*. [www page]. URL http://aspe.os.dhhs.gov/admnsimp/bannerps.htm#security

DHHS. (2008). Medical Privacy - National Standards to Protect the Privacy of Personal Health Information. [WWW page]. URL http://www.hhs.gov/ocr/hipaa/

DHHS (U.S. Department of Health & Human Services). (2004). The National Health Information Infrastructure (NHII 2002-2004) [WWW page]. URL. http://aspe.hhs.gov/sp/NHII/index.html

Director-General, Health Policy Bureau of Japan. (1999). The Electronic Storage of Clinical Records. [www page]. URL http://www.medis.or.jp/2_kaihatu/denshi/file/e_notification990422.pdf

Drevenstedt, G. L., McDonald, J. C., & Drevenstedt, L. W. (2005). The role of voice activated technology in today's dental practice. *The Journal of the American Dental Association*, *136*, 157–161.

Eisner, J., Chasteen, J., Schleyer, T., & Feldman, C. (1993). *The computer based oral health record: a new foundation for oral health information systems.* Chicago: American Fund for Dental Health.

Eplee, H., Murray, B., Revere, J. H., Bollmann, F., Haddad, G., Klimek, J., Barna, S., Rhodes, G., Looki, T., Malone, A., Molvar, M., Pienkowski, B., Schoonheim, M., & Teravainen J. (2002). Electronic management systems. *Eur J Dent Educ, 6*(Suppl. 3), 152-160 File 16.

European Commission. (1995). Directive 95/46/EC. [www page]. URL www.cdt.org/privacy/eudirective/EU_Directive_.html

Finkeissen, E., Weber, R., Haßfeld, S., Koke, U., & Wetter, T. (2002). AIDA - Experiences in compensating the mutual weaknesses of knowledge-based and object-oriented development in a complex dental planning domain. *Methods of Information in Medicine*, *41*(2), 168–176.

Flores-Mir, C., Palmer, N. G., Northcott, H. C., Khurshed, F., & Major, P. W. (2006). Perceptions and attitudes of Canadian dentists toward digital and electronic technologies. *J Can Dent Assoc*, *72*(3), 243.

Fouad, A. F., & Burleson, J. (2003). The effect of diabetes mellitus on endodontic treatment outcome Data from an electronic patient record. *The Journal of the American Dental Association*, *134*, 43–51.

Freydberg, B. K. (2001). Connecting to success: Practice management on the Net. *J Contemp Dent Pract, 3*(2), 050-061.

Goff, S. (2004). The Computerized operatory. *Dental products report* [WWW page]. URL: http://www.dentalproducts.net

Goldberg, H. I., Ralston, J. D., Hirsch, I. B., Hoath, J. I., & Ahmed, K. I. (2003). Using an Internet comanagement module to improve the quality of chronic disease care. *Joint Commission Journal on Quality and Safety*, *29*(9), 443–451.

Green, S. R. (1996). Electronic vs. traditional recordkeeping. *Dental Economics - Oral Hygiene*, *86*(8), 60–65.

Greenwood, S. R., Grigg, P. A., Vowles, R. V., & Stephens, C. D. (1997). Clinical informatics and the dental curriculum. A review of the impact of informatics in dental care, its implications for dental education. *European Journal of Dental Education*, *1*(4), 153–161.

Hamilton, J. (2005). Is the paperless practice possible?: A look at the ADA's electronic health record initiatives. *The Journal of the American Dental Association*, *136*, 161–162.

Harrell, W. E. Jr, Stanford, S., & Bralower, P. (2005). ADA initiates development of orthodontic informatics standards. *American Journal of Orthodontics and Dentofacial Orthopedics*, *128*(2), 153–156. doi:10.1016/j.ajodo.2005.04.017

HealthGrades. (2004). *Patient safety in American hospitals* [WWW page] URL http://www.healthgrades.com/media/english/pdf/HG_Patient_Safety_Study_Final.pdf

Heid, D. W., Chasteen, J.,& Forrey, A. W. (2002) The electronic oral health record. *J Contemp Dent Pract., 15, 3*(1), 43-54.

Institute of Medicine (IOM). (2000). *To err is human: Building a safer health system.* Washington DC: National Academy Press.

John, J. H., Thomas, D., & Richards, D. (2003). Questionnaire survey on the use of computerisation in dental practices across the Thames Valley region. *British Dental Journal*, *195*, 585–590. doi:10.1038/sj.bdj.4810734

Kim, S. (2004). Modern endodontic practice: Instruments and techniques. *Dental Clinics of North America*, *48*(1), 1–9. doi:10.1016/j.cden.2003.12.002

Krall, M. (1995). Acceptance and performance by clinicians using an ambulatory electronic medical record in an HMO. *Proceedings of the Annual Symposium on Computer Applications in Medical Care*, 708–711.

Krol, D. M., Stump, L., Collins, D., Roumanis, S. A., & Radford, M. J. (2002). A qualitative analysis of medication use variance reports. *The Joint Commission Journal on Quality Improvement*, *28*(6), 316–323.

Kukafka, R., Ancker, J. S., Chan, C., Chelico, J., Khan, S., & Mortoti, S. (2007). Redesigning electronic health record systems to support public health. *Journal of Biomedical Informatics*, *40*(4), 398–409. doi:10.1016/j.jbi.2007.07.001

Kumar, J. V. (2008). *Problems with use of PDA in oral health surveillance in New York State.* Unpublished personal communication.

Leake, J. L., & Werneck, R. I. (2005). The use of administrative databases to assess oral health care. *Journal of Public Health Dentistry*, *65*(1), 21–35. doi:10.1111/j.1752-7325.2005.tb02783.x

MacGregor, D. G., & Halabisky, W. A. (1967). Electronic data processing in the storage and retrieval of dental patient file information. *Journal of Dental Education*, *31*(4), 499–507.

Magni, A., de Oliveira Albuquerque, R., de Sousa, R. T., Hans, M. G., & Magnid, F. G. (2007). Solving incompatibilities between electronic records for orthodontic patients. *American Journal of Orthodontics and Dentofacial Orthopedics*, *132*, 116–121. doi:10.1016/j.ajodo.2006.07.024

Miller, M. C. (1995, Sep). Expanding dental practices with computer technology. *Dentistry Today*, *14*(9), 72–81.

Monteith, B. D. (1991). The electronic patient record and second generation clinical databases: problems of standards and nomenclature. *Journal of Dental Education*, *55*(4), 246–252.

Moskowitz, E. (2007). Clinical Research in Dentistry. *The New York State Dental Journal*, *73*(3), 4.

Mupparapu, M. (2007). Remote access of electronic patient data with cellular wireless broadband technology. *American Journal of Orthodontics and Dentofacial Orthopedics*, *132*, 260–265. doi:10.1016/j.ajodo.2006.07.023

Nagy, M., Hanzlicek, P., Zvarova, J., Dostalova, T., Seydlova, M., & Hippman, R. (2008). Voice-controlled data entry in dental electronic health record. *Studies in Health Technology and Informatics*, *136*, 529–534.

NIDCR. (2008). NIDCR Awards Grants for New Practice-Based Initiative.) [WWW page]. URL http://www.nidcr.nih.gov/Research/ResearchResults/ScienceBriefs/CurrentSNIB/PBRNOverviewClinicalResearch.htm

Oakley, C., & Brunette, D. M. (2002). The use of diagnostic data in clinical dental practice. *Dental Clinics of North America*, *46*(1), 87–115. doi:10.1016/S0011-8532(03)00052-1

Ogunbodede, E. O., Fatusi, O. A., Folayan, M. O., & Olayiwola, G. (2005). Retrospective survey of antibiotic prescriptions in dentistry. *J Contemp Dent Pract. 15, 6*(2):64-71.

Pai, S. S., & Zimmerman, J. L. (2002). Health Insurance Portability and Accountability Act (HIPAA). Implications for dental practice. *Dentistry Today*, *21*(10), 106–111.

Pontes, F., Pontes, H., Adachi, P., Rodini, C., Almeida, D., & Pinto, D. Jr. (2008). Gingival and bone necrosis caused by accidental sodium hypochlorite injection instead of anaesthetic solution. *International Endodontic Journal*, *41*(3), 267–270. doi:10.1111/j.1365-2591.2007.01340.x

Rada, R. E. (1995). Document imaging and the patient chart: Envisioning the future for your practice. *Illinois Dental Journal*, *64*(3), 127–132.

Reis-Schmidt, T. (2000). Clinical software & electronic charting--Essential tools. *Compend Contin Educ Dent*, *21*(5), 416–421.

Reynolds, P. A., Harper, J., & Dunne, S. (2008). Better informed in clinical practice - A brief overview of dental informatics. *British Dental Journal*, *204*, 313–317. doi:10.1038/bdj.2008.193

Rogers, E. M. (2003). *Diffusion of innovations*, Fifth Edition. New York: Free Press.

Roy, M. (2008). Your data breach was probably avoidable. *eWeek, 25*(19):24.

Salo, S., Salo, H., Liisanantti, A., & Reponen, J. (2007). Data transmission in dental identification of mass disaster victims. *The Journal of Forensic Odonto-Stomatology*, *25*(1), 17–22.

Schleyer, T. (1995). *TEPR95 Proceedings*, (pp. 299-306). Newton, MA: Medical Record Institute.

Schleyer, T., & Spallek, H. (2001). Dental informatics. A cornerstone of dental practice. *The Journal of the American Dental Association*, *132*(5), 605–613.

Schleyer, T., Spallek, H., & Hernandez, P. (2007). A qualitative investigation of the content of dental paper-based and computer-based patient record formats. *Journal of the American Medical Informatics Association*, *14*, 515–526. doi:10.1197/jamia.M2335

Schleyer, T., Speller, H., Battling, W. C., & Corby, P. (2003). The technologically well-equipped dental office. *The Journal of the American Dental Association*, *134*, 30–41.

Schleyer, T. K. (2004a). Why integration is key for dental office technology. *The Journal of the American Dental Association*, *135*(Suppl), 4S–9S.

Schleyer, T. K. (2004b). Should dentistry be part of the National Health Information infrastructure? *The Journal of the American Dental Association*, *135*(12), 1687–1695.

Schleyer, T. K., Thyvalikakath, T. P., Spallek, H., Torres-Urquidy, M. H., Hernandez, P., & Yuhaniak, J. (2006). Clinical computing in general dentistry. *Journal of the American Medical Informatics Association*, *13*, 344–352. doi:10.1197/jamia.M1990

Schutze, H. J. (2001). Walk with a pen, or fly with a computer. Can electronic dentistry work for you? *The New York State Dental Journal*, *67*(10), 24–29.

Sfikas, P. M. (2003). HIPAA security regulations. Protecting patients' electronic health information. *The Journal of the American Dental Association*, *134*, 640–643.

Shaughnessy, A. F., & Nickel, R. O. (1989). Prescription-writing patterns and errors in a family medicine residency program. *The Journal of Family Practice*, *29*, 290–295.

Shelley, P. Q., & Johnson, B. R., & BeGole, E. A. (2007). Use of an electronic patient record system to evaluate restorative treatment following root canal therapy. *Journal of Dental Education*, *71*, 1333–1339.

Sittig, D. F., Kirshner, M., & Maupomé, G. (2003). Grand challenges in dental informatics. *Advances in Dental Research*, *17*, 16–19. doi:10.1177/154407370301700105

Snyder, T. L. (1995). Integrating technology into dental practices. *The Journal of the American Dental Association*, *126*, 171–178.

Sullivan, D. (2008). [Dental record systems]. Unpublished personal communication.

Szekely, D. G., & Milam, S. (1996). Legal issues of the electronic dental record: security and confidentiality. *Journal of Dental Education*, *60*(1), 19–23.

Umar, H. (2002a). Capabilities of computerized clinical decision support systems: The implications for the practicing dental professional. *J Contemp Dent Pract*, 1(3), 027-042.

Umar, H. (2002b). Clinical decision-making using computers: Opportunities and limitations. *Dental Clinics of North America*, *46*(3), 521–538. doi:10.1016/S0011-8532(02)00008-3

Vaubert, V. M., Moon, P. C., & Love, B. J. (1999). Extractable free monomers from self-cured dental sealants resulting from dispensing errors. *Journal of Biomedical Materials Research*, *48*(1), 5–8. doi:10.1002/(SICI)1097-4636(1999)48:1<5::AID-JBM2>3.0.CO;2-U

Veitz-Keenan, A., Berkowitz, G. S., Brandes, I., Goldberg, K. L., Hamlin, D. A., Margolin, R., & Oen, K. (2007). Practice-based research networks. *The New York State Dental Journal*, *73*(3), 14–15.

Ventres, W., Kooienga, S., Vuckovic, N., Marlin, R., Nygren, P., & Stewart, V. (2006). Physicians, patients, and the electronic health record: An ethnographic analysis. *Annals of Family Medicine*, *4*(2), 124–131. doi:10.1370/afm.425

Wagner, E. H. (1998). Chronic disease management: what will it take to improve care for chronic illness? *Effective Clinical Practice*, *1*(1), 2–4.

Walker, R. J. (2002). HIPAA strategy for dental Schools. *Journal of Dental Education*, *66*(5), 624–633.

Walther, W. (1998). Knowledge through documentation: From patients' data records to the basis of knowledge. *International Journal of Computerized Dentistry*, *1*(1), 18–28.

WHO. (2006). *Electronic health records: Manual for developing countries*. WHO, Manila, Philippines.

Yuhaniak, I. J., Fernando, S., Schleyer, T., & Spallek, H. (2007). Speech recognition in dental software systems: Features and functionality. *Studies in Health Technology and Informatics*, *129*(Pt 2), 1127–1131.

Zvárová, J., Dostálová, T., Hanzlícek, P., Teuberová, Z., Nagy, M., & Pies, M. (2008). Electronic health record for forensic dentistry. *Methods of Information in Medicine*, *47*(1), 8–13.

KEY TERMS AND DEFINITIONS

Electronic Oral Health Record: An electronic repository of patients oral health related information that contains all personal health information belonging to an individual and is entered and accessed electronically by healthcare providers over the person's lifetime

HIPAA: Health Insurance Portability and Accountability Act (USA), enacted in 1996; protects health insurance coverage for workers and their families when they change or lose their jobs; Provides for maintaining confidentiality of an individual's identifiable health information if it is transmitted by electronic means.

Clinical Decision Systems: Systems representing a conglomeration of clinical knowledge management technologies that support the clinical process to help with differential diagnosis, final diagnosis, investigations, treatment selection and follow up care.

Practice Based Research Network: Teams of practicing dentists who investigate "everyday" issues in the delivery of oral healthcare with greater scientific rigor

Practice Management Software: Software that allows management of all aspects of a clinical practice including patient history, health records, billing etc.

Paperless Dental Office: A dental office where use of paper for record keeping, billing and other official work is eliminated unless absolutely necessary. Such an office keeps all records in electronic format, and also interacts with patients, insurance, specialist and other officials electronically.

This work was previously published in Dental Computing and Applications: Advanced Techniques for Clinical Dentistry, edited by A. Daskalaki, pp. 191-218, copyright 2009 by Medical Information Science Reference (an imprint of IGI Global).

Section II
Development and Design Methodologies

This section provides in-depth coverage of conceptual architectures, frameworks and methodologies related to the design and implementation of health information systems. Throughout these contributions, research fundamentals in the discipline are presented and discussed. From broad examinations to specific discussions on particular frameworks and infrastructures, the research found within this section spans the discipline while also offering detailed, specific discussions. Basic designs, as well as abstract developments, are explained within these chapters, and frameworks for designing successful e-health systems, pervasive healthcare applications, and ICTs for human services are provided.

Chapter 2.1

Patient-Centered E-Health Design

Alejandro Mauro
Hospital Italiano de Buenos Aires, Argentina

Fernán González Bernaldo de Quirós
Hospital Italiano de Buenos Aires, Argentina

ABSTRACT

This chapter introduces a series of techniques and tools useful for developing patient-centered e-health. As information technology (IT) is revolutionizing health care delivery, a wide range of personal health information management tools have become available to the patients. The variety and quality of information delivered by these tools will determine how useful consumers find them. Equally important is how the information is delivered. To create quality e-health, designers must attend to the needs and wants of users by engaging them in the design and testing processes. User-centered design (UCD) is a formal approach to ensuring that new products address the needs, wants, skills, and preferences of the user throughout the tool's development. UCD is a design and evaluation process which pays special attention to the intended users, what they will do with the product, where they will use it, and what features they consider essential. This iterative approach ensures that users' needs and wants are met and ultimately increases the likelihood users will accept the final product. This chapter focuses on UCD methods and techniques, giving examples of how to use them and when.

INTRODUCTION

E-health use by patients is steadily increasing, perhaps due to the patients being empowered by physicians and the health system itself (Andreassen, Trondsen, Kummervold, Gammon, & Hjortdahl, 2006; Baker, Wagner, Singer, & Bundorf, 2003; Coulter, 1997; Eysenbach & Kohler, 2003; Street, 2003). Personal health records, patient portals, and pathology-oriented information are just a few areas of growth in patients' use of e-health. However, to be useful these applications must be easy to use and meet patients' real needs and capabilities. This is a major challenge for the development of new interfaces and systems.

DOI: 10.4018/978-1-60566-016-5.ch002

Designing usable systems is difficult, and designers need effective and accurately-tested tools. Nowadays there are multiple user-centered design (UCD) methods which make system design more efficient and effective. Inquiring, inspection and testing methods are essential when planning a UCD, and although there is plenty of information about the importance of UCD in software development, many development programs fail to comply with key principles. When failing to comply, the software can be difficult to use, and this paves the way to failure. This failure can be observed both in software which is not completely put into use or is rejected due to user dissatisfaction.

When developing interfaces and designing software for medical patients to use, developers must thoroughly understand patients' needs and capabilities. Sometimes patient's needs are difficult to assess. Patients can become seriously frightened or anxious when diagnosed with a disease and they may hide important information. Lack of health literacy is another factor that makes it difficult to assess patients' needs. In any case, patients are known to have *unrecognized needs and capabilities* which are important to be considered when developing e-health. The concept of patient-centered design is intended to identify patients' needs and capabilities through tailored application of UCD principles to the context of e-health.

UCD is a highly structured, comprehensive software development methodology that is driven by clearly specified, task-oriented business objectives, and recognition of user needs, limitations and preferences (Mauro, 2000). Information collected using UCD analysis is scientifically applied in the design, testing, and implementation of products and services. When rigorously applied, a UCD approach meets both user needs and the business objectives of the sponsoring organization, such as managing risks (Siegel, 2003). UCD can make the difference between success and failure of software applications and can contribute to innovation by revealing unsuspected opportunities for innovative design, including aspects that would not emerge in other forms of idea generation.

APPLYING UCD TO DESIGN OF PATIENT-CENTERED E-HEALTH

UCD is a design philosophy and a process where the user is the design cornerstone, and his/her limitations, hopes and objectives are given extensive attention at each stage of the design process. UCD seeks to answer questions about users and their tasks and goals, and then uses those findings to drive development and design (Katz-Haas, 1998). The chief difference from other interface design philosophies is that user-centered design tries to optimize the user interface around what people may need and what their capabilities are in order to fulfill a task, rather than force them to adapt to designers' preferences.

There are countless methods, tools and techniques intended to help designers evaluate a target product or service (for brevity these are referred to hereafter simply as *products*) from the point of view of the user. By choosing an appropriate method, it is possible to learn in just a few hours how to improve usability of a product (Mauro, 2000). In this chapter we profile several useful tools and methods which will help an e-health design project to comply with the key principles of UCD. An exemplar set of UCD principles (UsabilityNet, 2006) is shown in Table 1.

Inquiring Research Methods

Understanding What Users Want

The proper identification of what users need and what the product should offer are essential at an early stage. Inquiring methods generally gather data in an open-ended way through interviews or observation, and these data are then progressively interpreted by the investigators.

Table 1. User-Centered Design Principles (UsabilityNet, 2006)

Designing for the users and their tasks
Being consistent
Using simple and natural dialogue
Reducing unnecessary mental effort by the user
Providing adequate feedback
Providing adequate navigation mechanisms
Letting the user drive
Presenting information clearly
Being helpful
Reducing errors

Several types of methods are typically used in combination. A general classification of these methods can be summarized as follows (Friedman & Wyatt, 2006).

- ***Observation methods***: When using these methods investigators immerse themselves in the domain under study. The investigator may act purely as a detached observer and rely on multiple "informants" as a source of information, or he/she can be a participant-observer by becoming to some degree a member of the work team, empowering him/her with a more vivid impression of the living or working environment under study.
- ***Interviewing methods***: These are conducted as *formal interviews*, where both the investigator and the interviewee are aware that the answers to questions are being recorded, or *informal interviews*, occurring as spontaneous discussions between the investigators and the observational subjects. Formal interviews vary in their degree of structure. At one extreme is the unstructured interview where there are no predetermined questions, and between the extremes is the semi-structured interview where the investigator specifies in advance a set of topics he/she would like to address, but is flexible to the order in the pre-specified list (field interview). At the other extreme is the structured interview with a set of questions which are presented to each participant using the same words and in the same order (questionnaires).
- ***Document analysis /artifact analysis***: This activity consists of analyzing documents and other artifacts produced by the organized human activity in a given place. These can include written notes and forms given to patients by their physicians or administrative personnel and accesses to the patient's Personal health record (PHR). Automatically-generated user log files are key artifacts in this analysis. Data from these records are often quantifiable, and can be important for subsequent analysis.

Specific inquiring methods are describe below.

Contextual Inquiry

The *contextual inquiry* is conducted through interviews and observation in the field and is based upon three fundamental principles: understanding the context in which the study object is used, knowing that the user is one of the most important parts of the design process, and having a precise focus or study object (Hom, 1996). Goals for the contextual inquiry should be established in advance, and include development of interview questions and observation tasks to achieve each goal. The overriding goal of contextual inquiry is to understand how and why something is done or why something is not done (Beyer & Holtzblatt, 1998). During interviews, the interviewer must create a bond with the interviewee and ask questions aimed toward creating a dialogue where the interviewee can express not only experiences or opinions, but also describe his/her involvement in the problem. When the interview is over, a careful analysis of the interview transcript should be conducted to assess if the goals have been achieved and to determine if there are further questions that need to be asked in subsequent visits.

Contextual inquiry is one of the best methods to understand issues from the patient's perspective. Many times the environment in which people use a system influences their use of a product. For example, if patients ordinarily access the Internet from a cybercafé they may prefer to have their PHR display health related information displayed in a more discreet form than if they are working at their home. Contextual inquiry is also very useful when researchers do not have a clear understanding of the domain being studied, such as in the early stages of development. Because much of the information obtained through contextual inquiry is subjective, it is important to confirm the results using other methods which are more objective in nature.

Method in practice: Let's consider that you are planning to change the procedure in which patients confirm their arrival at a large ambulatory patient practice. Contextual inquiry can be applied to initially assess the needs of people involved in the process. The patients can be requested to think about what would make their waiting time easier; and what design changes would help their waiting and would avoid the queuing. In this way they become partners in the design process and their opinion will be carefully analyzed.The researcher should stay focused on one thing at the time: in this specific case, the focus would be only on reception and waiting times. It was possible for the Hospital Italiano de Buenos Aires to improve on this process by developing a system for the patients to confirm their arrival at a kiosk, therefore avoiding the need for a hospital employee to be present and increasing the rate at which patients are checked in (Plazzotta, Otero, Campos, Pedernera, Navas, Martínez, Plazzotta, et al., 2005).

Ethnographic Study / Field Observation

Ethnography (from the Greek ethnos (εθνος), "people", and grapho (γραφω), "I write") is a method of anthropological investigation in which data is gathered in the field with the members of a given community acting as informants. Analysis of this data is used to provide a compact and detailed description of their customs, beliefs, myths, genealogies and history. Similar to the contextual inquiry, ethnographic study identifies how a product is personally experienced and used by each individual within his/her cultural and organizational contexts. Observing people in the field is often one of the best ways to determine their needs and capabilities, as observation can illuminate the concepts and premises of what people understand unconsciously but may not be able to articulate. Another aspect of field observation is informally interviewing people about the way they perform tasks and the way they use the product.

Ethnographic study of patients in a hospital has been used to evaluate the various hospital domains, including waiting rooms, blood laboratory rooms, information boards, patient's wards and consulting rooms (Schultz, Bottorff, & Johnson, 2006). As an alternative, Kaufman and colleagues have applied ethnographic study methods remotely, by video-recording patients using a diabetes management software from their homes (Kaufman, Patel, Hilliman, Morin, Pevzner, Weinstock, et al., 2003).

The idea behind ethnographic study methods is to understand how tasks are done and how products are used within actual contexts of use, including aspects which the people under study may not be aware of. It is advisable to apply this method in the early stages of development, when it is most important to understand the aspects related to the use of a product rather than other characteristics of the product.

Method in practice: Continuing with the scenario begun in the initial assessment, investigators should consider the conditions in which patients arrival is checked, whether there is a receptionist, if there is a long waiting queue to confirm their arrival, if patients have to repeat their name or last name more than once in spite of having shown their identity card, or if the queues are the result of receptionists doing other things apart from checking on patient's arrival. Every detail of the place where the patients are asked to confirm their arrival should be evaluated. It is essential not only to study the desk to which the patients come to and the number of patients standing in the queues, but also the practice room itself. Every detail should be carefully assessed, including the room's tidiness, the colors of the room and the noise levels.

Focus Groups

Focus groups are carefully planned group discussions conducted by trained moderators. A small number of questions, developed in advance, are used to generate in-depth consideration of a narrowly defined topic. By using this method a direct interaction with participants is established as they are asked to express their opinions about the topic, for example, relating to interface functionality or design (Pope & Mays, 2006).

This method involves identifying questions through which it will be possible to gather relevant information about a topic or a product. It is important to frame questions as widely as possible in order to facilitate discussion in which subsequent interaction among the participants can bring out varied and thoughtful ideas, such as identifying problems which might arise when using the product.

This method can be used at any stage of system development, as long as questions are appropriate to the context. This can begin at very early stages of development, when the product requirements are still being designed, and continue through the time following product release, where the objective may be to test customer satisfaction (Kinzie, Cohn, Julian, & Knaus, 2002).

Method in practice: Let's imagine that the manager of a medical practice notices that the patients are becoming annoyed by the delays they have encountered while waiting for an appointment. He therefore decides to interview some of the patients in the waiting room to tackle this problem. He then analyzes what steps the patients take before seeing the physician in order to understand what drawbacks there are in the system. Next he organizes a focus group that includes participants who represent those involved in the situation (patients, receptionists, physicians among others) and moderates a discussion on delays in order to assess whether his observations were correct and complete and to identify potential solutions to the problem.

Questionnaire Surveys

The two terms *questionnaire* and *survey* are often confused, and some people consider surveys as a synonym for questionnaires. However this is not so. The survey is a process of investigation across a substantial population, whereas the questionnaires is a specific tool that can be used to implement the survey. Thus, the term *questionnaire survey* indicates a survey investigation conducted through the use of a questionnaire, versus other methods, such as an interview survey.

The questionnaire survey is exceptionally useful to efficiently obtain information from large numbers of individuals. This method consists of a set of questions on the subject of study which can be administered on paper or electronically.

Surveys are inherently interactive. The function of a surveyor is to lead the respondent in such a way to bring light to all the topics or ideas the surveyor wants to learn about. Design of the questions is the most important step of the survey development process. The questions should be as open and clear as possible, but this can be difficult for novices to achieve. It is helpful to consult a focused guide to creating and evaluating survey questions, such as (Rea & Parker, 2005).

It is possible to make a quantitative analysis with the results from the questionnaire survey through interpretation of charts and graphs or use of statistical analysis software. The last part of survey analysis is interpretation of the patterns and trends that arise in the results.

Method in practice: Having improved the standards by which patients confirm their arrival through a kiosk, it might be necessary afterwards to use a questionnaire to assess level of satisfaction among a larger sample of the people involved in this process. Questionnaires are a very efficient mechanism for administering this type of assessment. One example is the QUIS, a validated questionnaire for assessing users' satisfaction with interfaces that was designed at the University of Maryland at College Park. The QUIS has been widely used and can help developers to estimate the impact the new product will have (Chin, Diehl, & Norman, 1988).

Other Inquiring Methods

Other methods of inquiry may be useful at various stages of the process. Among these are *screen snapshots,* where a prototype of a product is tested (usually at mid-stage of development) and screen snapshots are taken to document users' actions at specific points, and *journaled sessions,* where journaling software is used to record user's actions, including cursor movements, mouse clicks, and other interface interactions. Journaling software can also provide dialogue boxes in which the user types in comments or observations while performing the tasks. Both approaches can provide valuable information about the usability of the software and are relatively inexpensive to implement. Internet development offers the opportunity to expand the reach of journaling software, lowering costs further and allowing large-scale product tests.

Inspection Design Methods What the Analyst Can See

Usability inspection is the generic name for a set of methods that are based on having analysts inspect a user interface. A *usability analyst* is a trained professional specialized in applying usability methods (including UCD) to ensure the ease-of-use and positive user-experience of products. Typically, usability inspection is aimed at finding usability problems in the design, with some methods also addressing specific issues such as the severity of the usability problems and the overall usability of an entire system. Inspection methods are based on the concept of task analysis, where the evaluation takes place within information processing tasks. However, inspection methods also lend themselves to the review of user interface specifications that have not necessarily been implemented yet, meaning that inspection can be performed early in the usability engineering lifecycle (Nielsen & Mack, 1994).

There are several methods of inspection, but for practical reasons this chapter focuses on two that are particularly well-suited for evaluating interfaces for patients. These are the heuristic evaluation and cognitive walkthrough methods.

Heuristic Evaluation

Heuristic evaluation is an informal method of inspection involving usability experts who judge whether each dialogue element or task follows established usability and design heuristics, i.e., rules that are intended to be applied flexibly rather than followed rigidly (Nielsen & Mack, 1994). The analyst inspects the user interface system, often by carrying out a specific task while using the system, and notes any violations of a predefined set of heuristics. It is essential, therefore, that analysts are well trained. They must clearly understand the heuristics and also be experienced in applying them across a range of situations. Nielsen and Landauer (1993) observe that most usability problems can be identified if there are between three to five analysts working on the project.

Each analyst should check the interface at least twice, observing the function of each of its elements carefully and evaluating its design, location and implementation according to the heuristic list. Analysts independently evaluate the user interface and generate a list of heuristic violations. These are then combined into a joint list of all violations reported by all the analysts. The results of the heuristic evaluation can be summarized and presented to the design team along with recommendations for improvement.

Nielsen & Mack (1994) provide the following ten heuristics as guidelines for user interface design.

1. **Visibility of system status.** Keep users informed about what is going on, through appropriate feedback in a timely fashion.
2. **Match between system and the real world.** Speak the users' language, using words, phrases and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions.
3. **User control and freedom.** Users need a clearly marked "emergency exit" to escape from any unwanted state. Support undo and redo. A goal is for the user to feel he/she is in control of the system.
4. **Consistency and standards.** Use standard conventions for all aspects of the interaction, including navigation and carrying out basic operations. Adopt all conventions of the operating system or platform.
5. **Error prevention.** Where possible, avoid problems before they can occur. Eliminate error-prone conditions or check for them and present users with a confirmation option before they commit to the action.
6. **Recognition rather than recall.** Minimize the user's memory load by making objects, actions, and options visible. Make all information that is not visible easy to find and retrieve.
7. **Flexibility and efficiency of use.** Provide mechanisms to increase efficiency by experienced users, such as control key functions and shortcuts, and to support novice users in using the product and learning use processes.
8. **Aesthetic and minimalist design:** Remove all extraneous information from dialogs with users. Avoid distractions.
9. **Help users recognize, diagnose, and recover from errors**: Error messages should be expressed in plain language that clearly indicates what the problem is and suggests solutions where this is practical.
10. **Help and documentation**: Sources for help should be indicated clearly. Where documentation is included, it should be easy to search, be focused on the user's task, list concrete steps to be carried out, and not be excessively large.

The heuristic evaluation can be used at any stage of development, but it is especially practical at the early stages, when the product is not yet ready to be shown to non-expert users. It is also possible to provide paper models or even design details to the trained analysts and to thereby detect many usability problems before software development begins.

Method in practice: Carroll and his collaborators used heuristic evaluation to inspect a clinical decision support system (CDSS). They were able to make changes in the interfaces and develop a visual thermometer in an Electronic Health Record which allowed both patients and clinicians to readily identify absolute cardiovascular risk factors (Carroll, Marsden, Soden, Naylor, New, & Dornan, 2002).

Cognitive Walkthrough

The cognitive walkthrough is a method used to identify usability issues in software or web sites by focusing on how easy it is for new users to accomplish tasks within the system. This method is based on the fact that users typically prefer to learn a system by using it rather than studying a manual. Analysts construct task scenarios and then role-play the part of a user engaged in "walking through" the interface and note which user actions are needed to carry out the steps, what goals/subgoals the users would have and what potential problems might be encountered at each step. The objective of the cognitive walkthrough is to uncover possible errors in design that would interfere with user's ability to learn how to use the system and carry out tasks. Analysts complete a series of representative tasks from which an encompassing report of potential issues is compiled and used to guide improvements to the interface.

Cognitive walkthrough has been applied to the study of usability and learnability of several distinct medical information technologies (Carroll et al., 2002; Kushniruk, Kaufman, Patel, Levesque, & Lottin, 1996; Patel & Kaufman, 1998). For example, Kaufman and collaborators used this method to improve a home-based telemedicine system for a diabetic population (Kaufman et al., 2003). Cognitive walkthroughs identified aspects of the interface that were sub-optimal or impeded the performance of certain tasks and patient-related factors that constituted barriers to productive use, such as numeracy and psychomotor skills.

The cognitive walkthrough can be effective in identifying potential problems which then can be evaluated via usability testing methods, which involve testing with representative users in real situational contexts. These are described in a subsequent section of the chapter.

Method in practice: Cognitive walkthroughs help to identify whether a product meets the user's goals and can be used efficiently to accomplish the purpose of each task. This can be seen in a system of geographical location for patients at a hospital kiosk, where a patient can ascertain, for example, the location of the laboratory where she has to get her blood tested. The patient's goal will be to find, among other tasks, where exactly the laboratory is located, what part of the building or on which floor it is and which lift she needs to take to get there. The various tasks the patient should perform will be first to identify the correct key she must press to start looking for the place she wants to reach, and then to find the laboratory in an interactive map. When analysts "walk through" the interface, it is important to identify if the patient will have difficulties in performing the tasks, for example, because the keys are not easily seen or the labels are not clear or she is distracted by other options.

Other Inspection Methods

Other helpful inspection methods include *formal usability inspections*, developed by IBM and used, among others, to identify bugs in programming, *standard inspections* which ensure compliance with industry standards and *guideline checklists* which can help ensure that usability principles will be considered in a design.

Usability Testing Methods

Usability testing refers to the evaluation of information systems by testing with representatives of the target user population as they perform representative tasks using the product in a particular context, such as patients using an e-health application to schedule an appointment. Usability testing is a means for measuring how well people can use a product for its intended purpose(s). The aim is to observe people using the product in an as realistic a setting as possible, in order to discover errors and identify areas that need improvement. Researchers report that 80% of the usability problems can be detected through these usability testing of as few as eight to ten representative subjects (Nielsen, 1993; Rubin & Hudson, 1994).

Kushniruk & Patel (2004) have defined nine phases for applying usability testing to the evaluation of clinical information systems that must be followed in order to ensure that the intended users of a clinical system, including patients, physicians, and nurses, can carry out the tasks efficiently and effectively. These phases are summarized as follows.

The **first phase** is the identification of the evaluation objectives, which may vary considerably according to the product being tested and the target users. The **second phase** is the sample selection; the subjects should be *representative* of end users of the system under study, for example, chronic disease patients in the case of a Pathology portal. It also is important to apply criteria for classifying subjects in terms of their prior computer experience. **Phase three** is the selection of representative tasks and contexts for analysis to adequately represent real scenarios. The tasks for analysis should be carefully chosen if the testing is in a usability laboratory; use of a real life scenario (naturalistic study) increases the ecological validity of the test. For example, Kaufman used a video-analytic approach to study how patients used home-care software in their own homes (Kaufman et al., 2003). The **fourth phase** is the selection of background questionnaires that can be administered either before or after the usability testing. These questionnaires are used to obtain historical information about the participants that will help evaluators to understand their behavior and performance during the test. The **fifth phase** is the selection of the evaluation environment, which can be either a usability laboratory with controlled experimental conditions, or the place where the user works or lives or uses the system, for example, selections addressed by Kushniruk and collaborators include the waiting room for testing a scheduling kiosk system for patients, automated interviewing and automated triggering questionnaires in a web-based system (Kushniruk, Patel, Patel, & Cimino, 2001). The **sixth phase** is data collection from video and audio recording, VCR recordings of the video screens or people faces were commonly used, but now screen recording tends to be software based. There are several software systems that allow recording the screens, mouse movements and clicks, as well as audio. Video recording provides a remarkably rich and vivid reproduction of an encounter. It also provides a permanent record of an event and supports multiple viewings and re-analysis of data (Jordan & Henderson, 1995). The **seventh phase** is the analysis of the video and audio files. The transformation of data into recommendations involves qualitative and quantitative analysis of the video-based usability data. The **eighth phase** is the interpretation of the findings, where the collected data are compiled and summarized in a number of aspects of a system (task accuracy, user preference data, time to completion of task, frequency and classes of problems encountered). The **ninth phase** is the iterative input into design, where the system is improved on the basis of the problems that usability testing identifies and is then re-tested to determine how the changes affect the system's usability.

Think-Aloud Protocol

The think-aloud protocol is one of the most useful and simple evaluation methods to emerge from the study of cognitive science. Subjects are instructed to "think aloud" (i.e., verbalize their thoughts) as they perform a set of specified tasks. They are asked to verbalize whatever they are looking at, thinking, doing, and feeling, as they go about their task (Lewis & Rieman, 1994). It is useful to record user actions during this process to support detailed analysis of actions, such as mouse clicks and menu selections in conjunction with audio recording of subjects verbalizations (Kushniruk, Patel, Cimino, & Barrows, 1996).

The think-aloud protocol allows the researcher to identify how the user approaches and performs tasks using the interface (Kaplan, 2003). Analyzing this information, it is possible for the researcher to better understand the user's mental model of his/her interaction with the product. There are other benefits as well, such as the ability to repeat tasks that are problematic or to introduce changes into the terminology used, as the user typically will express clearly what exact instructions he/she would have needed to have at hand when performing the task. (Johnson, Johnson, & Zhang, 2000). The think-aloud protocol is effective at all stages of development once a prototype is available for use, however, repeated testing with this method requires availability of new users in order to be effective.

Method in practice: Let's take the case of a researcher developing an application for patients to see laboratory results from their homes. He should keep in mind that laboratory reports are often difficult for patients to understand. Performing a think-aloud protocol would be a useful tool for identifying interface problems, such as visual display of laboratory numbers and test history results, the order in which buttons are displayed, or the terminology that is used.

Question-Asking Protocol

The *question asking protocol* goes beyond the think-aloud protocol by posing questions to users (Lindgaard, 1994). As with the think-aloud protocol, in the question asking protocol the user is shown a prototype or a final version of an interface and is requested to perform certain tasks while verbalizing his/her thoughts. The observer will shadow (stay behind the user watching the user's movements) and ask direct questions at specific stages to obtain more information on a given item or action. Both the readiness (ease-of-use) or drawbacks (difficulty-of-use) the user reports can be used to identify which parts of the interface are clear and which parts need to be improved.

Method in practice: While developing a health information web page, the researcher may wish to test whether an item of information is easily found. He will ask a patient to look for information about a flu vaccine. The patient will reply according to what she can see or according to what she believes should be the right place to find this information. The patient may also answer according to her experience of other interfaces and these responses will provide insights into her mental model of the product in addition to her ongoing verbalization.

Prototyping Methods

Prototyping is the process of quickly putting together a working model (a prototype) in order to test various aspects of a design, illustrate ideas or features and gather early user feedback. It allows testing to begin early in the design process. When the prototype is sufficiently refined and meets design goals relating, for example, to functionality, robustness, and manufacturability, the product is ready for production.

There are various methods in prototyping, ranging from working with a sheet of paper and a pencil (paper prototyping), to developing working but not fully capable computer applications (high-fidelity prototyping). Prototyping can be used at any time in during product development. At the early stages it can be useful to study the needs and desires of users, at a midstage it will provide information about the development of the product and how usable it is, and at later stages it will provide the necessary information to make alterations in areas which need to be refined.

Paper Prototypes

Paper prototyping is a method that lets the designer of a project mock up, test, and refine a design on paper before writing program code. It allows informal usability tests with real users to be undertaken at early stages of product development. Users can also participate in developing paper prototypes, as is detailed in a case study presented subsequently in the chapter.

A number of benefits have been identified in using paper prototypes to develop health care applications (Marill, Miller, & Kitendaugh, 2006; Plovnick & Zeng, 2004). This include the following:

1. **Paper prototypes make the researcher focus on keeping the interface simple**. Various approaches to the design of an interface can be tested with several users to see which one is the preferred.
2. **They are time savers**. Creating paper prototypes requires relatively less effort than coding, so paper prototypes can be easily abandoned if they are not working.
3. **They allow the researcher to start at an unsure stage**. Because paper prototypes have no code, they free the designer from the necessity of building a working platform for the interface. The designer can start with the parts he/she has the most questions about, rather than those that are most stable.
4. **They allow the testing of new terminology at early stages of development**. This is an important feature of paper prototypes in health related designs as many health systems and web pages face problems in presenting terminology that patients can understand.

The aim of this section is to show how it is possible to start with a simple method such as paper prototyping and produce useful improvements in usability. The following case study reports an example of using paper prototyping in the context of designing e-health software applications from a patient-centered perspective.

Case Study: Paper Prototyping in Developing a Personal Health Record (PHR)

The Hospital Italiano de Buenos Aires Experience

Since 1998, The Hospital Italiano de Buenos Aires has gradually implemented a full scale Health Information System (HIS), including ambulatory Electronic Medical Record (EMR), inpatient discharge summaries, administrative systems, scheduling systems, inpatient tracking systems, pharmacy systems and complementary studies report and visualization. It is currently working on the development of a Personal health record (PHR) to support patients' access to various functionalities and services from HIS. For this purpose, patients of the HMO were invited to participate in the activity "Internet Use: can it improve your health care?" by means of a notice published on the hospital's website and in a newsletter sent monthly by post.

Two activities were carried out in two hours. In a brief introduction it was explained to the par-

Table 2. Characteristics of study respondents

	All (n=17)
Age in years (range)	59.88 (34-81)
Female gender	11 (64.7%)
University level of study	11 (64.7%)
Internet access	15 (88.2%)
Broadband connection	13 (86.6%)
Internet health information*	12 (70.6%)

* Used Internet in the past to access health related information

ticipants what a PHR is. Then they were divided into 4 groups so that over the next 25 minutes they could discuss and write down what services or information they thought a PHR should offer. Table 2 shows participants' characteristics, based on a survey they answered at the end of the activities.

Even though the study participants were patients and potential users of the system being developed, during the session they were not in a real context of use. For this reason, the first activity used a focus group technique rather than an inquiring method, such as ethnographic study. However, their discussion included experiences and impressions of the context and their personal relationships, which offered relevant information and generated ideas. Each focus group wrote down notes about what they believed were the most important aspects a PHR should offer. At the end of the activity each of the groups shared its results with the other groups, while one investigator wrote down the information on a whiteboard.

To carry out the second activity, each group was given a photocopied sheet of paper in the form of a monitor screen and design materials (scissors, markers, papers, cardboard, and stickers). Participants were instructed to create a paper prototype of a web portal which would provide the services and information listed in the previous activity. When they finished, each group presented its prototype, explaining each of the components chosen and the function and/or information which each component should offer. An example is shown in Figure 1.

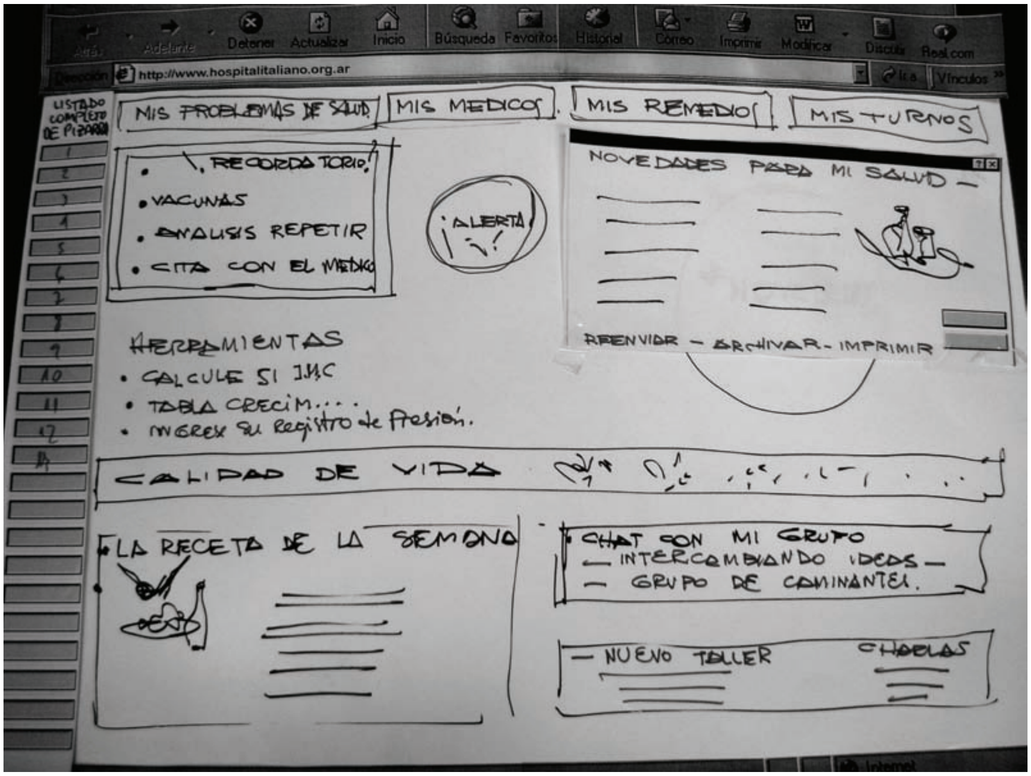
During both activities one investigator acted as moderator while another took down notes. To ensure the quality of the record, the two hours were filmed and recorded. At the end of the activities, each patient completed an anonymous questionnaire survey for us to get to know details of gender, age, educational level, access to Internet, and the perceived usefulness of the patient portal components. The information gathered through the activities was useful in:

- **Identifying users' needs and desires for a personal health record.** Focus groups, questionnaires and video-recording analysis were useful methods for gathering this information. These are some examples of participants' needs and desires that were identified:

"...we give priority to basic pathology" "we would like all the information about diabetes to be together" "in reality, what we want is that the information should be integrated" [Problem-oriented information need]

"I don't want just to know what my clinical physician thinks; I want to know what the neurologist says, the opinion of the pharmacist, the nurse's recommendations." [Integrated information]

Figure 1. Example Paper Prototype



- **Identifying user's motivations and fears.** Focus group discussion revealed several motivations and fears on the part of participants which may not be observable otherwise.

"I am afraid that with so much technology we'll lose contact with the doctor… It would be important to have access to the e-mails of the different doctors who are concerned with my health" [New ways of communication]

"I would also like to be have access to a Chat room which allowed me a more spontaneous consultation in case some drug made me feel unwell" [New ways of communication]

"We need a patients' forum, a network where we feel represented, a space where we don't feel unprotected" [New ways of communication]

"I would like to be able to access my clinical history, and that the doctors should have access to my portal, but on condition that I should be able to decide which doctor sees what, because there are things I talk about with one doctor while with another I feel embarrassed" [Access to Clinical Histories, and Data Privacy]

- **Identifying user's ideal visual display of the interface**. Paper prototyping allowed participants to contribute to PHR design.

"We would like certain criteria to be complied with for the navigation of the portal, for example that it should be easy to change the size of the letters for those who have sight difficulties" [Interface Flexibility]

"We would like a section of favorites links" "that every illness should have links to pages with information that could be useful, associations, or that would put us in contact with groups of patients who suffer from the same pathology" [Access to Information Sources]

"I would like the system to warn me in case of my forgetting to vaccinate my children by giving me an alert in red" [Warnings in red]

- Identifying user's wish and desired terminology to be seen on the screen.

"I would like to be able to understand the medical terms used. I would expect the PHR to use every day language" "Seeing my medical record from my physician's monitor screen I had to ask him what Leiomyoma was. He told me that it were the uterine fibroids I had been complaining about for a long time" [Terminology issue]

By using UCD methods the developers were able to obtain sound information about patient's needs and desires and at the same time learn about the patient's preferred methods of information display. The use of prototyping methods are highly relevant to e-health developers, as these will provide information early in design stages when it is inexpensive and quick to initiate product changes.

CONCLUSION

UCD methods can be applied effectively with patients, even to the point of allowing patients the opportunity to contribute to product design. The resulting *patient centered design* is an essential step when undertaking development of e-health that is intended to meet patients' needs and address their capabilities. However it is necessary to keep in mind that there are motives, fears, and challenges which will influence results of interaction with patients. The methods described in this chapter can be very useful in overcoming these challenges, especially when used in combination as in the case study we presented.

REFERENCES

Andreassen, H. K., Trondsen, M., Kummervold, P. E., Gammon, D., & Hjortdahl, P. (2006). Patients who use e-mediated communication with their doctor: New constructions of trust in the patient-doctor relationship. *Qualitative Health Research*, *16*(2), 238–248. doi:10.1177/1049732305284667

Baker, L., Wagner, T. H., Singer, S., & Bundorf, M. K. (2003). Use of the Internet and e-mail for health care information: Results from a national survey. *Journal of the American Medical Association*, *289*(18), 2400–2406. doi:10.1001/jama.289.18.2400

Beyer, H., & Holtzblatt, K. (1998). *Contextual design: Defining customer-centered systems*. San Francisco: Morgan Kaufmann.

Carroll, C., Marsden, P., Soden, P., Naylor, E., New, J., & Dornan, T. (2002). Involving users in the design and usability evaluation of a clinical decision support system. *Computer Methods and Programs in Biomedicine*, *69*(2), 123–135. doi:10.1016/S0169-2607(02)00036-6

Chin, J. P., Diehl, V. A., & Norman, L. K. (1988). *Development of an instrument measuring user satisfaction of the human-computer interface*. New York: ACM Press

Coulter, A. (1997). Partnerships with patients: the pros and cons of shared clinical decision-making. *Journal of Health Services Research & Policy*, *2*(2), 112–121.

Eysenbach, G., & Kohler, C. (2003). What is the prevalence of health-related searches on the world wide web? Qualitative and quantitative analysis of search engine queries on the internet. *2003 AMIA Annual Symposium Proceedings,* 225-229.

Friedman, C. P., & Wyatt, J. (2006). *Evaluation methods in medical informatics* (Second edition). New York: Springer.

Hom, J. (1996). *The usability methods toolbox*. from http://jthom.best.vwh.net/usability

Johnson, C. M., Johnson, T., & Zhang, J. (2000). Increasing productivity and reducing errors through usability analysis: A case study and recommendations. *2001 AMIA Symposium Proceedings*, 394-398.

Jordan, B., & Henderson, A. (1995). Interaction analysis: Foundations and practice. *Journal of the Learning Sciences*, *4*(1), 39–103. doi:10.1207/s15327809jls0401_2

Kaplan, B. (2003). Deriving design recommendations through discount usability engineering: Ethnographic observation and thinking-aloud protocol in usability testing for computer-based teaching cases. *2003 AMIA Annual Symposium Proceedings,* 346-350.

Katz-Haas, R. (1998). Ten guidelines for user-centered web design. *Usability Interface, 5*(1).

Kaufman, D. R., Patel, V. L., Hilliman, C., Morin, P. C., Pevzner, J., & Weinstock, R. S. (2003). Usability in the real world: Assessing medical information technologies in patients' homes. *Journal of Biomedical Informatics*, *36*(1-2), 45–60. doi:10.1016/S1532-0464(03)00056-X

Kinzie, M. B., Cohn, W. F., Julian, M. F., & Knaus, W. A. (2002). A user-centered model for web site design: Needs assessment, user interface design, and rapid prototyping. *Journal of the American Medical Informatics Association*, *9*(4), 320–330. doi:10.1197/jamia.M0822

Kushniruk, A., Patel, V., Cimino, J. J., & Barrows, R. A. (1996). Cognitive evaluation of the user interface and vocabulary of an outpatient information system. *1996 AMIA Annual Symposium Proceedings*, 22-26.

Kushniruk, A. W., Kaufman, D. R., Patel, V. L., Levesque, Y., & Lottin, P. (1996). Assessment of a computerized patient record system: A cognitive approach to evaluating medical technology. *M.D. Computing*, *13*(5), 406–415.

Kushniruk, A. W., Patel, C., Patel, V. L., & Cimino, J. J. (2001). 'Televaluation' of clinical information systems: An integrative approach to assessing Web-based systems. *International Journal of Medical Informatics*, *61*(1), 45–70. doi:10.1016/S1386-5056(00)00133-7

Kushniruk, A. W., & Patel, V. L. (2004). Cognitive and usability engineering methods for the evaluation of clinical information systems. *Journal of Biomedical Informatics*, *37*(1), 56–76. doi:10.1016/j.jbi.2004.01.003

Lewis, C., & Rieman, J. (1994). *Task-centered user interface design: A practical introduction.* Retrieved December 13,2007 from http://www.hcibib.org/tcuid/

Lindgaard, G. (1994). *Usability testing and system evaluation: A guide for designing useful computer systems.* London: Chapman & Hall.

Marill, J. L., Miller, N., & Kitendaugh, P. (2006). The MedlinePlus public user interface: Studies of design challenges and opportunities. *Journal of the Medical Library Association*, *94*(1), 30–40.

Mauro, C. L. (2000). Formal definition of user-centered design (UCD). Retrieved May, 2007, from http://www.taskz.com/definitions.php

Nielsen, J. (1993). *Usability engineering*. Boston: Academic Press.

Nielsen, J., & Landauer, T. K. 1993. A mathematical model of the finding of usability problems. *Proceedings ACM/IFIP INTERCHI'93 Conference* (Amsterdam, The Netherlands, April 24-29), 206-213.

Nielsen, J., & Mack, R. L. (1994). *Usability inspection methods*. New York: Wiley.

Patel, V. L., & Kaufman, D. R. (1998). Medical informatics and the science of cognition. *Journal of the American Medical Informatics Association*, *5*(6), 493–502.

Plazzotta, F., Otero, P., Campos, F., Pedernera, F., Navas, H., Martínez, M., et al. (2005). *Estrategias para agilizar la atención ambulatoria: integración de los sistemas de información.* Paper presented at the 8mo Simposio de Informática en Salud - 34 JAIIO, Santa Fé, Argentina.

Plovnick, R. M., & Zeng, Q. T. (2004). Reformulation of consumer health queries with professional terminology: a pilot study. *Journal of Medical Internet Research*, *6*(3), e27. doi:10.2196/jmir.6.3.e27

Pope, C., & Mays, N. (2006). *Qualitative research in health care* (Third edition). Malden, MA: Blackwell Pub./BMJ Books.

Rea, M., & Parker, R. A. (2005). *Designing and conducting survey research: A comprehensive guide* (Third edition). San Francisco: Jossey-Bass.

Rubin, J., & Hudson, T. (1994). *Handbook of usability testing: How to plan, design, and conduct effective tests*. New York: John Wiley & Sons, Inc.

Schultz, A. S. H., Bottorff, J. L., & Johnson, J. L. (2006). An ethnographic study of tobacco control in hospital settings. *Tobacco Control*, *15*(4), 317–322. doi:10.1136/tc.2005.015388

Siegel, D. A. (2003). The business case for user-centered design: Increasing your power of persuasion. *Interaction*, *10*(3), 30–36. doi:10.1145/769759.769772

Street, R. L. Jr. (2003). Mediated consumer-provider communication in cancer care: The empowering potential of new technologies. *Patient Education and Counseling*, *50*(1), 99–104.

UsabilityNet. (2006). Key principles of user-centred design. Retrieved June 2006, from http://www.usabilitynet.org/management/b_design.htm

This work was previously published in Patient-Centered E-Health, edited by E. Wilson, pp. 10-25, copyright 2009 by Medical Information Science Reference (an imprint of IGI Global).

Chapter 2.2

Informational Priorities in Health Information System

Malgorzata Kisilowska
University of Warsaw, Poland

ABSTRACT

This chapter presents the model of a wide health information system, designed in accordance with information science theories and requirements. The model, based on modern ICT solutions, reflects the idea of information processes (collection, indexing, transfer) as seen in an information science perspective. It concentrates on optimal answering information needs of different categories of patrons, including adaptation of information-retrieval tools to their competencies. The author discusses different types of information indispensable in healthcare practice, analyzes methods of knowledge representation in health information system, proposes methodology of surveying information needs of health professionals, and describes challenges of linguistic tools used in information systems. The author hopes that such a model will emphasis the need of cooperation among ICT, health, and information professionals in designing information structures and processes.

DOI: 10.4018/978-1-60566-356-2.ch047

INTRODUCTION

Managing specialist information within one of human spheres of activity requires today very efficient procedures, structures, and qualifications. However, functionality of information management may not clearly refer to complicated networks of tools, resources, and relations. As it would be proposed below, its efficiency may depend on such factors of vital importance like simplicity and precision in searching and finding pertinent information. These can be assured not only by using modern ICT tools, but also a set of knowledge management tasks and procedures, like: architecture of information, optimizing information transfer, indexing, studying users' needs and behaviours.

Information-related research is indispensable in terms of a broad and diversified range of healthcare management issues. Information architecture and knowledge management tools and rules shall influence the architecture of health-related software. The model proposed below, if applied into ICT solutions, works for their compatibility, effectiveness, and user-friendly organisation, for the benefit of both authors and users of applications. It's specific value relies on including a user as a vital part of the health information system, especially in the light of current management surveys, indicating human factor as the most sensitive, changeable, and unpredictable element. User's participation in such a structure reflects it's role, enables system's sensitivity and learning new behaviours, information needs, and actually better management of information and knowledge.

Modelling a wide health information system (WHIS) shall refer to a few assumptions. Specifics of designing information systems in information science consists of categorizing and prioritizing information, as a main element of such a structure, holistic approach to the users, emphasizing permanent surveying of their information needs, and adapting services to the results of such a survey.

Conceptual framework includes:

- Aims and goals of a wide health information system.
- Participants of a system: units realizing information processes and the users.
- Range of their activity, categories of information they are interested in.
- Architecture – relationships among elements and participants, communication channels either among them or with the users.
- Linguistic tools for information processing.

The WHIS aims in creation of an information environment for a health domain, answering information needs of different (individual and legal) entities. Types of answers, methods of WHIS usage depend on their authorization referred to profiles of activity (medicine doctors, nurses, patients, managers, etc.). Differentiation and amount of data result in the necessity of shared responsibility and resources, for examples in distributed knowledge repositories.

Information in WHIS is indispensable for realization of specialized tasks on different levels – micro (individual both professional and private users), mezzo (primary health care units), and macro (entities responsible for resort policy, supervising national and international cooperation, like the World Health Organization's projects).

Optimal functioning of a system requires common decisions concerning shared responsibility and tasks, unified metadata, access rules, control of resources and quality-assurance tools.

WHIS USERS

Health information users can be grouped into three main categories: individual professionals, institutions, and patients. The first category consists usually of: medical doctors, dentists, pharmacists, physiotherapists, nursing, midwives, diagnosticians, and specialists in different tests, like ECG, x-ray, etc. Their representatives can work in direct care, administration, education and/or research, nevertheless their tasks stay always linked to healthcare. The users can be also seen as: potential, probable (having access to information), real/ factual (using information), and beneficiaries, getting benefits from having knowledge (Flakiewicz, 2002).

Institutions employing individual professionals can also belong to the users, as very often they either are original source of information, or answer information needs of health professionals and patients. The type and precision of required data depend on their place in a domain hierarchy, as well as a profile of activity (administrative, supervisory, research, education or practice). Differentiation of institutions' tasks and goals results also in diversified perception and usage of information for "institutional" goals. Such an information can have either narrow (medical and/or financial documentation and statistics) or broad (research, policy, national and international strategies) range. Institutional users of health information include: a ministry, national statistical office, medical academies and other education providers, health professions' chambers, research organizations and institutes, trade unions, and healthcare settings. They need and use information for organizing, ordering, and supervising execution of tasks. However, experience of information transfer is obviously related to individual decisions and practice.

The patients can be both real and potential. These first usually seek and use information concerning their health status. In general, their perception of information is often intuitional and popular, very subjective. They are quite inconsistent regarding types and forms of information given to health professionals, depending on knowledge and health status, previous experiences, reactions on therapy, attitude towards diagnosis and prognosis, health information literacy. Their information needs can also be very different: from detailed information about symptoms and therapy perspective, to very general data, for those avoiding bad news. These needs are closely related to previous experiences and knowledge, determining both range and form of data being searched. From the other side – there is also a problem of getting information from the patients, and successful interpretation of – sometimes very few and incomplete – data.

Potential patients are usually addressees of health promotion, according to international (like WHO "Health for All") and national (National Health Programmes) strategies, recommending development of public health awareness, to motivate people to improve their lifestyles and take care for their health. Such a type of information shall also be adapted to health information competencies of the users, both in contents and forms.

Analysis of the users indicates three main categories of information needed: as a unit of professional knowledge, as a tool in healthcare practice, and as a subject of relations with external environment, in particular with the patients.

Information as a unit of professional knowledge emerges firstly during education (and further lifelong learning). Updating knowledge and finding evidence are now obligatory for all health professionals, regarding their influence on life and health of the individuals. This can be either theoretical or practical information. Research information can be not only found and accepted, but also created actively, in the result of own studies and practice.

Information as a tool of professional practice in fact consists of two roles: a unit of professional knowledge, and a unit of information from and about the users/ patients. A health professional – depending on his/her position – using this information can formulate a diagnosis, present tests results, organize health services, etc. Such a "new knowledge" is then passed to a patient and/or the health team colleagues (as statements, consultations, orders, prescriptions, etc.).

Information used in research and practice is diversified, i.e. not only related to medicine, nursing, etc. Each user needs also legal, financial, organizational, or administrative information for his/her tasks. It is usually taken from adequate institutions and organizations external to a healthcare sector, in a process of communication with an environment. Health promotion is also a type of external contacts, as information for the public (or its parts, like risk groups) concerning health risks, methods of prevention, etc.

Contact with the individuals (patients) can be defined as a particular type of information exchange. In such a relation a healthcare provider tries to get knowledge about patient's health status or problems, and then a consent for therapy. In response – he/she presents a diagnosis, therapy plan, prognosis, and self-care instructions (diet, rehabilitation). It should be remembered, that information exchange between a healthcare provider and a patient is a communication process depending mostly on psychological, social, and cultural background of the participants.

Surveying and Answering Information Needs

Appropriateness of information systems' functioning depends mainly on the users satisfaction. Regarding that, surveying their information needs belongs to their basic functions, to optimize offered sources and services. Such a survey requires definition of its range, methods and techniques of data collection and processing.

The Range of Information Needs Survey

Surveying information needs shall cover all their meritorious and formal features, to get knowledge about present user's characteristic, as well as well possibilities of forecasting his/her information behaviours.

It requires collection of data concerning (Nicholas, 2000; Nicholas, Huntington, Jamali & Williams, 2007):

- Needs' range (what kind of information are being searched), according to accepted criteria.
- Quality of data (categorisation of sources, their authority, etc.)
- Scopes (chronological, geographical, language, formal)
- Goals (for what information is collected).
- Acceptable waiting time for information, as well as time for usage of a source (or: being logged to a service).
- Quantity (number of answers received vs. number of visited websites and downloaded files), also number of visits (movement in a network).
- Processing level (data forms and formats)
- A need of privacy concerning identity and range of searching
- Frequency (and/or regularity) of needs, and in consequence retrieval activity
- Methods of usage of information gained.
- Level of information indispensability
- Changes in meritorious and information competencies of the users (development of health information literacy)
- Methods of communication with information retrieval tools (accepted terminology, building retrieval instructions, etc.).

The features listed above make only a part of those characterizing information needs. Obviously, their significance differs according to a WHIS range.

For the needs of modelling a health information system, information needs of three types of the users can be surveyed: managers, providers, and patients.

Referring to specifics of the health domain, developers and administrators of WHIS have to regard particularly dependence between data quality and retrieval tools (privacy) vs. their usage for the needs of health care practice, and further maintenance and/or improvement of quality of life of persons, groups, and societies. This dependence influences also the range and tools to be used in a study itself.

Of course, individual features of information needs can be studied with different methods and techniques. (See Table 1)

Methods and Techniques of Data Collection

There are the following methods of surveying information needs:

- Inventorying, covering existing information resources and flows regarding their usefulness for the users.
- Interviews (group, individual, direct, telephone, etc.), enabling collection of subjective data, as well as new, unexpected information given by the interviewees
- Questionnaires, offering knowledge about subjective users' perceptions of their own information needs.

Table 1. Example of a survey of information needs for optimization of WHIS regarding the users' satisfaction. Source: own study.

Study subject	**Aim of study, results used for**	**Frequency of data analysis**
Number of visits	Controlling movement in portals in regard to the users of different authorization	monthly
Range and scopes of questions	Information needs according to different range criteria Modification of databases and their content Organization of access to data (verification of links, improvement of hypertext tools) Monitoring changes in information needs	weekly
Terms and structure of questions	Health information competencies of the users Courses, instructions, manuals, help Development of ontologies Optimizing retrieval tools (information-retrieval languages)	weekly, permanent actualization of a dictionary (index)
Sources visited most frequently	Trends of development of information sources Verification of resources Modification of interface (studying users' information competencies, instructions) Monitoring of changes in information needs	weekly
Individual users' portals (options, links used most frequently, etc.)	Monitoring changes in information needs and competencies	weekly
Time spent on website	Observation of changes (increase – decrease of interest, relations between time and information needs, including content)	monthly
Selected forms of communication (with service, other users individually or in groups)	Optimizing information offer, development of interactive tools	monthly
Forms of data presentation selected most frequently (text, graphics, image, multimedia, statistical data, etc.)	Modification and development of the tools of information presentation	monthly

- Preliminary offer, consulting the assumptions of a service/resource being developed with the users, also offering subjective data
- Administrative, referring to the needs coming from professional obligations (like administration tasks based on information processing).
- Modelling (case studies, system analysis, analytical modelling, methods of key factors, accepting strategic assumptions)
- Observations of tasks executed and analysis of functions (type, range, changeability, selection of sources – interviews, documents, etc.), including self-observation.
- Data mining, exploring data from databases with ICT tools (popular techniques: statistical, analysis of log registers, neuron networks, evolution methods, rough sets, fuzzy logic; data collected with these techniques require further processing to gain knowledge needed by system designers and organizers).

Table 2 presents possible application of different methods of data collection concerning information needs for the features of the latter proposed above. Application of more than one method increases reliability of data (thanks to the possibility of comparing them), and assures the synergy effect of the knowledge gained.

Diversification of the users causes the need of analyzing the features mentioned above for particular categories, with different methods. The amount of data gathered enables development of knowledge about the users, and fore-

Table 2. Applicability of different methods for studying information needs and their features

	inventorying	interviews	questionnaires	preliminary offer	administrative	modelling	observation	data mining
range	+	+	+		+	+	+	+
quality		+		+				+
scopes	+	+		+	+	+	+	+
goals	+	+	+		+	+	+	+
time				+			+	+
quantity	+			+	+	+		+
processing	+	+			+	+		+
privacy		+	+		+	+	+	
frequency	+		+				+	+
usage		+	+		+		+	
indispensability		+	+	+	+	+		
competencies	+			+			+	+
communication		+				+	+	+

casting trends of changes in information needs and competencies.

Building WHIS on ICT network influences also selection of surveying methods, like observation of working network, and data mining. Additional tools, like questionnaires (online and offline), interviews, etc. can be used for verification of data, also in regard of available evidence of information science, informatics, psychology, public health, etc.

Good example of a system tool both serving the users, exploring their needs, and collecting knowledge, is a “virtual librarian” – virtual customer service representative – vRep Cosmo in National Library of Medicine (Ahmed, 2006). It is a tool of communication with the users, based on natural language, available permanently, assuring better anonymity than other methods of electronic or phone contact. Cosmo answers questions concerning the way of library’s work, range of collections, as well as meritorious questions concerning health (offering information searched in MedlinePlus). It collects statistical and meritorious data concerning users’ movement and questions, which are then analysed, and conclusions implemented to the user service system (software modification, studying information behaviours, development of knowledge resources, and lexis of an information-retrieval system).

Methods of Data Processing

Data processed with traditional and/or ICT methods (interpretation, concluding, modelling, neuron networks, classification, etc.) are verified regarding both available theoretical knowledge, and results of other, similar studies. Positive result of this evaluation enables them to become a foundation of changes in functioning subsystems, modifications in those being designed, checking assumptions for quite new information services.

Awareness of a subjective character of all data gathered with sociological tools (like questionnaires or interviews) is a condition of effective surveying information needs. One shall also remember, that optimizing system regarding the users’ satisfaction cannot also assume “average needs”, resulting in resignation from services with (according to the data) quite small interest in. Controlling the needs requires further checking quality (weight) of a need, i.e. by whom and for what an information is being searched, regardless frequency of searching.

INFORMATION CATEGORIES

Information in the system can be categorized according to two main criteria: a goal (for what it is being used), and a method of creation. Then the following categories can be defined, according to the proposal of the World Health Organisation (WHO, 1999):

- Information about activity being realized within a domain (the broadest content category).
- Information about the public in regard to its information needs and qualifications.
- Research
- Education
- Management (legal, financial, human resources, logistics)
- Geographical

These categories are not separated, as their main goal is to cover all kinds of information which can emerge within a system. Below detailed description of particular categories.

Research Information

Development of one, high-quality health information service for science and research needs seems to be impossible. Numerous specializations (only among the doctors) and fields of research is difficult to be covered by only one structure. These information are being gathered mostly by libraries of medical universities and research institutes, for documentary, research and educational purposes. Serving members of a network society, these libraries have to discuss current possibilities of entering and/or creating virtual networks within a research community, functioning as so-called participatory libraries, i.e. facilitating and promoting exchange of health information and knowledge, according to their role as seen in a conversation theory (Lankes, Silverstein, Nicholson & Marshall, 2007).

Mentioning impossibility of designing such a one service, one should suggest design of a network services of cooperating databases and services managed by medical universities, clinics, primary and specialist health care units, research societies, and professional organizations representing all health professions. Each of these institutions shall manage reliable services for its specialization, regarding projects, publications, contacts, cooperation, etc.

Educational Information

Professional education is strictly regulated and accredited by specialized boards, depends also on a specifics of a discipline, and a job market. Educational health information service shall include:

- Basic information about all higher education institutions in health disciplines
- Requirements for the candidates
- Data concerning research interests
- Accreditation rules and reports
- Curricula (ECTS syllabuses)
- Courses offered
- Requirements for job candidates in healthcare
- Information about cooperation projects, students' and lecturers' exchange

The users of these types of information shall be: candidates for universities, students, health professionals searching for additional courses and qualifications, persons responsible for health education policy, supervising agents (like resort authorities), professional chambers, lecturers and teachers.

Management Information

This type gathers all data concerning realization of tasks in each and every health care unit, regarding health status of population, and costs of care. It refers also to statistical, financial, logistics, or human resources data, quality standards, and ethical codes.

Management refers also to leadership in health professions, especially those with their own authorities (chambers), like doctors, nursing, midwives, and diagnosticians. Though this type covers also information about organization of a profession, rules and consequences of belonging to the group, professional organizations and regulations.

Management information shall be accessible in services offered by health care units, supervising agents, and organizations, to be found in Internet domain portals.

This category consists also of:

- **Legal information** (all binding legal acts, regulations, both of national and local authorities, resort, chamber, trade unions, concerning all aspects of health care. Accessibility of all statutes, rules, organizational rules, ethical codes, etc. shall be regarded. It shall also include (or refer to) international regulations, those general (like convention on human rights, regulations of EU, WHO, UN, ILO), and specialist, of main health organizations, and regulations concerning current social-economic- political and health situation. Such a database of legal information in healthcare shall be managed on a national level by resort authorities, in cooperation with professional chambers, ministry responsible for higher education, and trade unions. The data shall be accessible via a health resort portal.).
- **Financial information** (like other human activities, also health care (and information services) shall have clear rules and resources of financing. Subjects of information processes of this kind are both legal entities (administration agents, health care units), and individuals (caregivers, patients). For most of them information service is of complementary or auxiliary character, i.e. is realized along with their main activity, defined as participation in health caring for a given population. Payments in health care refers mostly to primary and specialist medical and/or nursing services, and all other additional services (like laboratory tests). Either caregivers, managers, or patients participate in financial information flow. One cannot expect public accessibility of private data, however – the rules, and aggregated statistical data and reports for different categories, regions, etc. shall be available.).
- **Human resources information** (HR information includes: all general, national, legal rules concerning employment issues, as well as adequate EU and international regulations. There also should be found: data concerning employment needs in different units and professional types (both nationally and abroad); information about qualification requirements, quality of work, etc.; trade unions, and their offer. This kind of information shall be available via trade unions.).
- **Logistic information** (it consists of data concerning infrastructure and equipment in health care, accessibility of services in regard to number of places and equipment indispensable in tests and therapy. These information are collected by healthcare units, analyzed and referred by supervising organs.).

Information about Healthcare/ Public Health

Information about everyday practice and being used in caring seems to be the largest and most differentiated resource in the whole system being designed. It covers in general data concerning for example:

- Health status of a population being cared by a given unit
- Diagnostic and therapeutic needs
- Cooperation of different professionals within a health care team
- Rules, procedures, instructions obligatory in caring a patient
- Those entered in patients' records, medical and administrative reports

This differentiation comes from specifics of information needs, resulting from a type of unit (public and private healthcare, hospital or local setting, nursing home, etc.), and a position of an individual engaged in collecting and usage of data.

However, one shall also try to design information sub-systems for the needs of particular professions. This task shall belong to professional chambers, as representing interests of their members, and though offering them access to knowledge needed in an everyday work.

Laboratory Information

Laboratory information is quite specific in its form. It concerns health status of individual patients, revealed in biological and chemical indicators in numeric, graphical or image forms.

It's specific refers also to privacy requirements, as the tests' results cannot be passed to third persons. However, not just the pure results, but diagnosis become elements of information passed for the needs of health care management, for statistics of illnesses, epidemiological supervision, employment needs, costs, etc.

Information about Diseases and Epidemiological Supervision

Knowledge about diseases is built on statistical data illustrating their demographical and geographical dispersion. Monitoring life-risk diseases (like tuberculosis, malaria, AIDS, cancers, influenza, etc.) is of particular importance. Such data are collected by health care, epidemiological, and sanitary units. Long-term monitoring and information collection enable estimation of epidemiological risks in different populations and regions, developing strategies and reactions in crisis situations.

Geographical Information

This category has been named regarding horizontal scope; referring to it's range, it includes all the above mentioned categories. Geographical dispersion of such data is useful in all management processes. Each of databases and/or services shall be able to present information according to geographical limits.

Users' Participation in Development and Application of Information According to Categories

Differences in usage of information between individual (professional or not) and institutional users can be found.

The patients concentrate on direct care, its quality and costs (financial, time). Their information needs are often limited to their health problems. In general, information needs of the public may refer to information about organization of healthcare settings and services, types of diseases, epidemiological risks. However, these and other needs depend on the level of health information literacy of the public, including education status, income level, language competencies, etc.

Diversified group of health professionals works usually on information concerning prac-

Table 3. Categories of information transferred within a WHIS and in communication with an environment. Source: own study.

Type of information	Flow direction
Information FOR health care	comes from environment (international organizations, government authorities, etc. – Level 1), taken by institutions representative for a domain (resort and local authorities, supervisory bodies – Level 2) and passed to units of healthcare – Level 3
Information WITHIN health care	being created during and in the result of healthcare practice (3), passed to resort authorities and other supervisory bodies (2), and used back in healthcare services (3), partially passed to patients and/or their carers (Level 4)
Therapeutic information	concerning health status, diagnosis and therapy, passed to patients and/or their carers (4)
Information ABOUT heath care	comes from supervisory bodies (2) and healthcare units (3), passed to all interested, i.e. internal and external environment (1-4)

tice, including analytical tests' results, financial and logistic information, knowledge about health status of a given community (public health, types of diseases). In some circumstances they can also be interested in epidemiological information. They are either users of this knowledge, or it's authors or suppliers.

Institutional users, if diversified into managing healthcare, care providers, research or education institutions, are sources and authors of information in adequate subsystems. Moreover, a group of decision makers can be selected, as information receivers: about public health, management, epidemiological supervision, or geographical.

Summarising, the patients (as individuals or as the public generally) are mostly information receivers. Health professionals are both authors and users of knowledge resources. Selected subsystems are products of management procedures (financial, logistic, HRM, geographical information), created more in the result of institutions' than individual health carers' activity.

Moreover, subject and functional categories of information available in a WHIS fulfil criteria of information evaluation as used in management on different levels: operational, tactical, and statistical (Flakiewicz, 2002). (See Table 3)

Structure and Communication Channels

A wide health information system seems to be a very complicated, multilevel structure. Its complexity can be illustrated by:

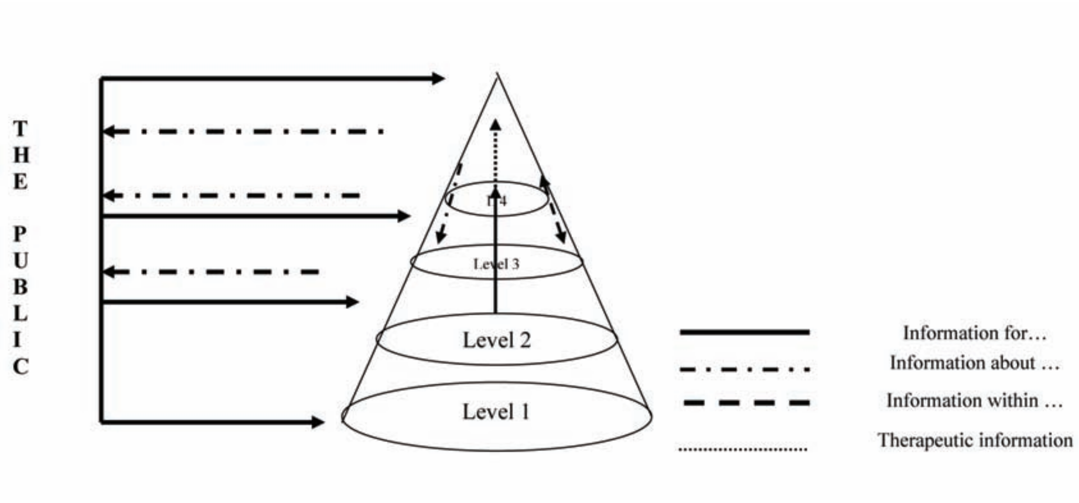
- Channels and directions of information flow
- Frequency of contacts among all interested institutions (and actualization of data)
- Rules and procedures of accessibility of different categories of information for numerous types of the users.

Design of each its unit must be preceded by surveying information needs of the users.

Several categories of information can be defined, being transferred and used both within a WHIS and between a health care sector and an external environment. They are listed and described in Table 3. Direction of their communication is presented in Figure 1.

Developing an information system requires indication of channels and directions of information transmission. It is reflected in regulations defining methods, forms, and frequency of information delivery in both horizontal and vertical communication.

Figure 1. Directions of information flow in WHIS. Source: own study.



Science communication is based on authorized, recommended channels and forms, like peer-reviewed journals and monographies (electronic and printed), conferences and seminars. Legal information is published in official journals of adequate bodies. Information about practice is obligatory kept in standard patients' and units' records, reports, regularly updated. Channels of great importance are also informal contacts among healthcare professionals. Therapeutic information is being passed in direct contact. Both its verbal and non-verbal dimensions are extremely important, as well as adequate feedback, either for effective communicating and understanding of a patient's health status and prognosis, or for showing him/her empathy and understanding. HRM information is partially enclosed in legal communication, or internal horizontal communication in organization. Popular forms enclose written communicates, direct and/or phone contacts.

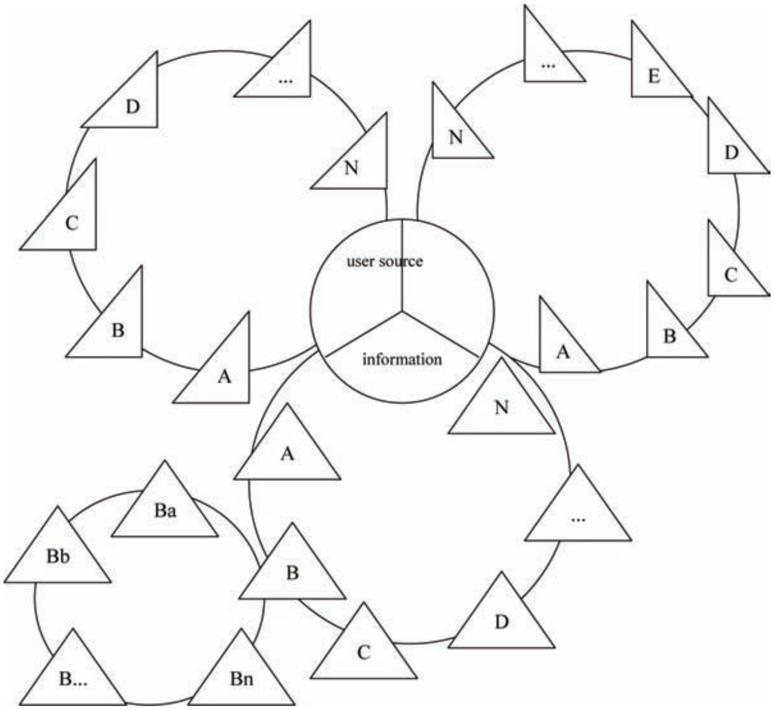
THE WHIS MODEL

Analysis of the users, their information needs, and categories of information being used within healthcare sector makes a foundation for indication of three constitutional elements of a wide health information system, a triad. These are: a user, an information, and a (information) source.

These elements need to be ordered in a structure, completing each other, as it is illustrated on the Figure 2 by a circle made from three different pieces. In other words, all of them are indispensable for proper functioning of the wide information system.

Individual units on circles represent adequately categories of: users (individual professionals, institutions, patients, the public, etc.), sources (healthcare units, administration units, education units, etc.), and information (science, educational, legal, epidemiological, etc.). General categories of each type can be further divided, like for example: information – science information – science information in medicine/ nursing/ dentistry, etc. Group of information sources shall consists of all agendas obliged to realize information processes (creation, collection, indexing, accessing). Differentiation of sources will lead to development of another "circles" on the diagram, representing more detailed information (like individual circles for hospitals, community settings, education, etc.). It is worth to emphasize, that this group consists also of people participating in information processes,

Figure 2. Model of a wide health information system as proposed by M. Kisilowska



representing interested institutions. Structure of circles enables "movement" of selected elements on central positions (creation of different "triads"), and further – free usage of different types of information by all interested parties, for optimal answering users' information needs.

The model is of morphological and process character, i.e. it includes elements indispensable for efficient realization of information processes, and a course of the latter, thanks to adequate functions of particular parts of the structure. It also refers to the system's external dependencies in the environment, like collecting external information or offering access to internal knowledge for entities from outside of the system (like supervisory institutions, media, etc.). Regarding its function, it can be perceived as a model facilitating presentation of the problem thanks to graphical representation of functional and structural connections.

The model enables presentation of 7 typical elements of an ideal system, as from an information science perspective. They are:

- A task, i.e. realization of information processes
- An entrance, i.e. data given by different participants of the systems
- An exit, i.e. knowledge produced in the result of data and information processing
- A course, i.e. direction, frequency, forms of realization of information processes
- An environment, i.e. external elements offering information
- An equipment, i.e. system's technology and architecture
- A human activity, i.e. definition of needed human actions, in particular referring to data interpretation, information processing, knowledge usage, definition of information flow, etc.

Basic three-element structure is assumed as necessary for information flow. Lack of any of these elements would made proper functioning of a WHIS impossible. For example a two-element system consisting of "information" and "sources" would in fact be a "one-element" structure consisting only of the latter, according to the communication theory statement, that "information not received and or not read cannot fulfil its fundamental function". Furthermore, resignation of "information" violates the sense of the wide *information* system, and challenge the idea of such a construction. In fact, lack of a few categories of existing health information systems was at the beginning of development of a discussed model.

A two-element structure of "information" and "user" is threatened with a significant impairment of its functionality, regarding impossibility of verification of quality of knowledge gained. A "source" belongs to the fundamental criteria of information evaluation, as well as fastens information searching – it is easier to find an answer, if known where to search.

Simple structure of this model enables its adaptation to either national, regional, or international requirements, like a subject structure of an information system as proposed by the WHO. Intentional and adequate usage of information is a condition of aiming the goals of health projects, programs and policies, like WHO's "Health for All". It enables development and usage of own, as well as participation in international health information systems, like the WHO Health and Environment Geographic Information System (HEGIS) of an European range, collecting data concerning population health and risk factors in geographical regions (WHO ROE, 1996). Access to different types and levels of information is restricted and depends on an authorisation given to institutions and individuals.

KNOWLEDGE REPRESENTATION IN WHIS

Designing knowledge organization in information systems is based mostly on empirical (statistic, historical, pragmatic) methods (Sosinska-Kalata, 2001), referring usually to disciplinary division, development of a field, and statistics of selected, representative phenomena. Specifics of health disciplines requires inclusion in a WHIS both declarative (about objects, situations, and relations among them) and procedural (about operating "declarative data") knowledge. Knowledge in WHIS is of science character, i.e. it consists of reliable information about the world. It also shall be characterised by reliability and structure (mapping world, revealing relations between elements). These information are used then either for research, or organization of health care. As Artowicz (1997) says, knowledge representation is a way of mapping pieces of a world in a given time, and types of transformations realized by a system (information searching, concluding).

Systems of concepts/terms accepted in a sphere being surveyed are reflected in terminological classifications, lists, and information-retrieval languages, like MeSH (NLM, 2007), SNOMED (SNOMED, 2007), WHO Family of Classifications (WHO, 2008), International Classification of Nursing Practice (ICN, 2007).

Information-retrieval languages adapt their structure to traditional division of medicine and related disciplines into fields and specializations, and further – subjects and methods. Their lexis often refers to original anatomical names of body parts. Differences in perception among health professionals (or even experts in the same field) are easily notified in translation processes. Structure of an original language, domination of some concept categories, shows indirectly either the way of understanding, significance of selected problems, or a policy concerning research topics and trends. Specifics of interpretation of phenomena and terminology, together with the specifics of information-retrieval lexis, as well as difficulties in optimal translation into national languages, also illustrate different methods of perceiving the world.

Each domestic system reflects unique, national approach to a profession. It reflects not only its history, the role of a discipline and its tools, but also some dominants and differences in financing research. Better developed fields have also more specified terminology in information-retrieval languages.

A few studies (Baernhodt & Lang, 2003) evidence preferential presentation of medicine against related disciplines in information-retrieval systems. Searching commonly-known databases for nursing diagnoses had positive results only in case of the US National Library of Medicine. That was possible because of UMLS (Unified Medical Language System) being developed by the team representing different health professions. Searching other databases gave positive results only if nursing terms were identical with medical ones. Meanwhile, as Baernhodt & Lang (2003) shows, a health problem is perceived differently by professionals (medical, nursing, physiotherapist) as a therapeutic "task", as they all have different professional goals. For example diagnosis concerning open fracture can result in:

- Procedure of chirurgical joining (medicine)
- Applying adequate dressing (nursing) to avoid complications (infections, scarring), and ordering painkilling drugs.
- Rehabilitation (physiotherapy)

These differences, and lack of nursing terminology in many information systems, are between the reasons of developing the International Classification of Nursing Practice, as well as other professional terminologies (like Nanda – Nursing Diagnoses).

Availability of multimedia and hypermedia enables more precious mapping of reality. They enrich linear organization of texts. Hyperinformation model of knowledge organization can be described by five features: non-linearity, flexibility, transparency, hospitality, and contextuality (Sosinska-Kalata, 1999). Hypermedia solutions enable users finding knowledge irrespective of sequence order of information. Obviously, they are very popular in education, expert, and electronic patient's record systems, in particular regarding tests' results (RTG, TK/CT, MRI, PET, CR, ECG, etc.). Sometimes these different graphic forms, and different ranges of concepts (like in case of foreign languages) enable getting unexpected results, connecting facts which would not be linked without ICT tools.

System modelling shall assume uncertainty of evaluation of information reliability, inaccuracy of mapping reality, and uncertainty of optimal knowledge representation (Sosinska-Kalata, 1999). It requires application of different retrieval criteria and tools, studying system-user interactions, and information competencies of the latter. In consequence a system of functional models of user's knowledge (5 types of knowledge) is developed:

- About user's status in problem-solving process regarding information searching.
- About subject being searched itself.
- About user's knowledge concerning the subject.
- About user's aims and goals implicated by his/her current status and forecasted actions.
- About methods of user-system cooperation, enabling getting knowledge of the previous four types listed above (Sosinska-Kalata, 1999).

System modelling assumes that users representing a given field do have adequate knowledge, and that those not related to a discipline – do not. This assumption is actually reflected in a process of translating common terms into information-retrieval language terminology, with adequate mapping of professional terminologies and classifications.

LINGUISTIC TOOLS

Development of disciplines is reflected in development of communication and specialist terminologies. Type of language selected for describing reality influences quality of data received, and level of their particularity (Flakiewicz, 2002). For example in object languages, with important share of ethnic languages, one may transmit many detailed information, but loose knowledge about relations between objects. Languages of formal models, with dominating special terminology, or formal languages (mathematic or chemical notation) transmit knowledge more synthetical, but including information about very complicated relations between objects and their features.

In medical and related sciences first classifications concerning diseases were developed in 18th century (by for example Francois de Lacroix, William Cullen, William Farr) (Kozierkiewicz, 1999). Nowadays the World Health Organization is responsible mostly for classification works in health area. It has coordinated preparation and modification in the WHO Family of International Classifications (WHO, 2008), consisting of: International Classification of Diseases (ICD-10), International Classification of Functioning, Disability and Health (ICF), and International Classification of Health Interventions (ICHI – under construction). There are also related products, like International Classification of Primary Care (ICPC), International Classification of External Causes of Injury (ICECI), The Anatomical Therapeutic Chemical Classification System, and ISO 9999 Technical Aids for Persons with Disabilities. Derived classification include field applications of ICD, for example in oncology (ICD-O-3), mental disorders, Dentistry (ICD-DA), health of children and youth (ICF-CY).

Health classifications not only organize terminology, but also facilitate realization of statistical tasks and recording health care procedures.

The SNOMED (Systemized Nomenclature in MEDicine) system is a multi-language linguistic tool used in health recording, laboratory and radiological systems, infection reporting, research coding, information searching, telemedicine, etc. around the world. It is probably the most complete classification for clinical use. Its main advantage is reference to terminologies of different health professions, facilitating communication within diversified health teams, and in searching health information.

Globalization of research and practice induces unification of terminology. Common definition of concepts are being discussed and formulated in ontologies (Gangemi, Ousanekku & Steve, 2007; Golbeck, Fragoso, Hartel, Hendler, Oberthaler & Parsia, 2007). Among different types of them, there are also authority lists, taxonomies, thesauruses (like MeSH and UMLS), data models, etc., also trying to consolidate different domains of health disciplines (Lambrix & Tan, 2006). Many authors (see: Large, 2005; Organization, 2003; Semantic Web, 2005; Summary Report, 2004; W3C, 2001) emphasise the necessity of developing ontologies facilitating knowledge management and access in health disciplines. Further works in this range shall include:

- Harmonisation of lexis, development of basic ontologies concerning sources' identification and context
- Development of common dictionaries, and following ontologies serving specific domains and research fields
- Implementation of LSI (Life Sciences Identifier) standard
- Permanent exchange of knowledge among experts in ontologies

There are also numerous examples of knowledge management in information systems supporting management of national health services, like reorganization of the US National Health Information Infrastructure (NHII) into the National Health Knowledge Infrastructure (NHKI) (Kashyap & Hongsermeier, 2005), based on the

Semantic Web. This network is going to include inter-operational systems of clinic information, information about public health, and health status of individual patients. It is assumed to improve functionality of national public health service, to fasten innovations, and to decrease costs along with increase of effectiveness. Main barriers in such a process include: linking very different information processes (in meritorious, technological, and formal aspects), realized on different data (regarding forms and formats), development of new ontologies or adaptation of existing ones and metadata standards, flexibility enabling adaptation to evolution of the Semantic Web and human knowledge.

A type of ontology is also a reference terminology model for nursing, defined in the ISO standard (ISO, 2003). A reference terminology settles number and categories of concepts to be used in describing reality – here: nursing practice – and relations among them. All professional terminologies shall be adapted regarding such a standard, if they are going to be compatible with each other, with other linguistic tools (like information-retrieval languages), and software being applied in healthcare information systems. Compatibility of professional classifications with information-retrieval languages (UMLS, MeSH) is of great importance, as it empowers success of searching for professional knowledge by health care providers, educators, managers, etc.

Development of WHO FIC, as well as structures and dictionaries used by different health professionals, reflect fast development of health disciplines, and the need of linguistic tools facilitating knowledge organization. It is also related to intensification of professional communication and documentation, based on ICT tools. Codes linked to individual terms and concepts decrease a risk of mistakes in information exchange.

Effectiveness of information processes depends directly on selection of terminology either by the users, or knowledge providers. Development of terminology is a permanent task, a condition of improvement of such a system. Construction of the International Classification of Nursing Practice and works over its structure and implementation during last 25 years can illustrate changes in awareness of indispensability of professional terminologies, for the needs of internal and external communication. Their main task is to answer optimally information needs of different categories of patrons, and to adapt information-retrieval tools to their needs and competencies.

CONCLUSION

Research on information processes within a health sector is strictly related to knowledge management. Efficient utilization of knowledge requires sufficient information skills of the users. They must be aware of the concept of professional information, and qualified in effective searching and evaluating knowledge. Proposed model of wide health information system seems to optimize realization of information processes, in regard of answering information needs of different categories of the users.

Further research trends focus on the users, communication (linguistic tools, data transmission, mobile communication), digitisation. Specifics of relation between information processes and the users' information needs comes from their dynamics, related to permanent changes in social, research, and technological circumstances. No one can assume development of one, stable information structure. It's effectiveness depends on flexibility, i.e. adaptability to current needs and potentials.

Constant development of "real virtuality" results in mediatised awareness of new generations, ICT-skilled, with new information needs in both range and form. From the other side, there are numerous surveys and projects concerning health information literacy and education for specific groups of the users, to reduce the risk of health/digital/social exclusion.

Works on health-related web ontologies indicate the direction on linguistic tools' development. Digitisation of health contents and flexibility of data transmission (also mobile), forces further works on metadata and ICT tools.

Difficulties or weaknesses of the model are connected with an unpredictable human factor. There is so far no universal method or tool to observe (and plan) human information behaviours, so there still exist not-answered questions. Also simplicity of the model is endangered with a risk of loosing too complicated or too particular objects.

The above illustrates the need of common research of health, ICT and management experts on designing more sensitive knowledge systems to be applied in organisations functioning in permanently changing environment, able to cooperate not only with information sources, but also with so-called tacit knowledge.

REFERENCES

W3C Semantic Web. (2001). *Semantic Web healthcare and life sciences interest group*. Retrieved on June 11, 2008, from http://www.w3.org/2001/sw/hcls/

Ahmed, T. T., Willard, C., & Zorn, M. (2006). Automated customer service at the National Library of Medicine. *First Monday, 11*(11). Retrieved on June 11, 2008, from http://www.firstmonday.org/issues/issue11_11/ahmed/

Artowicz, E. (1997). *Reprezentacja wiedzy w systemie informacyjno-wyszukiwawczym*. Warsaw: Wydawnictwo SBP.

Baernhodt, M., & Lang, N. M. (2003). Why an ICNP? Links among quality, information, and policy. *International Nursing Review*, *2*(50), 73–78. doi:10.1046/j.1466-7657.2003.00184.x

Flakiewicz, S. W. (2002). *Systemy informacyjne w zarzadzaniu*. Warsaw: C.H. Beck.

Gangemi, A., Pisanelli, D., & Steve, G. (2007). *An overview of the ONION project. Applying ontologies to the integration of medical terminologies*. Retrieved on June 11, 2008, from http://www.loa-cnr.it/Papers/dke.pdf

Golbeck, J., Fragoso, G., Hartel, F., Hendler, J., Oberthaler, J., & Parsia, B. (2007). *The National Cancer Institute's thesaurus and ontology*. Retrieved on June 11, 2008, from http://www.mindswap.org/papers/WebSemantics-NCI.pdf

International Council of Nurses. (2007). *International classification of nursing practice*. Retrieved on June 11, 2008, from http://www.icn.ch/icnp.htm

International Standard Organisation. (2003). [*Health informatics–integration of a reference terminology model for nursing*. Geneva: ISO.]. *ISO*, *18104*, 2003.

Kashyap, V., & Hongsermeier, T. (2005). *Towards a national health knowledge infrastructure (NHKI). The role of semantics-based knowledge management*. Retrieved on June 11, 2008, from http://www.w3.org/2005/04/swls/White_Paper.pdf

Kozierkiewicz, M. (1999). Regulacje i standardy w elektronicznym rekordzie pacjenta. *Zdrowie i Zarzadzanie*, *6*, 31–40.

Lambrix, P., & Tan, H. (2006). *SAMBO–a system for aligning and merging biomedical ontologies*. Retrieved on June 11, 2008, from http://www.ida.liu.se/labs/iislab/people/patla/publications/JWS06-preprint.pdf

Lankes, R. D., Silverstein, J. L., Nicholson, S., & Marshall, T. (2007). Participatory networks: The library as conversation. *Information Research, 12*(4). Retrieved on June 11, 2008, from http://InformationR.net/ir/12-4/colis05.html

Large Scale Distributed Information Systems. (2005). *Active semantic documents*. Retrieved on June 11, 2008, from http://lsdis.cs.uga.edu/projects/asdoc/

Miller, R. A., & Gardner, R. M. (1997). Summary recommendations for responsible monitoring and regulation of clinical software systems. *Annals of Internal Medicine*, *9*(127), 842–845.

National Library of Medicine. (2007). *Medical subject headings*. Retrieved on June 11, 2008, from http://www.nlm.nih.gov/mesh/

Nicholas, D. (2000). *Assessing information needs: Tools and techniques and concepts for the Internet age*. London: Aslib.

Nicholas, D., Huntington, P., Jamali, H., & Williams, P. (2007). *Digital health information for the consumer. Evidence and policy implications*. Aldershot: Ashgate.

Organization for Standards and Ontologies for Functional Genomics. (2003). Retrieved on June 11, 2008, from http://www.sofg.org

Semantic Web in healthcare and life sciences–applications and demonstrations. (2005). Retrieved on June 11, 2008, from http://www.w3.org/2005/04/swls/

SNOMED International. *The systemized nomenclature of medicine*. (2007). Retrieved on December 5, 2007, from http://www.snomed.org/

Sosinska-Kalata, B. (1999). *Modele organizacji wiedzy w systemach wyszukiwania informacji o dokumentach*. Warsaw: Wydawnictwo SBP.

Sosinska-Kalata, B. (2001). Jezyk informacyjno-wyszukiwawczy jako narzedzie organizacji wiedzy. *Zagadnienia Informacji Naukowej*, *2*, 28–42.

Summary report–W3C workshop on Semantic Web for life sciences. (2004). Retrieved on June 11, 2008, from http://www.w3.org/2004/10/swls-workshop-report.html

World Health Organisation. (1999, August 23-27). *Interregional consultation on WHO support to health information system development as part of health systems development*. Kuala Lumpur, Malaysia. Retrieved on June 11, 2008, from http://whqlibdoc.who.int/hq/1999/WHO_EIP_OSD_99.2.pdf

World Health Organisation. (2008). *The WHO family of international classifications*. Retrieved on June 11, 2008, from http://www.who.int/classifications/en/

World Health Organisation Regional Office for Europe. (1996). *Development of a national health and environment geographic information system (HEGIS) for countries in Central and Eastern Europe*. Retrieved on June 11, 2008, from http://whqlibdoc.who.int/euro/1994-97/EUR_ICP_CEH_257(A).pdf

KEY TERMS AND DEFINITIONS

Information Need: An individual's condition when he/she wants to improve (enlarge and/or correct) his/her knowledge.

Information Processes: In library and information science there are 4 general types of such processes: collecting information, processing information, storing information, and delivering information.

Information System: A system organizing information resources and realizing information processes, equipped with information-retrieval tools (like information-retrieval languages) and procedures, with defined information providers and categories of users.

Information User: An individual who actively exercises his/her right to access different information sources (those who do not, are potential information users).

Knowledge Representation: The way of modelling and storing knowledge in information and knowledge systems and services.

Linguistic Tool: An artificial language, often an information-retrieval language or ontology, used in describing and searching information in information systems.

Wide Information System: A complicated, multispherial and multileveled information system with wide both range and scopes (geographical, formal, language, etc.), either classical information-retrieval systems in library science, or other information systems enabling access to non-documentary information.

This work was previously published in Handbook of Research on Information Technology Management and Clinical Data Administration in Healthcare, edited by A. Dwivedi, pp. 763-781, copyright 2009 by Medical Information Science Reference (an imprint of IGI Global).

Chapter 2.3

Open Information Management in User-Driven Healthcare

Rakesh Biswas
People's College of Medical Sciences, India

Kevin Smith
National Digital Research Centre, Ireland

Carmel M. Martin
Northern Ontario School of Medicine, Canada

Joachim P. Sturmberg
Monash University & The University of Newcastle, Australia

Ankur Joshi
People's College of Medical Sciences, India

Vinod Narkhede
People's College of Medical Sciences, India

Jitendra Jain
People's College of Medical Sciences, India

ABSTRACT

This chapter discusses the role of open health information management in the the development of a novel, adaptable mixed-platform for supporting health care informational needs. This platform enables clients (patient users) requiring healthcare to enter an unstructured but detailed account of their day-to-day health information requirements that may be structured into a lifetime electronic health record. It illustrates the discussion with an operational model and a pilot project in order to begin to explore the potential of a collaborative network of patient and health professional users to support the provision of health care services, and helping to effectively engage patient users with their own healthcare. Such a solution has the potential to allow both patient and health professional users to produce useful materials, to contribute to improved

DOI: 10.4018/978-1-60566-246-6.ch018

social health outcomes in terms of health education and primary disease prevention, and to address both pre-treatment and post-treatment phases of illness that are often neglected in the context of overburdened support services.

INTRODUCTION

Managing chronic medical illnesses in the community is a universal challenge. The traditional patient and health professional clinical encounter has evolved into a series of fragmented exchanges of information, often between several professionals. The information exchange between professionals mostly excludes the patient and is usually limited to a synthesized 'factual' written account – often referred to as 'the clinical (integrated) medical record'. The synthesized 'factual' written account however fails to convey much of the subtlety gained through the information exchanges in the encounter (which would have built a more valuable knowledge base about a patient) (Sturmberg, 2007). The clinical encounter has the potential to actually evolve into an informational collaborative process, i.e. ongoing learning persistent in virtual space and time. A persistent clinical encounter has immense potential advantages for the patient as well as her health professionals.

Medicine is a collaborative effort in problem solving between individual patients and their health professionals. The collaborations also involve others who are directly or indirectly related to the patient and health professional (for example, the patient's relatives, the practice staff, other members of the physicians' institutions etc) who provide the necessary support to the two main actors.

We suggest viewing such an integrated approach to health care as 'User driven health care' that may be defined as, "Improved health care achieved with concerted collaborative learning between multiple users and stakeholders, primarily patients, health professionals and other actors in the care giving collaborative network across a web interface." (Biswas et al., 2008 a) It needs to be differentiated from the current ubiquitous 'Consumer driven health care' model, which is essentially a strategy for users/consumers to decide how they may pay for their own health care through multiple stakeholders like employers who provide the money and insurance companies who receive the premiums (Tan, 2005).

OPEN INFORMATION MANAGEMENT AND HEALTH 2.0

Patient user generated and suitably anonymous informational content initially confined to email boxes or web based individual health record vaults can be further invested in online web pages linked to what is loosely termed as Web 2.0 technologies. That may provide opportunities for linking common experiences in order to generate improved patient and caregiver learning

In web sites using this technology user-generated tags would allow the site to evolve, enabling individual users to conduct more precise searches, make additional associations, and explore a diverse undercurrent of themes to synthesize for learning purposes.

Health 2.0 in realtion to health care has been described to be all about Patient Empowered Healthcare whereby patients have the information they need to be able to make rational healthcare decisions (transparency of information) based on value (outcomes over price).

The Four Cornerstones (Connectivity, Price, Quality, and Incentives) of the Value Driven Healthcare movement begin to create a virtuous cycle of innovation and reform. Transparency serves as a key catalyst in this process by creating positive sum competition that can deliver better outcomes at a lower cost...

As more information becomes available as a result of increased transparency, there will be a wave of innovation at all points along the full cycle of care, which includes phases where health care professionals Educate, Prevent, Diagnose, Prepare, Intervene, Recover, Monitor, and Manage the various disease states (Health 2.0 Definition, 2007).

Each and every human has the capacity for and likelihood of performing both roles of caregiver and care seeker (patient) in their lifetimes. The illness experience posts would automatically generate related posts depending on the keyword-tags they use to represent their posts and this would enable every user posting his/her individual experience, to access similar relevant lived experiences of other individuals. This would be a tool delivered remotely, often anonymously, and yet may foster a sense of belonging and intimacy. In this way any individual user feeding input into the net can receive automatic feedback that can grow as individual users keep updating their own data in this Web-based solution. This may function purely on the power of human collaborative intelligence rather than artificial intelligence and yet may prove to be much more efficient.

Each and every individual is the author of his/her own destiny (as well as his/her own web log) that reflects their experiential life processes and decisions that can shape their future. User driven health care is an attempt to help make those decisions. It is a grassroots activity to document valuable individual experiences of patients, physicians, allied health professionals and medical students which have to-date usually gone undocumented and have been a loss to the medical literature (Biswas 2008a some text in this section has been reused with permission).

OPEN HEALTH INFORMATION MANAGEMENT AND SELF ORGANIZATION

Self-organization is the property of well functioning complex adaptive systems that allows the natural relationships among individuals and groups to shape the nature of an evolving knowledge base (Martin & Kaufman, 2007).

The organizational complexity of an individual's interactions with his/her environment defines the level of his functionality. The more the connections an individual is able to develop and the greater the diversity of his network the more it may reflect his/her vitality (Biswas 2003). This is even witnessed at a micro-level inside the human body where there is a demonstrable withering of neuronal connections and complexity with senescence and a resultant loss of neuronal functionality reflected in overall loss of functionality of aging. (Lipsitz & Goldberger, 1992). Quite a few studies demonstrate the relationship between intimacy and health, and how disease survivors who report positive family relationships or access to support groups consistently live longer than those without them. The challenge for us ahead is coupling our traditional focus on monitoring efficiencies with providing deeper human connections to promote sustainable behavior change (Darsee, 2007).

The inscrutably enduring power of the anecdote itself is what incites all our most fearsome defences. The irony in our growing intolerance of the anecdote is that storytelling is full of lessons in imagination and invention so beneficial to the creative investigator. (Campo, 2006). If only all our daily processes were documented along with the anecdotes generated from them they may yet be a valuable form of evidence. It may not be an impossible dream in this electronic information age. Web-based sharing of individual patient and health professional experiences based on individual user needs through fixed and mobile information technology interfaces, would make for better E-learning in health care. This would enable all learners to integrate information and knowledge and manage health and medicine with additional wisdom. (Sturmberg, 2007).

James Surowiecki in his book "The Wisdom of Crowds," mentions four key qualities that make for collective wisdom. It needs to be diverse, so that people are bringing different pieces of information to the table. It needs to be decentralized, so that no one at the top is dictating the crowd's answer. It needs a way of summarizing people's opinions into one collective verdict. And the people in the crowd need to be independent, so that they pay attention mostly to their own information, and not worrying about what everyone around them thinks (Surowiecki, 2004).

As a word of caution it is possible to imagine highly profitable and very destructive feedback platforms based on servers in unscrupulous jurisdictions that are driven by advertising, from personal litigation lawyers to purveyors of therapeutic snake oil. Avoiding this and achieving the best for citizens will require vision, balance and coordinated effort between all those concerned for the individual user in this new age of democratized voice (Hodgkin & Munro, 2007).

User driven health care applying multidimensional approaches of persistent clinical encounters and wisdom of crowds has the potential to be transformational in challenging the complex, high cost, institutional approach that typifies health care delivery systems today. The health care industry desperately needs ideas that offer lower costs, higher quality and greater convenience and accessibility. Also relaxing central control will make local trust and strategic health workers feel more engaged in the project (Kmietowicz, 2007). While dominant players are focused on preserving business models of expensive care and technology arsenals, user driven innovations promise cheaper and simpler access to virtual clinical encounters thus meeting learning needs of the vast majority of patients who may otherwise suffer simply due to lack of information (Biswas 2008a some text in this section has been reused with permission).

CREATING PERSISTENT CLINICAL ENCOUNTERS THROUGH OPEN HEALTH INFORMATION MANAGEMENT

At present most of our chronic disease population is managed in hospitals and clinics (both in the public and private sector). The average appointment time a patient is reviewed in the hospital may arrive at 2-3 monthly intervals. This discontinuity in patient monitoring may be due to patient related factors for example if a daily wage earner has to spend hours attending a hospital outpatient department during working hours it may mean no income for that particular day. A farmer may not be able to come for follow up during sowing and harvesting. Similarly a busy executive or business man may find it difficult to address his/her healthcare needs in terms of maintaining continuity which is vital to improve health outcomes.

In the interval between the physician visits, the patient (for example a diabetic) on his/her own is expected to continue a judicious diabetic diet, maintain an optimal exercise schedule and dutifully consume all his/her medicines on time (and presumably also have an understanding of correct dosage). Any confusion or queries on the patient's part would be solved on the next visit unless it can be prescheduled (which is not easy due to the patient related factors mentioned previously).

Apart from these usual information needs that are compromised there may be other emotional information needs that would otherwise go unexpressed.

The gap between the paucity of what is proved to be effective for selected groups of patients versus the infinitely complex clinical decisions required for individual patients has been recently recognized and termed the 'inferential gap.' The breadth of the inferential gap varies according to

Figure 1. From current limited clinical encounter to an ideal persistent clinical encounter

available knowledge, its relevance to clinical decisions, access to the knowledge (that is, what the physician actually knows at the time of a clinical decision), the variable ways in which knowledge is interpreted and translated into a decision, the patient's needs and preferences, and a host of other factors. Clinicians are required to fill in where their knowledge (or knowledge itself) falls short. (Stewart, Shah & Selna, 2007), and where their patients look for answers outside of the prevailing knowledge frameworks (Shaughnessy, Slawson & Becker, 1998).

As this need for information remains unaddressed, there may be a gradual build up of patient dissatisfaction unrelated to the worsening of the disease. Timely answering of question and concerns would have resulted in a better-educated patient and may have prevented this. Patient education has long been a recognized as a positive factor in successful management of illness and a good education may result from problem based experiential learning that begins with addressing patient's information needs

At present most patient data exist either in their own or their physician's memories as well as in very brief unstructured paper notes or records that are difficult to preserve and update. As a result there is considerable duplication as well as attrition of a single patient's data at multiple entry points as s/he shifts from one health professional to another across various healthcare facilities.

Often patients do not remember all the minute, but sometimes significant details in their illness history even on careful questioning – on each occasion we have to reconstruct our stories anew in light of our current understanding. (Greenhalgh, 2006). This may however be preserved in regular daily/weekly or even monthly inputs made by the patient her/himself that is stored and summarized into a readily retrievable electronic health record, creating a persistent clinical encounter (Figure 1) (Biswas 2008b some text and Figure 1 in this section has been reused with permission).

KEY ATTRIBUTES OF THE PROPOSED OPEN INFORMATION MANAGEMENT SOLUTION PLATFORM IN INDIA

The solution will consist of a patient information input point into a system that would produce content in the form of a dynamic electronic health record that evolves with time and is complemented by a web interface with interactive inputs from health professionals for structuring and interacting with this content in between intervals of face-to-face sessions.

The entry point for patient data would be in strategically located internet kiosks that would contain a desktop with broadband access and would be managed by a person from the same community who would type patient verbal data into the desktop portal in Hindi using English fonts or alternatively record the patient's conversation onto a voice mail.

Patient Input Data Capture and Storage

A typical case scenario would consist of a patient user who may visit the Internet kiosk at the end of a working day and pour out his/her physical/mental troubles experienced over the course of the day/week/month all of which may be recorded verbatim into an e-mail with a gmail address (for example userdrivenhealth@gmail.com). This would be done by the person managing the desktop at the rural/urban health kiosk and s/he would simultaneously mail the same unstructured data to the primary care physician project participant who would then structure the data to the best of his/her abilities and if necessary forward it to other health professionals in the collaborative online network best suited to tackle the particular patient problem.

Patient data may be recorded by the village health kiosk data entry operator simply on video or a voice mail that can be stored online inside multiple gmail boxes beginning with the internet kiosk gmail account (for example userdrivenhealth@gmail.com), the patient's own gmail account to which this data could be mailed, the gmail account of the Hindi medical transcriptionist who would convert this raw patient unstructured conversational voice data to text using Hindi and English fonts, to the gmail account of the language translator who would translate this into English and finally to the primary caregiver in charge of the patient. Other than voice and text, images (still and video) taken by patients, their relatives or caregivers with direct or indirect bearing on their disease (with due care to preserve privacy) may be easily stored in their gmail boxes (individual health record vaults).

Patient Confidentiality and Privacy

This user driven solution will encourage patient users to avoid entering any identifying information, which they may feel uncomfortable divulging or associating themselves with. The most important identifying information that would need to be omitted is patient names, addresses and names of others that may have been associated with them in the course of their illness history. Patients may only identify themselves using self assigned 10 digit numbers (one suggestion would be to use the patient's mobile phone number). There is a common assumption that a patient may not be easily identified in general through his/her mobile phone number although in reality they may still be easily identified if someone who knows their mobile number specifically looks for them. To circumvent this problem we propose giving patient's the option of using a separate Subscriber Identity Module (SIM) in a separate mobile handset solely for interacting with our healthcare network.

Patients maybe expected to have issues regarding safety of using emails (especially gmail) but as long as they utilize usernames which they can suitably make anonymous and feel comfortable with and stick to not entering any identifying information their privacy and confidentiality would be preserved.

Patient Input Data Sharing and Feedback

Patients will need regular feedback on their informational inputs particularly to address their informational requirements; their disease based queries and its myriad diagnostic and management uncertainties. This can be done by the primary physician in charge of the patient (patients may be given the option of choosing their own primary physicians). The primary physician in charge can make use of online empirical or experiential evidence to engage in persistent conversational learning with the patient all of which would be stored in the electronic health record (EHR). The physician could also ask opinion of other experts on the collaborative network (through email) again all conversations of which would be recorded on the electronic health record.

Healthcare professionals may enter their feedback onto gmail and mail it to the email addresses of the individual patient concerned as well as the gmail address where all patient electronic health records would be stored (as a central place to collate and further process the data for example userdrivenhealth@gmail.com). Putting all this patient data together on the gmail box can enable searching for similar patient experiences by simply typing a few matching keywords on to the gmail search engine and checking out matching patient records stored in the gmail box. This is one important aspect of the solution that is expected to grow with time as more and more patient data is stored in the gmail box (which also has an adaptable storage capacity to match user needs).

Other than this, patients can be transmitted limited feedback utilizing existing web-based services that allow free short messaging services (SMSes) to be sent (although limited to 80 characters as opposed to the standard 160 characters available in a basic mobile).

In rural as well as urban India there exists a large digital divide. In recent times a number of attempts have been made to bridge this gap by utilizing mobile phone technology.

These web based services could be effectively utilized by the primary physicians and other healthcare professionals in our collaborative network to provide essential informational feedback to each individual patient tailored to their informational requirements. In this manner the solution could develop a sustained conversation between patient and healthcare professional users. The best return on investment for the patient (who invests her time into this) would be in the form of health professional and other patient informational feedback that eventually helps let him/her gain favorable outcomes. For health professionals investing their time into this the biggest driver would be the insights gained into their patient's lives.

For all actors in this collaborative venture learning would be the common driver. All this learning for the health professional could be organized into health professional E-portfolios linking the health professional with his/her patient records. A patient could look up the range of cases his/her health professional has come across corroborated and validated by the network and decide if this particular health professional has handled a similar case with a similar initial illness trajectory (which could be a new approach to selecting a health professional rather than go by the not so well informed referrals from other health professionals).

FUTURE TRENDS

In the simplified solution, with the platform discussed in this chapter, a detailed Personal Health Record (PHR) shall be accessible to the patient only on the web and a very truncated version of the above may be sent through SMS on demand from the registered user. Once the present basic mobile phone version is phased out in the near future and the PDA (personal digital assistant) mobile phone becomes the basic model along with ubiquitous WiMAX (Worldwide Interoperability for Microwave Access) connectivity, larger PHRs such as these could be easily accessed by patients into their device directly from the Internet.

On completion of the test phase this web-based solution to integrate healthcare E-learning needs can be opened to the world in a simple forum model, already in use at present in various web sites using what is loosely termed as web 2.0 technology. Regular experiential informational input may be posted on to the forum along with a copy to the individual user's password protected web account that would function as an E-portfolio if s/he were posting as a caregiver and a personal health record if s/he is posting as a patient. The individual user could even do this through email and every post made by mail could easily open a new post on to the forum. Most PC users in recent times spend most of their internet time in their mailbox and integrating this solution into the mailbox would target this population (Biswas et al., 2008b).

CONCLUSION

This is an operational model of user driven health care developed in an attempt to optimally answer multidimensional needs, in individual patients and health professionals to cater to an urban-rural Indian community. It is hypothesized that this may allow them to achieve better health outcomes through inter-individual collaboration between multiple stakeholders in the care giving and care seeking collaborative network.

Overall, the project will help to explore the potential of a collaborative network of patient and health professional users to support the provision of health care services, helping to effectively engage patient users with their own healthcare. Such a solution has the potential to allow both patient and health professional users to produce useful materials, to contribute towards improved social health outcomes in terms of health education and primary disease prevention, and to address both pre-treatment and post-treatment phases of illness that are often neglected in the context of overburdened support services.

This operational prototype, which still continues to evolve, has been shared with other future stakeholders particularly in the healthcare system. We look forward to the beginning of the validation process along with a future positive collaborative venture in user driven healthcare with multiple stakeholders in the public and private sectors.

ACKNOWLEDGMENT

Professor GC Dixit, Dean, People's College of Medical Sciences, Bhopal, India, Mr Arun Gurtu, Director of Research, People's College of Medical Sciences, Bhopal, India and Captain Ruchi Vijaywarghia, Director, HR and IT, People's College of Medical Sciences, Bhopal, India for their continued support.

REFERENCES

Biswas, R. (2003). *Patient networks and their level of complexity as an outcome measure in clinical intervention.* Retrieved December 16, 2007, from http://www.bmj.com/cgi/eletters/324/7329/63

Biswas, R., Maniam, J., Lee, E. W. H., Das, P. G., Umakanth, S., Dahiya, S., & Ahmed, S. (2008b). User driven health care- Answering multidimensional information needs in individual patients utilizing post EBM approaches: An operational model. *Journal of Evaluation in Clinical Practice*.

Biswas, R., Martin, M., Sturmberg, J., Shankar, R., Umakanth, S., Shanker, & Kasthuri A. S. (2008a). User driven health care - Answering multidimensional information needs in individual patients utilizing post EBM approaches: A conceptual model. *Journal of Evaluation in Clinical Practice*.

Campo, R. (2006). Anecdotal evidence: Why narratives matter to medical practice. *PLoS Medicine, 3*(10), e423 doi:10.1371/journal.pmed.0030423. Retrieved July 25, 2008, from http://medicine.plosjournals.org/perlserv/?request=get-document&doi=10.1371/journal.pmed.0030423

Darsee, J. (2007). *Creating healing communities through telemedicine.* Retrieved December 16, 2007, from http://www.hhnmostwired.com/hhnmostwired_app/jsp/articledisplay.jsp?dcrpath=HHNMOSTWIRED/PubsNewsArticleMostWired/data/07Summer/070905MW_online_Darsee&domain=HHNMOSTWIRED

Greenhalgh, T. (2006). *What seems to be the trouble? Stories in illness and healthcare.* Oxford: Radcliffe Publishing.

Health 2.0 Definition. (n.d.). Retrieved December 16, 2007, from http://health20.org/wiki/Health_2.0_Definition

Hodgkin, P., & Munro, J. (2007). The long tale: public services and Web 2.0. *Consumer Policy Review*, *17*(2), 84–88.

Kmietowicz, Z. (2007). MPs "dismayed" at confusion about electronic patient records. *British Medical Journal*, *335*(7620), 581. doi:10.1136/bmj.39339.414306.DB

Lipsitz, L. A., & Goldberger, A. L. (1992). Loss of 'complexity' and aging. Potential applications of fractals and chaos theory to senescence. *Journal of the American Medical Association*, *267*(13), 1806–1809. doi:10.1001/jama.267.13.1806

Martin, C. M., & Kaufman, T. (2007). *Glossary of Terms in New Orientations, a Shared Framework: A Way Forward to Adaptive Primary Health Care Systems Across Canada: A Discussion Monograph.* Commissioned by the Canadian Association of Community Health Centre Associations and the Association of Ontario Health Centers.

Shaughnessy, A. F., Slawson, D. C., & Becker, L. (1998). Clinical jazz: harmonizing clinical experience and evidence-based medicine. *The Journal of Family Practice*, *47*(6), 425–428.

Stewart, W. F., Shah, N. R., & Selna, M. J. (2007). Bridging the inferential gap: The electronic health record and clinical evidence. *Health Affairs*, *26*(2), w181–w191. doi:10.1377/hlthaff.26.2.w181

Sturmberg, J. P. (2007). *The foundations of primary care.* Oxford: Radcliffe Publishing

Surowiecki, J. (2004). *The wisdom of crowds.* New York: Random House

Tan, J. (Ed.). (2005). *E-health care information systems*. Jossey-Bass: Wiley Imprint and private sectors.

This work was previously published in Open Information Management: Applications of Interconnectivity and Collaboration, edited by S. Niiranen; J. Yli-Hietanen; A. Lugmayr, pp. 397-405, copyright 2009 by Information Science Reference (an imprint of IGI Global).

Chapter 2.4

Medical Information Representation Framework for Mobile Healthcare

Ing Widya
University of Twente, The Netherlands

HaiLiang Mei
University of Twente, The Netherlands

Bert-Jan van Beijnum
University of Twente, The Netherlands

Jacqueline Wijsman
University of Twente, The Netherlands

Hermie J. Hermens
University of Twente, The Netherlands

ABSTRACT

In mobile healthcare, medical information are often expressed in different formats due to the local policies and regulations and the heterogeneity of the applications, systems, and the adopted Information and communication technology. This chapter describes a framework which enables medical information, in particular clinical vital signs and professional annotations, be processed, exchanged, stored and managed modularly and flexibly in a mobile, distributed and heterogeneous environment despite the diversity of the formats used to represent the information. To deal with medical information represented in multiple formats the authors adopt techniques and constructs similar to the ones used on the Internet, in particular, the authors are inspired by the constructs used in multi-media e-mail and audio-visual data streaming standards. They additionally make a distinction of the syntax for data transfer and store from the syntax for expressing medical domain concepts. In this way, they separate the concerns of what to process, exchange and store from how the information can be encoded or transcoded for transfer over the internet. The authors use an object

DOI: 10.4018/978-1-60566-332-6.ch004

oriented information model to express the domain concepts and their relations while briefly illustrate how framework tools can be used to encode vital sign data for exchange and store in a distributed and heterogeneous environment.

INTRODUCTION

Mobile healthcare applications receive more and more attention due to the ability to reshape healthcare delivery, for example, enabling self-management of patients whilst they pursue their daily activity. Information and communication (ICT) technology and infrastructures which provide the necessary ubiquitous connectivity enable these applications. Competitive value-add ICT providers moreover facilitate these applications with alternatives to computation and communication services. Today's environment for networked applications is therefore rich in ICT services which are accessible anywhere and anytime, for example by prepaid or subscription contracts between users and ICT service providers or by collaboration contracts between these providers. Such environment enables applications to select (wireless) connections of required quality and technology which are considered best for their purpose. A mobile application may for instance seamlessly switch over between GSM, UMTS or WiFi 802.11 (Schiller, 2003) connections that are offered by competing providers. These developments enable mobile healthcare applications in choosing the appropriate situations with adequate ICT support that permit healthcare to be delivered where previously it was difficult or impossible to do so (Wootton, 2006).

Due to these ICT and business advancements, a travelling patient with a chronic disorder can be monitored continuously everywhere in the country of residence as well as abroad. If his health condition requires, he may be examined at a care centre abroad that uses equipment different than at his country of residence. This may further imply that the format of the processed healthcare data differs from the format used at his residential care centre. Local care centre's policy or local governmental health regulations may also impose the use of a different healthcare data format standard. In (near) future mobile healthcare therefore, we typically need to deal with healthcare data which are represented in multiple format standards due to the different policy or regulations and the heterogeneity of applications, systems and ICT technology.

This chapter describes a framework which enables healthcare data, in particular (digitized) continuous-time patient's vital signs and professional annotations, be processed, exchanged, stored and managed modularly and flexibly in a mobile, distributed and heterogeneous environment. A framework is often described as a basic conceptual structure to compose something from fitting parts. In the context of this chapter, a framework is an integrative (standardized) conceptual structure which brings together a set of components which themselves may be standards such as vital signs format & encoding standards (Blair & Stefani, 1998). It therefore addresses questions like:

- How to deal with healthcare data expressed in accordance with several data format standards and how to encode the data to fit to the characteristics of the provided connections to enable effective and efficient data transfers;
- How to deal with professional (textual, graphical or multimodal) annotations and derived (i.e. trend) signs in sync with the analyzed vital sign segments;
- How to manage vital sign data sets of a patient that originate from the same measurement session in a (distributed) study, which typically process data in several steps using processing tools with specific parameter settings. Similarly, how to manage vital sign data sets (of the same patient

> and the same measurement session) in different formats, e.g. if the returning traveling patient, who has been monitored and diagnosed in a care centre abroad, consults his general practitioner, who then inspects the annotations and the vital signs measured and processed using a locally certified system to confirm the annotations, the diagnosis and treatment of his colleague abroad.

The proposed framework should furthermore fit to the practices used in ICT to manage the use of multiple format and encoding standards, as discussed in the next sections.

In the next section, we discuss some of the issues of information exchange using computer networks and illustrate the need for a framework which flexibly supports exchange of healthcare data, in particular digitized continuous-time vital signs and professional annotations, in a distributed and heterogeneous environment. Thereafter, we analyze the functional requirements of mobile healthcare stakeholders on the framework. We address only those stakeholders that influence the functional aspects of a framework for multiple formatted vital signs for use in a heterogeneous distributed environment. Stakeholders addressing financial aspects like insurance companies are therefore beyond the scope of this chapter. In the section thereafter, we address the representational model, which distinguishes between the syntax for data transfer and store from the syntax for expressing medical domain concepts. Then, we discuss the information model of the framework and some ECG standards. Thereafter, we address some other syntax notations and briefly discuss tool based translations of conceptual or abstract syntax to transfer syntax. The last section presents our conclusions.

BACKGROUND

One of the issues of transferring information in an ICT environment is to preserve meaning despites the dynamic property of the data transfer characteristics of the connections and the different ways of representing information at the computer systems at the connection endpoints. A connection in this environment can be modeled by a bit or a character pipe (i.e. a model which supports the transfers of sequences of bits or characters, respectively). For example, an echocardiogram needs to be formatted as a sequence of pictures, serialized, and encoded further to suit the pipe, transferred via the pipe, and at the receiving end reconstructed (i.e. decoded). This chain of data formatting and encoding steps requires a suitable end-to-end quality to preserve the clinical interpretations of the echocardiogram. Mechanisms and techniques for data formatting and encoding have been widely investigated and developed in the area of computer networking. In this chapter, we present the data representation model of the Open Systems Interconnections (OSI) of International Organization for Standardization (ISO) (MacKinnon, 1990). This model provides clarity to and better understanding in the structures of many format and encoding standards like MPEG, JPEG, H.261, or DICOM (Le Gall, 1991; NEMA, 2007a). This is due to the distinction between abstract syntax representation, which is suitable for the entities that exchange information, and transfer syntax representation, which is suitable for the pipe that transfers the serialized and encoded data. This distinction therefore separates the concerns of exchanging concepts of the domain ontology from the concerns of serializing and transferring the encoded concepts in a meaning preserving way.

As in multimedia, several formats and encodings have been proposed or developed for vital signs, in particular for electrocardiograms (ECGs). We may identify de-jure standards developed by standardization bodies, such as the CEN/SCP-

ECG (CEN/TC251 prEN 1064, 2002), which is developed by the European Committee for Standardization CEN (CEN/TC251, 2007) and defined specifically for ECGs, or HL7 (Hinchley, 2005), which is developed by an organization cooperating with standardization bodies and accredited by the accrediting organization for US national standards, but which has a larger scope than only addressing monitored healthcare data like ECGs. Another example of a de-jure standard that can be used to represent ECGs, or vital signs in general, is VITAL (Weigand, 2005). We may also identify de-facto standards, i.e. standards that were developed by industrial or research consortia, or proprietary standards used by vendors of medical equipment or proposed by a research institute, e.g. ecgML (Wang, 2003). For our convenience, we denote ECG data format and encoding proposals found in the literature as (proprietary) standards. ECG data representation standards vary in their semantic expression levels. Some of these standards focus only on the waveform representation, some others additionally provide heart physiological or bioelectrical domain concepts like the notion of P or ST waves. These differences may imply loss of interpretation power when ECG data has to be converted from one onto another standard (lossy conversion). In this chapter, we show how the OSI data representation model (MacKinnon, 1990), in particular the abstract syntax, can be used to identify these differences in semantic expression level and how to associate equivalent ECG segments formatted in different standards. We also discuss how the abstract syntax can be used to specify professional annotations or derived (/trend) signs like heart-beats such that rendering tools are able to visualize these annotations or trend signs in sync with the associated data segment.

We apply the Unified Modeling Language (UML) (Booch, 1999) as a (graphical) abstract syntax language to express the concepts of vital signs, in particular ECGs; this results in an information model of the framework. Some of the ECG standards format ECGs as sampled time-domain bio-signals (e.g. the format described in (Browns, 2002)), others include bio-electrical or heart physiological concepts like the notion of P-waves and QRS complexes (e.g. the standard described in (CEN/TC251 prEN 1064, 2002)). The specification of ECGs using UML, addressed in (Concalves, 2007), has elaborated several ECG ontological models from different perspectives like the heart physiological, bio-electrical, including the recording session perspectives. UML is also used by other standards, for example HL7, to capture the association semantics between the healthcare domain concepts. In this chapter, however, we specify the vital signs information model from the perspective of the different format and encoding standards. This approach fits to our objective to develop a framework for processing, transferring and storing vital signs in a multiple formats environment. Our information model therefore includes multiple structures for (replicated) ECG data that are specified by the different standards and it includes structures to express their relations, for example the applied conversion tools, the settings of the tool and the actor in charge of the conversion, or the processing algorithm and settings that derive a trend sign.

To deal with the exchange of medical information represented in multiple formats we adopt similar techniques and constructs as are used on the internet. In particular, we are inspired by MIME (Multipurpose Internet Mail Extensions) (Freed, 1996) which enables users to exchange text, pictures, video clips, excel sheets, etc. independently of the computing devices, software packages or the operating systems involved. For example, the MIME construct "multipart/alternative" can be used to express the relation between two or more ECG segments of the same measurements of a patient but formatted differently, e.g. one in the CEN/SCP-ECG format and the other in the DICOM waveform format (NEMA, 2007b). The latter can be a conversion of the first to match the format of the data to the software or the equipment of the professional, for example in the earlier illustrated case of the travelling patients. As this construct specifies that the multiple parts are alternatives of one another, an ECG viewer tool can select the part that is encoded in a preferred format as indicated by a profile of preferences. Moreover, a policy that regulates tools to ignore parts that are encoded in a format unknown to the tool provides flexibility when introducing new formats without influencing existing systems (upwards compatibility and open-endedness with respect to new features or new functionality).

Furthermore, to enable synchronization of care professional's (textual or graphical) annotations with segments of analyzed vital signs, we adopt a construct similar to MIME "multipart/parallel" to inform a rendering tool that the annotations could better be visualized together with the corresponding vital sign segments.

We additionally adopt a similar technique as is applied in MPEG (Le Gall, 1991) for joining and splitting types of media, e.g. synchronized under-titles with video, to merge professional annotations, trend signs or other auxiliary data on the fly. As in MPEG, the framework includes identifiers to distinct between the data types at abstract as well as at transfer syntax level.

Besides the discussed facilities for healthcare data processing, transfer and store, this chapter also addresses the facilities to manage the dynamics experienced by mobile healthcare applications due to changes in patient's health conditions or fluctuations of the ICT infrastructural resources due to environment data traffic or roaming patients.

A framework for multiple formatted vital signs therefore needs to adopt the discussed techniques or constructs. In the next section, we justify these needs by analyzing the requirements of healthcare stakeholders that are relevant for the framework's functionality.

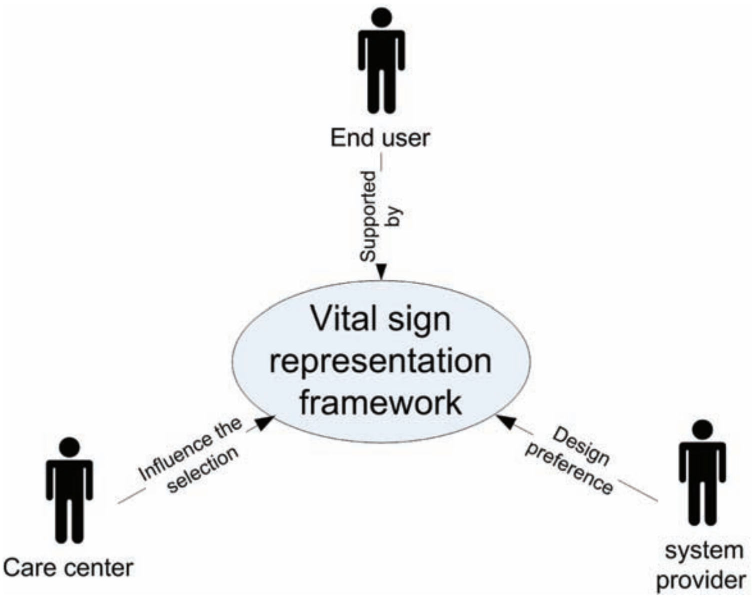
STAKEHOLDER CONSTRAINTS AND REQUIREMENTS

We analyze the needs of three mobile healthcare stakeholders to identify the functional needs that have to be accommodated by the framework. For this analysis we use our experiences collected during several mobile healthcare projects (MobiHealth, 2002; HealthService24, 2005; Myotel, 2008) and our study of several healthcare systems reported in the literature. Some of the identified needs were examined during the development of Extensible Markup Language - XML (Bray, 2004) constructs for vital signs representations. These constructs were discussed in (Mei, 2006) and several simplified scenarios were used in (Mei, 2006) to illustrate the benefits of the framework which accommodates these constructs.

We distinguish three mobile healthcare stakeholders who typically influence the vital sign representations and their use (Figure 1):

- End-users; stakeholders who use the services provided by the mobile healthcare systems. End-users include both patients and the healthcare professionals, for example the medical specialists, nurses, physiotherapists;
- Mobile healthcare system providers; stakeholders who are involved in the provisioning of mobile healthcare systems for clinical remote monitoring and treatment. In the context of this chapter, these providers are assumed to be aware of the applied information and communication technologies;
- Care centers, such as the primary care centers, healthcare call centers (also called healthcare portals), and the secondary care centre's (e.g. corporate hospitals with their departments of different specialties). For our convenience, regulatory bodies as well as medical ethical committees are categorized as this stakeholder. That is, the care centers are assumed aware of the healthcare

Figure 1. Stakeholders of vital sign representation framework



regulations that influence the way of handling patient's vital signs.

Requirements from End-Users

From the healthcare professional's point of view, the vital sign representation should be suitable for effective clinical interpretation as required by the health condition of the patient and in accordance with the working practices of these professionals:

- Healthcare professionals typically access units of interpretable segments of vital signs in a quality appropriate for the purpose of the clinical task, e.g. patient's ECG filtered from noise and movement artifacts and visualized in a resolution necessary to inspect ventricular contraction;
- Healthcare professionals may need to correlate signs that belong to a group of coherent vital signs, e.g. patient's oxygen saturation, heart beat, blood pressure, and respiration that together form an indicator of the oxygenation of the patient's brain in trauma care;
- Healthcare professionals may have priorities regarding the importance of vital signs, e.g. doctors may prefer to see trend signs and only in case of abnormalities, they need the underlying vital signs;
- Healthcare professionals may need to annotate vital sign segments;
- Healthcare professionals may need to know how vital sign data was measured and processed for evidence based treatment.

In some mobile healthcare applications, patients typically generate vital signs by attaching sensors on their body and initializing the sensing devices. These patients, especially mobile patients, may need to check and calibrate the sensors' readings from time to time to ensure accurate (local) monitoring and treatment feedback. For example, patients may need to re-attach sensors in case of bad skin contacts. For this, vital signs visualization or other feedback modality has to have a resolution suitable for patient's interpretation.

Moreover, medical and sensor technologies are evolving and new vital signs or sensors may be developed for measuring patient's health condition in mobile environments. Therefore, vital sign representations should be extensible to enable the introduction of new vital signs or the integration with new data like professional annotations.

Requirements from System Providers

Mobile healthcare system providers have the mission to facilitate the computation and communication needs of the patient's care process. In a remote monitoring and supervised treatment session, the healthcare system regularly matches the computation and communication needs of the supported care process with the resource capability and capacity of the ICT infrastructure. These systems often apply a hunting strategy to collect the available ICT resources of the contracted ICT providers. They often apply an adaptation strategy to control the vital sign data processing and transmission. For example, by down-sampling, prioritizing or discarding some of the vital sign packets, a system may improve the utility of transferring vital signs in a meaning preserving and adequate way. Therefore, a vital sign framework should enable prioritized transfers of important signs and deferred transfers of remaining signs, which may traverse other delivery routes and at cheap data communication hours. Consequently, the framework should further support aggregation and resynchronization to reconstruct the set of vital signs.

Requirements from Care Centers

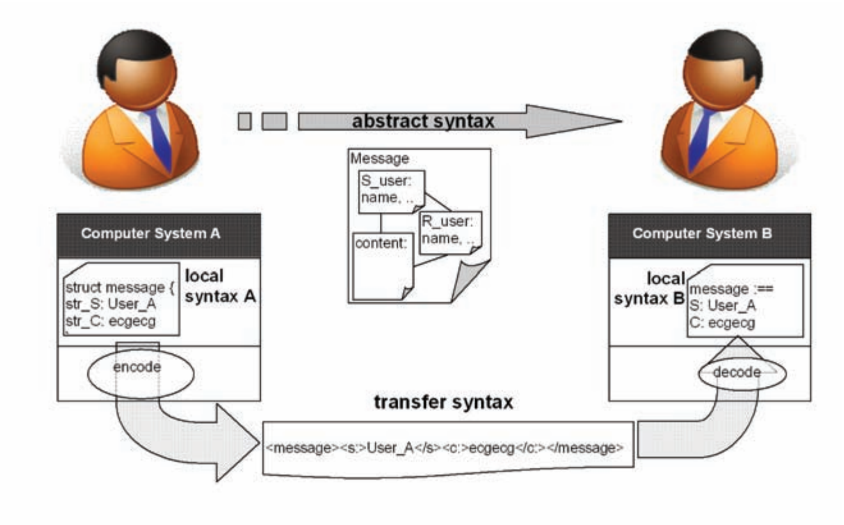
Care centers, especially corporate hospitals, often accommodate a diversity of specialized systems, each of which may apply specific vital sign formats. If furthermore, these centers also treat travelling patients, interoperability between these remote systems needs to be supported. In such cross-platform environments, vital sign representations require an open environment to facilitate multiple vital signs formats.

Healthcare data is considered private and has to be subjected to privacy rules. Monitoring and treatment protocols described in the trial designs which were proposed to the Medical Ethical Committees in the earlier mentioned healthcare projects address healthcare data privacy, such as password protected and role based access to recorded and processed data, vital signs are also made anonymous. The framework should enable transferring, processing and storing of vital signs subjected to privacy rules.

INFORMATION REPRESENTATION MODEL

A model suitable for information transfer in a heterogeneous environment, which accommodates different (wireless) communication technologies and qualities and different computer systems, is the OSI Presentation Layer model (MacKinnon, 1990) (Figure 2). This model uses three kinds of syntaxes to represent information. The earlier described *abstract syntax* represents the domain ontological structure of the information in respect of the entities exchanging the information. It is therefore the vocabulary and the structuring rules used to represent the information. This syntax is considered useful in a meaningful meaning preserving transfer, in which the sending and the receiving entities share a common universe of discourse. An abstract syntax enables these entities to interpret the exchanged information in the same way. The earlier described *transfer syntax* is the syntax used to represent data in transfer. Information expressed in a transfer syntax is therefore represented as sequential groups of bits or characters sequences. Groups, in turn, associate to terms of the abstract syntax vocabulary. The third kind is the *local syntax* which is the syntax used to represent stored data at the involved com-

Figure 2. Information representational model



puter systems. In a heterogeneous environment, the local syntaxes used by the communicating computer systems can be different, e.g. one uses a Java based local syntax and the other a C based syntax in a Unix system.

An abstract syntax is therefore not a concrete syntax as are transfer and the local syntaxes. ECGs specified from a specific perspective in an abstract syntax result in a conceptual model of the ECGs. This model can be used to reason about the elements of the ECG, for instance the bio electrical properties of the heart or the heart condition if the model is defined from those perspectives. In the perspective of interoperability in an environment that uses multiple standards, the ECG model at abstract syntax level should enable the identification of the same ECG segments which are formatted using different standards and should further enable conversion from one format to another.

An abstract syntax moreover enables the development of information exchange techniques and mechanisms for a heterogeneous environment. Information conceptually represented in an abstract syntax can be encoded to different transfer syntaxes. Information encoding from abstract syntax to a transfer syntax is virtual, because in reality the information is represented at a computer system in a local syntax. Information encoding in reality is therefore the conversion from a local syntax to a transfer syntax. The rules needed for the conversion can be derived from the encoding rules from abstract syntax to transfer syntax.

As mentioned earlier, information represented in an abstract syntax can be encoded in several transfer syntaxes, each of them binary or character sequence oriented. Moreover, some transfer syntaxes are more suitable for efficient processing rather then generating compact codes; others generate compact codes but are not processing efficient. In an e-mail application, a plain text message can be encoded amongst others as an ASCII characters sequence or a base64 character sequence (Freed, 1996). Base64 encodes 6 bits of the abstract syntax representation to one base64 transfer syntax character. Three (8 bits) characters of the plain text message will therefore be encoded to 4 base64 characters. However, binary data can be encoded using the base64 encoding to fit to a character pipe as used by internet e-mail. The benefit of binary data encoded in base64 is the availability of many internet protocols to convey the data using computer networks. On the other hand, conversions of digitized ECGs to base64 and back to a digital form at the receiving end point consume processing capacity and a lot of time, a bit oriented transfer syntax is much more efficient in such cases.

VITAL-SIGNS INFORMATION MODEL

In this section, we discuss the information model of the conceptual structure that binds together the abstract syntax level structures of vital signs, in particular ECGs, as defined in the various vital sign standards. In particular, the model specifies the different kinds of relations between the vital sign structures as identified in the stakeholder's analysis section. As discussed in that section, several kinds of relations need to be addressed:

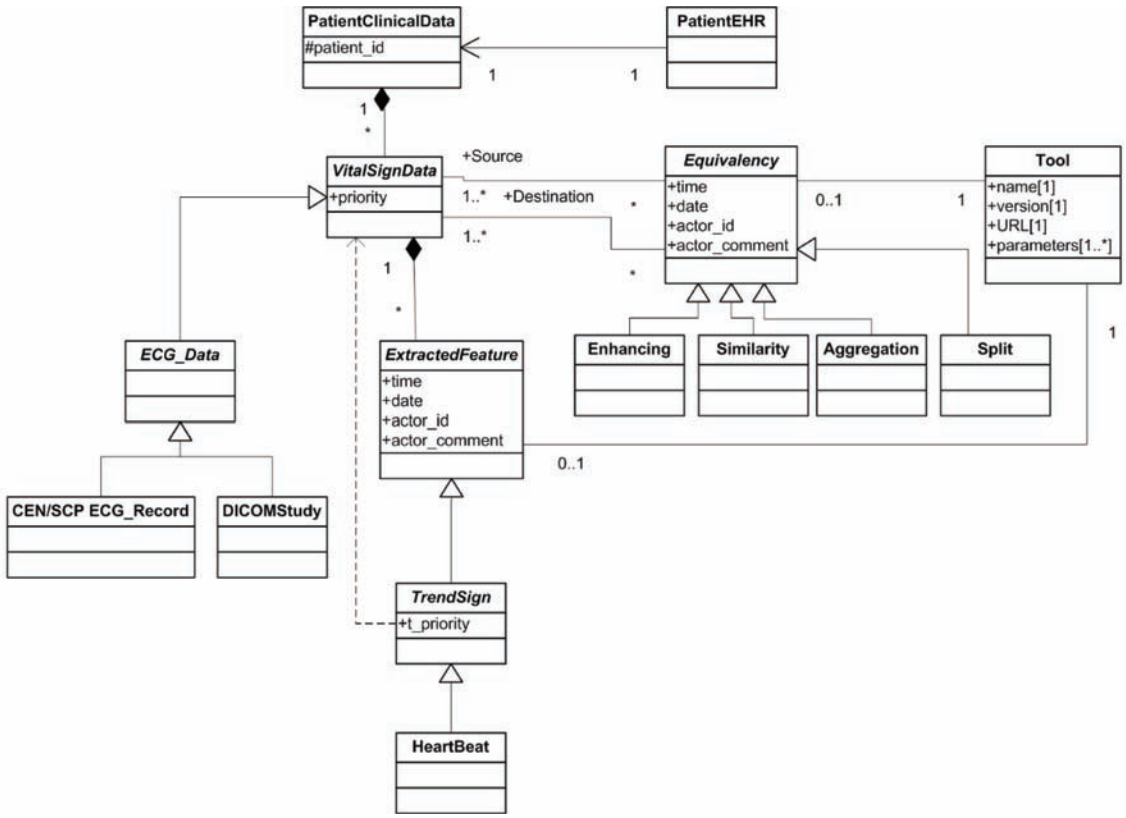
- **Similarity relation:** This relation expresses that the related segments of vital signs are similar to one another in respect of a defined context, such as the context of their use which reflects the purpose of the vital signs. Similarity is used here to associate vital signs that reflect the same (physiological) phenomena but are represented and structured in different ways in the different standards. For example, an ECG P-wave may be represented as sampled amplitude values of the wave and parameterized by a sample distant variable specified in another part of the ECG standard. This wave may similarly be represented in terms of the wave onset, duration and peak value. A converted ECG segment, which is formatted in a standard other than the original one but considered having the same interpretation and quality in the perspective of the addressed context, is defined here as being similar to the original source segment. This similarity relation therefore needs to contain the context of the similarity; it for example includes the identity of the conversion tool or algorithm, the parameter settings, the actor in charge of this conversion and the actor's comments for example to further detail the context of similarity. This similarity relation originates from the need of the care center stakeholder to enable a multi standards environment and the policies of the regulatory bodies at the different points of care.

In many cases, this relation associates one source segment to one other converted segment. In general, a many to many, many to one or a one to many association may exists, for example in the case of multiple vital signs types or in the case that the abstract syntax of the source vital sign segment standard is much richer than the abstract syntax of each of the destination standards, but together these destination abstract syntaxes span the source abstract syntax. This is for example useful in a case in which an annotated ECG segment which includes both a time based signal representation and the physiological phenomena like P-wave and QRS complexes is converted to standards that support time based signal representations, but only one of them is able to represent physiological phenomena but, on the other hand, does not support annotations. In this example, annotations but not physiological phenomena are supported by the other destination standards.

Vital sign segments which are similar are also equivalent. That is, segments which are similar also have the reflexive, symmetry and transitivity property of an equivalency relation because the related vital signs are supposed to reflect the same (physiological) phenomena. As discussed earlier, these properties are defined in the sense of the applied conversion tools and settings. That is, similar ECG segments reflect the same heart condition in respect of the resolution of the applied tool. For example, an ECG formatted in the CEN/SCP-ECG standard, which is converted to the DICOM wave form standard and the latter converted again in ecgML (Wang, 2003), is considered equivalent and even similar to the ECG representation in ecgML in the context of the applied tools and parameter settings. Remark that one of the applied tools needs only to convert the wave form of the ECG and can be unaware of the physiological phenomena expressed by the data. Therefore, the resulting ECG formatted in ecgML is not necessarily completely identical to the CEN/SCP-ECP formatted ECG, but in the context of use, which is reflected by the applied tools and settings, they are considered equally useful for the clinical purpose because at the resolution of the cascaded tools they both reflect the same heart condition. This cascade of conversions is usually called lossy if a CEN/SCP piece of data representing an abstract syntax concept is not represented in ecgML.

- **Enhancing relation:** This relation expresses that the enhanced segments of vital signs are better conditioned in respect of the context of use. For example, ECG segments filtered from undesirable noise or EMG movement artifacts are enhanced if compared against the source ECG segments. Although the enhanced segments are more appealing for use, the originating source segments essentially have the same effectiveness in respect of the context of use. This enhancing relation is meant to express vital sign segments which contain the same bio-electrical or physiological phenomena relevant for the medical purpose, but the enhanced segments are considered better conditioned for the medical purpose, for example more efficient for use. As in the case of the similarity relation, this relation needs to contain the specification of the context of use, for example it needs to include the identity of the vital sign enhancing tool or algorithm, the parameter settings, the actor in charge of this enhancement and the actor's comments, for example, to further detail the intended context. In this perspective, the enhanced and the source segments are equivalent in the specified context, that is one may replace the other without influencing the interpretation of the clinical data in the addressed monitoring and treatment context. This enhancing relation originates from the need of the professional stakeholder to provide adequate vital sign units of interpretations.
- **Priority relation:** This relation expresses the inter vital signs degree of importance. It is a means for the mobile healthcare applications to ensure continuity of processing or transfer of vital signs which are considered important for the diagnosis or treatment tasks. In case of severe bandwidth degradation, vital signs which are considered less important may for example be stalled;
- **Aggregation and splitting relations:** these relations express that the related segments of vital signs are aggregated or split, respectively, from the others. As discussed in the previous cases, especially the similarity relation, the aggregated segments are equivalent to the source segments in the sense of the aggregation tool resolution. This equivalence is therefore specified by the aggregation tool and parameter settings. We may apply the same justifications for the splitting relations. However, in the latter relation, we additionally may deal with the downscaling of vital signs, for example to fit the data onto an available transmission channel of a specific quality that otherwise is not able to transfer the vital signs. Although the quality may be reduced, the resulting vital signs are considered useful for the professional; otherwise the downscaling was meaningless, thus not executed. In this context of use, the related vital signs are also considered equivalent. As in the other cases, it is therefore necessary to

Figure 3. Vital sign information model



specify the aggregation or splitting tool, tool settings, the actor in charge of the aggregation and the splitting or the splitting strategy and the actor's comments. The tool that splits vital signs may use the priority of the vital sign discussed earlier to determine the splitting. Aggregation of vital signs, on the other hand, may also be used to concatenate (digitized continuous-time) vital signs which otherwise are located remotely; this improves availability or efficiency of the processing or the vital sign analysis by a professional. These aggregation and splitting relations come mainly from the system provider's requirements analysis and partly from the professional needs.

Concepts of vital signs at abstract syntax level can be expressed by languages like ASN.1 (ASN.1, 2008; MacKinnon, 1990), XML schemas (Malik, 2008) or UML (Booch, 1999). Figure 3 describes the information model of the framework expressed in the Unified Modeling Language (UML) class diagram. A class is symbolized by a rectangular with a class name at the top, attributes in the cell in the middle, and operations at the bottom. In this chapter, we do not detail the operations of a class and only provide those attributes that are relevant to explain the framework. The associations between the classes are represented by the lines between the related classes.

Clinical Data of Patients

Figure 3 shows that patient's clinical data (represented by the UML class PatientClinicalData) is a collection of vital signs data (represented by the abstract class *VitalSignData* explained in the next section). In Figure 3, the set of vital sign data is represented as a (genuine) part of patient's clinical data by the black diamond composition symbol. The clinical data is anonymous, because it is identified by some patient identification number. Via the patient's electronic health record PatientEHR, however, a patient's clinical data can be associated to the patient, but the other way around is not specified (in UML, this unidirectional association is symbolized by the arrow, which arrow-head denotes the navigation direction between the involved classes). The 1 to 1 multiplicity of this association indicates further that patient's clinical data represents the whole collection of measured, processed and stored vital signs of this anonymous patient. Alternatively, one may replace the left value "1" with "1 .. *", which indicates a range of one or more collections of vital signs of the patient identified by patient_id. In the context of this chapter, we assume the availability of one set of clinical data per patient.

Vital Sign Data

As mentioned earlier, the vital sign data is represented by the abstract class *VitalSignData* in Figure 3. The class is a UML abstract class, because the class is only conceptually defined, other (non-abstract) classes will refine (i.e. specialize) this class. In UML, an abstract class can be identified by the class name written in italics. For example, the abstract class *ECG_Data* is a specialization of the abstract class *VitalSignData* (specialization is an "is-a" relation and is symbolized by the open triangular symbol in UML). This abstract class *ECG-Data* may be specialized further for example by the classes DICOMStudy and SCP-ECG_Record. In this chapter, the class DICOMStudy represents ECG data formatted in accordance with the DICOM waveform standard and the class SCP-ECG_Record represents ECG segments formatted in accordance with the CEN/SCP ECG standard. The information model can be further extended with other ECG data formatted in other (de jure, de facto or proprietary) standards.

Vital Sign Relations

Via the abstract class *Equivalency*, Figure 3 also shows that some source vital sign data can be related to some other destination vital sign data. In the figure, the similarity relation discussed earlier is represented by the class Similarity, which is a specialization of the class *Equivalency*. As discussed earlier, the equivalence between vital sign data is defined in a specific contextual setting. In the model, this context for equivalence is specified by the attributes actor_id, which identifies the responsible actor for the relation between the vital sign data, actor_comment, which denotes the comments of the actor, and also the time and date information. As discussed earlier, the context is also defined by the applied tool and its settings, both are represented by the class Tool. An additional design choice is that we define the similarity relation only for vital signs that are encoded in different standardized formats. This constraint is not shown in the figure, however, it can be expressed by a UML note or specified in Object Constraint Language (OCL) (OMG, 2003).

Analogous to the similarity relation, the enhancing relation, which is expressed by the class Enhancing (Figure 3), is a specialization of the class *Equivalency*. In this model, we define an enhancing relation only for vital signs that are formatted in the same standard.

Aggregation and split relations are also specialization of the class *Equivalency*. Aggregation is a many to one relation between vital signs formatted in conformance with the same standard and the other way around, the split relation is a one to many relation.

Derived Vital Signs

Trend signs or, in general, derived vital signs are frequently used in care programs as first indicators of the condition of the patients. Instead of a plethysmogram, care programs like emergency services or COPD programs use the derived oxygen saturation O_2sat (or SpO_2) parameter as a measure for the oxygenation of blood. Heart Rate and Heart Rate Variability are other examples of trend signs, typically derived from one of the ECG leads. In contrast to the similarity and the enhancing relations, we specify derived signs as specializations of the abstract class *ExtractedFeature*, which in turn is specified as a component of the class *VitalSignData* (in UML symbolized by a black diamond (cf. Figure 3)). As the case for equivalence relations, the applied tool, tool setting, actor in charge of the trend data processing and the actor's comments refines *ExtractedFeature* even further. We model trend or derived signs as a component of the original vital signs, rather than modeling them via the equivalence relation, because it better fits to the way vital sign standards deal with derived signs and because of the complexity of the required constraints due to the transitivity of equivalency relations. For example, Heart Rate and Heart Rate Variability are derived signs but they represent different concepts; therefore they are not equivalent. Other features which can be extracted from ECG leads are for instance the high and the low frequency components, including their ratio.

Care Program Dependent Priority of Vital Signs

As discussed earlier, in mobile healthcare, data transfer bandwidth especially from wireless communication channels like GPRS may fluctuate. If available bandwidth drops below the required level, less important vital signs can be stored locally in favor of the transmission of the more important ones. The management modules of the mobile healthcare applications may (semi) automatically decide which type of vital signs to stall and which to transfer or process further if these vital signs are prioritized. Sophisticated prioritizing structures which are care program or clinical task dependent can be developed, but in this chapter we use a simple priority attribute. If necessary, this attribute can be extended with a reference to the professional actor in charge of prioritizing vital signs for the care program.

We specify the attribute priority in the abstract class *VitalSignData* to enable priority based selection at the level of the types of vital signs rather than at a more detailed level, for example at the level of digitized vital sign samples. This choice has the additional benefit that vital sign sets formatted in a specific standard can be treated as a black box; an approach which intends to preserve the structures defined in standards as atomic units. This could be necessary in case of handling vital signs formatted in proprietary standards whose internal structures are unknown to the application developers of the mobile healthcare system provider stakeholder. In this kind of cases, third party tools that have knowledge of these structures are needed to enable processing, rendering or conversion of the vital sign sets. This black-box approach is for example supported by MIME via the "-x" constructs.

In case of multi-valued or multi-channeled vital signs (e.g. the leads of ECGs) or in case of (multiple) trend signs, the earlier mentioned priority attribute can be refined further to priority of these values, channels or trends (e.g. represented by the attribute t_priority in the class *TrendSign*). Consequently, these intra vital sign priorities depend on the attribute priority of the class *VitalSignData*. This dependency is represented by the dashed arrow in Figure 3.

Table 1. CEN/SCP-ECG sections

Section No.	Title	Description
0	Pointer	the sections and their locations in the data set record
1	Header Information	patient and acquisition related information
2	Huffman tables	the Huffman compression tables
3	ECG lead definition	the leads, the sample numbers and their relativity to a reference beat (cf. Section 4)
4	QRS location and Reference beat	the location of the QRS complexes and the position of the reference beat
5	Reference beat encodings	parameters like encoding flag, sample distance, gain.
6	Rhythm data	the ECG data
7	Global measurements	info pacemaker spikes and QRS complexes like the P-, QRS-, T- on-/offsets, QT intervals
8	Interpretive statements	text based (diagnostic) annotations
9	Manufacture specific statements	manufacturer specific diagnostic annotations
10	Lead measurement	leads information and fields reserved for manufacturer data
11	Universal ECG interpretive statements	universal statement codes (cf. SCP-ECG standard) and most recent annotations which have to be consistent with annotations in other sections

ECG STANDARDS

Several de-jure, proprietary and de-facto format and encoding standards are suitable for ECGs, amongst others CEN/SCP-ECG, DICOM waveform, ecgML, FDA-ECG, HL7 and VITAL. We express some of them in UML class diagrams to illustrate the use of the information model of the framework. It is not in the scope of this chapter to provide a complete list of ECG standards neither to provide detailed UML class diagrams of all these standards.

CEN SCP-ECG STANDARD

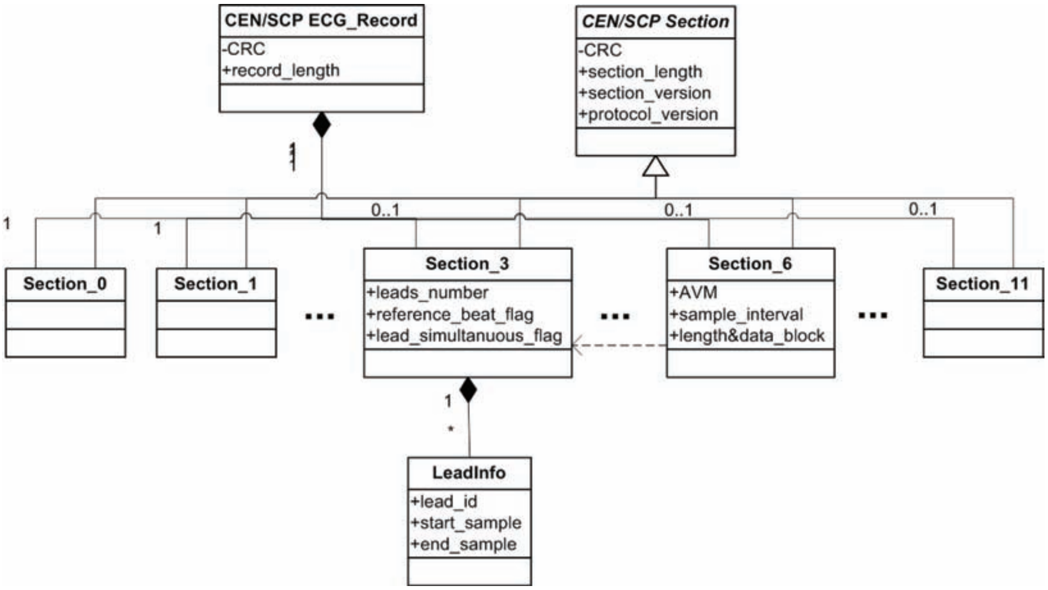
The Standard Communication Protocol for computer-assisted Electrocardiography (SCP-ECG) is a standard developed by CEN/Technical Committee (TC) 251 (CEN/TC251, 2007). Besides ECG data, SCP-ECG additionally defines ECG related data to enable the specification of patient's demographic data, the measurement settings, the performed signal processing on the ECG data, the compression and manufacturer specific information.

In SCP-ECG, the entire ECG data set is called a record. A record is further decomposed into "section" parts (indicated with section numbers from 0 to 11), each of which carrying a specific aspect like patient (demographic) information, compression tables, the ECG lead definitions, the ECG lead data, the reference ECG beat(s) of the leads, including the physiological complexes like QRS, and also interpretive annotations.

Eleven types of sections are defined in SCP-ECG. Table 1 presents the eleven sections and a brief description. Some sections are mandatory (e.g. Section 0 or Section 1), others are optional (e.g. Section 11). Sections have a common header structure, in the figure represented by the generalized class CEN/SCP Section. A high level SCP-ECG structure, expressed in a UML class diagram, is given in Figure 4.

Section_6 contains a black-box of ECG data. To render the individual ECG leads from Section_6, attributes of Section_3, which represent the metadata specifying the number of leads and

Figure 4. CEN/SCP-ECG model



the leads description, have to be accessed first. This dependency of Section_6 from Section_3 is represented in UML by the dashed arrow between these two classes.

DICOM ECG WAVEFORM SUPPLEMENT

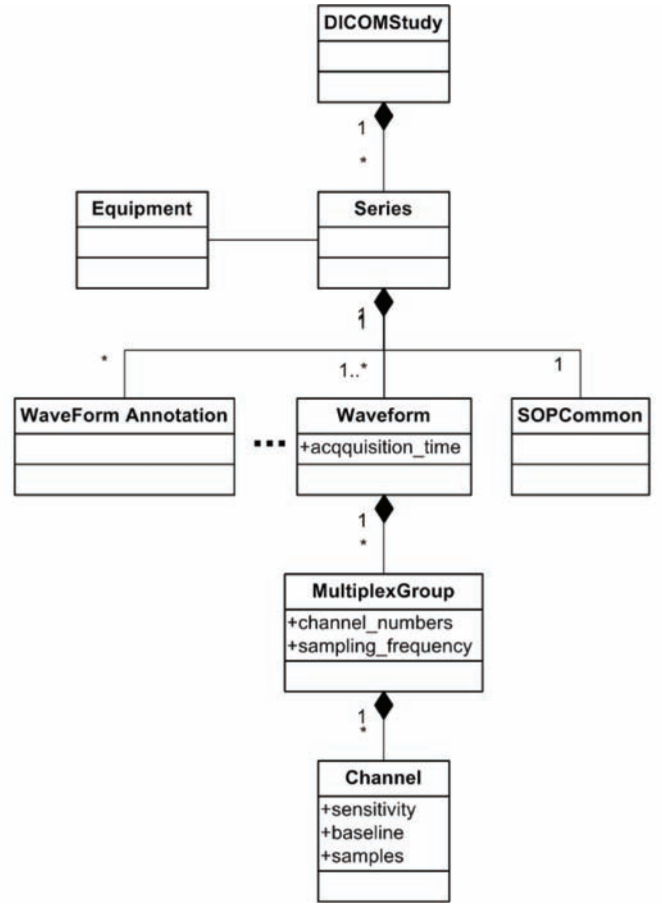
DICOM (Digital Imaging and Communications in Medicine) standards (NEMA, 2007a) are developed by a joint committee of the American College of Radiology (ACR) and the National Electrical Manufacturers Association (NEMA), often in liaison with other organisations like CEN TC251, JIRA in Japan, IEEE and the American National Standards Institute (ANSI). Although the DICOM organisation originally addresses imaging standards, it also developed a standard to exchange waveforms. This latter is therefore suitable for ECGs.

DICOM uses an object based model, therefore not only specifying the structure of the medical data content as information objects, but also the operations on the data (i.e. services). The functional units in DICOM define the classes of the information objects and the corresponding services, the so-called Service-Object Pair classes (SOP classes). One of the SOP classes is for instance meant for a waveform store.

In DICOM, a waveform information object is decomposed into information entities, each of which stored in data modules. Examples of information entities are patient, (clinical or patient) study, clinical data series within a study, equipment which creates the series, and waveforms as part of the series.

Figure 5 presents a simplified UML model of DICOM's waveform related information entities. The figure reflects the clinical procedure by using terms like studies (class DICOMStudy) and series of clinical data (class Series). Although not shown in the figure, these terms include the specification of the responsible professional, the clinical protocols, the waveform identifications (incl. the acquisition time), the annotations, the waveform data (which may be multiplexed bio signals, therefore also includes the multiplexing parameters, the sampling rate, etc.) and also the corresponding equipment used to generate the

Figure 5. DICOM waveform model



data. That is, the class Waveform may contain several multiplexed vital sign channels (represented by the classes MultiplexGroup and Channel in Figure 5)

FDA ECG SPECIFICATION

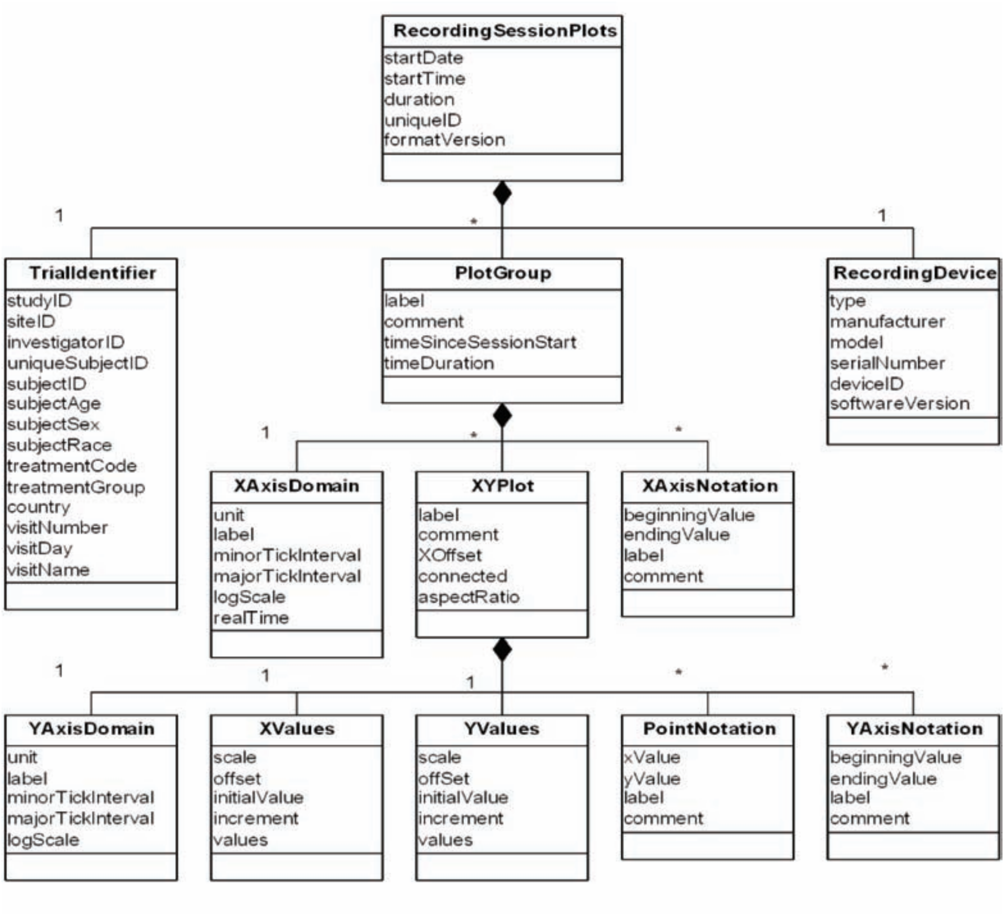
As observed in the previous section, the DICOM waveform standard is to some extent based on clinical procedures and accordingly the data is represented in terms of studies, the FDA format for waveforms (Browns, 2002) is based on the 2D property of sampled waveforms; it emphasizes the viewing representation of waveforms.

Figure 6 shows the FDA waveform information model. As in the earlier discussed standards, the FDA model also provides manufacturer information, patient (/subject) identification, and annotations. In the figure, the class PlotGroup models an ECG data set and aggregates data of the class XYPlot, each of which representing a piece of ECG data of a particular lead.

FRAMEWORK IMPLEMENTATION ASPECTS

In this section, we discuss some of the implementation aspects that illustrate the use and the benefit

Figure 6. FDA Waveform model

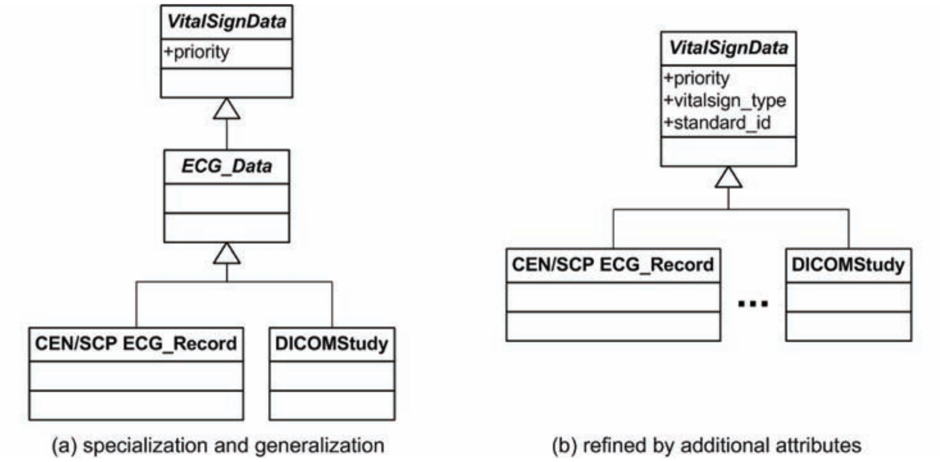


of the framework. First we discuss refinements of the information models presented earlier. These refinements enable the translation and serialization of the abstract syntax to the transfer syntax.

Refinement of the Specialization Constructs

In the earlier discussed information models, we apply the object oriented specialization construct, for example, to distinguish between vital signs that are formatted in accordance with different standards. This specialization can be refined by additional discriminating attributes, for example, an attribute identifying the vital sign type (i.e. vitalsign_type in Figure 7b) and an attribute identifying the format and encoding standard (i.e. standard_id in Figure 7b). The advantage of this refinement is that the encoded attributes in the transfer syntax can be used as header fields in the transfer syntax, for example to indicate that the subsequent payload block of data contains vital sign data formatted in the transfer syntax of the identified standard. This code enables (de-)multiplexing of serialized pieces of vital signs, for example necessary for a 24/7 continuous monitoring of patients. Together with the attribute priority (Figure 7), these discriminating attributes can be used to split a vital sign set, for example necessary in case of severe bandwidth degradation along the healthcare delivery path. This (de-)multiplexing technique is proven useful in multimedia communication using MPEG, which

Figure 7. Refinement with discriminating attributes



(a) specialization and generalization (b) refined by additional attributes

analogously applies process identifiers to join or remove language channels and to merge and split television program channels on the fly.

Refinement of Many to Many Relations

The information model can cope with one to many or many to many associations between sets of vital sign data, for example the similarity between a source set of ECG data formatted in CEN/SCP-ECG and destination data sets formatted in FDA-ECG and in DICOM waveform standard. In this case, a cardiologist may want to visualize both FDA and DICOM sets simultaneously in case that the CEN/SCP-ECG data set is not available on the premises or a rendering tool for the latter format is not available either.

As discussed earlier, the MIME type and subtype construct informs applications which tools to use and how tools should render the data. For example, in e-mail applications, the MIME value "multipart/parallel" indicates that the aggregated data sets have to be visualized simultaneously.

Similar to MIME, we can refine the equivalency class with additional attributes that specify which vital sign sets need to be rendered simultaneously.

Abstract and Transfer Syntax Notations

Other languages are available to express concepts at abstract syntax level, for example XML Schema and ASN.1. Using XML tools a character-based XML document can be derived that contains the vital sign data specified in accordance with the XML Schema. This document can then be serialized by reading it from left to right and from top to bottom, yielding a sequence of characters (transfer syntax) suitable for transfer using internet protocols. Tools are also available to visualize XML Schemas as XML Schema diagrams. However, tool based development kits are also available to develop XML Schemas from UML (Malik, 2008).

Abstract Syntax Notation One (ASN.1) is defined by the International Organization for Standardization ISO (ISO 8824, 1994). It is a notation for specifying data at abstract syntax level. Associated with ASN.1 are encoding rules for generating binary transfer syntaxes from the abstract syntax (ISO 8825, 1994). ASN.1 and its encoding rules provide compact transfer syntax code.

A joint committee of ISO and International Telecommunication Union (ITU-T) has produced several standards on the mapping of XML Schema to ASN.1 and vice versa. A web accessible on-line tool which translates XML Schemas to ASN.1 is for example available (ASN.1, 2008). A framework that accommodates the collection of the previously described tools provides a development environment that enables the translation of vital signs specified via UML class diagrams to concise binary transfer syntax code.

CONCLUSION

We propose a framework for flexible and modular processing, storing and transferring (segments of) medical information in a mobile, distributed and heterogeneous environment. The framework adopts an ICT information representation model, which separates the concerns of information transfer and store from the concerns of expressing, converting, splitting, synchronizing and joining information. The abstract syntax level methods, techniques and mechanisms, which address the latter mentioned concerns, provide the necessary support for processing medical information in an environment that contains multiple standards for data format and encoding. On the other hand, the transfer and local syntax level methods, techniques and tools, associated to the first mentioned concerns, enable transfer and store of medical information in an efficient and dependable way. The framework, which also contains the vital sign information model discussed in this chapter, therefore supports the exchange of medical information in a meaning preserving way despite the use of different format and encoding standards and the fluctuations of the property of the end to end data transfer connections.

This chapter discusses the framework at conceptual level. It provides a generic approach to deal with multiple formats and fluctuating properties of connections. This approach is considered useful for healthcare delivery in which patients are mobile and self managing. It is expected useful for new clinical pathways for mobile and distributed healthcare delivery that involves collaborating actors of different medical specialty, possibly acting in new roles and each of them needing medical information that are represented in accordance with the (new) working practices of their specialty.

The proposed framework, which amongst others is an integrative conceptual structure that binds methods, techniques and mechanisms for interoperability of different format and encodings of medical information, needs to be supplemented further with other ECG and vital sign standards. That is, the framework needs to be populated by relevant format and encoding standards. Consequently, the information model described in this chapter needs to be refined further, for example, to provide tool developers the necessary hooks (e.g. class attributes, object methods and dependency relations) to design medical information conversion, splitting and joining tools. Such refinements not only require details of the format and encoding standards which populate the framework but may also need abstract syntax level knowledge of the ontology of the corresponding bio physiological or bio electrical phenomena, for example, to specify in details the transitivity constraints of the similarity relation.

Another topic for future work is for example the specification of guidelines or rules to up- or down-scale digitized continuous-time vital signs in transfer automatically to match to the fluctuations of the properties of the end to end connections within the tolerance specified by care programs or professionals. These guidelines supplement the framework further and improve its use for mobile healthcare delivery in a heterogeneous environment.

ACKNOWLEDGMENT

The authors thank Bayu Erfianto, who did his MSc project on XML and ASN.1 based representations of ECGs. His project and results have been a starting point for our continued research in this area.

This work is part of the Freeband AWARENESS project (http://awareness.freeband.nl). Freeband is sponsored by the Dutch government under contract BSIK 03025.

REFERENCES

ASN. 1 Information site. (2008).

Blair, G., & Stefani, J.-B. (1998). *Open Distributed Processing and Multimedia*. Addison-Wesley.

Booch, G., Rumbaugh, J., & Jacobson, I. (1999). *The Unified Modeling Language: User Guide*. Addison-Wesley.

Bray, T., et al. (2004). *Extensible Markup Language (XML) 1.0*. 3rd edition.

Browns, B., Kohls, M., & Stockbridge, N. (2002), *FDA XML data format design specification*. Draft of the US Food and Drug Administration.

CEN/TC251. (2007). *CEN website*.

CEN/TC251 prEN 1064 (2002). *Health Informatics – Standard Communication Protocol – Computer-assisted Electrocardiography*. CEN/TC251 prEN 1064.

Concalves, B., Guizzardi, G., & Pereira Filho, J. G. (2007). An Electrocardiogram (ECG) Domain Ontology. In *Proceedings of the Second Brazilian Workshop on Ontologies and Metamodels for Software and Data Engineering (WOMSDE'07)*. 22nd Brazilian Symposium on Databases (SBBD)/21st Brazilian Symposium on Software Engineering (SBES). João Pessoa, Brazil.

Freed, N., & Borenstein, N. (1996). *Multipurpose Internet Mail Extensions (MIME) Part One: Format of Internet Message Bodies*. IETF RFC 2045.

HealthService24 project eTEN-C517352 (2005). EC eTEN Programme.

Hinchley, A. (2005). *Understanding Version 3, A primer on the HL7 Version 3 Communication Standard*. Munich: Alexander Mönch Publishing.

ISO 8824 (1994). Information Processing System – Open Systems Interconnection – *Abstract Syntax Notation 1 Specification*. ISO/IEC JTC1/SC21.

ISO 8825 (1994). Information Processing System – Open Systems Interconnection – *Basic Encoding Rules for Abstract Syntax Notation 1 (ASN.1)*. ISO/IEC JTC1/SC21.

Le Gall, D. (1991). MPEG: A Video Compression Standard for Multimedia Applications. *Communications of the ACM*, *4*(34).

MacKinnon, D., McCrum, W., & Sheppard, D. (1990). *An Introduction to Open Systems Interconnection*. New York: Computer Science Press.

Malik, A. (2008). *Design XML schemas using UML*.

Mei, H., Widya, I., van Halteren, A., & Erfianto, B. (2006). A Flexible Vital Sign Representation Framework for Mobile Healthcare. *1st International Conference on Pervasive Computing Technologies for Healthcare 2006*. Nov. 29th – Dec 1st, 2006. Innsbruck, Austria.

MobiHealth project IST-2001-36006 (2002). *EC programme IST*.

Myotel (2008). Myofeedback based Teletreatment Service Project. *EU programme eTEN – 046230*.

NEMA. (2007a). *Digital Imaging and Communications in Medicine (DICOM), Part 1: Introduction and Overview*. Virginia: NEMA.

NEMA. (2007b). *Digital Imaging and Communications in Medicine (DICOM), Part 3: Information Object Definitions*. Virginia: NEMA. OMG ptc/03-10-14 (2003). *UML 2.0 OCL Specification.* OMG Adopted Specification (ptc/03-10-14).

Schiller, J. (2003). *Mobile Communications*. Addison-Wesley.

Wang, H., Jung, B., Anuaje, F., & Black, N. (2003). ecgML: Tools and Technologies for multimedia ECG Presentations. *Proceedings of XML Europe Conference*. London.

Weigand, C. (2005). VITAL: Use and Implementation of a Medical Communication Standard in Practice. *Computers in Cardiology*, *32*, 319–322. doi:10.1109/CIC.2005.1588101

Wootton, R., Craig, J., & Patterson, V. (Eds.). (2006). *Introduction to Telemedicine.* 2nd edition. London: Royal Society of Medicine Press Ltd.

This work was previously published in Mobile Health Solutions for Biomedical Applications, edited by P. Olla; J. Tan, pp. 71-91, copyright 2009 by Medical Information Science Reference (an imprint of IGI Global).

Chapter 2.5

Interpreting Health and Wellness Information

Lena Mamykina
GVU Center, Georgia Institute of Technology, USA

Elizabeth D. Mynatt
GVU Center, Georgia Institute of Technology, USA

ABSTRACT

In the last decade, novel sensing technologies enabled development of applications that help individuals with chronic diseases monitor their health and activities. These applications can generate large volumes of data that need to be processed and analyzed. At the same time, many of these applications are designed for non-professional use by individuals of advanced age and low educational level. These users may find the data collected by the applications challenging and overwhelming, rather than helpful, and may require additional assistance in interpreting it. In this chapter, we discuss two different approaches to designing computing applications that not only collect the relevant health and wellness data but also find creative ways to engage individuals in the analysis and assist with interpretation of the data. These approaches include visualization of data using simple real world imagery and metaphors, and social scaffolding mechanisms that help novices learn by observing and imitating experts. We present example applications that utilize both of these approaches and discuss their relative strengths and limitations.

INTRODUCTION

Rapid developments in the sensing technologies lead to the introduction of sensors and object auto-identification in new areas of human life and activities. One such area that became a topic of extensive research is healthcare. In the healthcare domain, auto-identification takes a form of health and wellness monitoring and applies not only to objects, but also, and even more commonly, to activities, and to bio-indicators of individuals' health. For example, new sensing techniques attempt to determine individuals' diets by audio recording chewing sounds (Amft et al, 2006); individuals' interactions with RFID-tagged objects is used to infer the activities they engage in (Intille, 2003), and various sensors are designed to monitor new

DOI: 10.4018/978-1-60566-298-5.ch005

and traditional vital signs, such as heart rate, blood glucose, or gate.

Oftentimes, introduction of these new sensing techniques can lead to an exponential growth of the volumes of data available for interpreting. At the same time, many of the monitoring applications that utilize such sensors are designed in context of chronic disease management and are meant to be used by lay individuals and their non-clinical caregivers. As a result, the attention of researchers is starting to shift from sensing technologies to ways to incorporate these data into individuals' sensemaking and decision-making regarding their health and disease. After all, the richness of the captured data is of little value unless it can inform decisions and empower choices.

In this chapter we discuss two distinct approaches to enhancing the utility of auto-identification data for lay individuals, discuss recent research projects that utilize these approaches and compare and contrast their advantages and disadvantages. The two approaches we focus on are: 1) introduction of novel data presentation techniques that facilitate comprehension and analysis of the captured data and 2) incorporation of social scaffolding that helps individuals acquire skills necessary for data analysis by learning from experts.

We will begin our discussion by introducing three applications that utilize novel visualization techniques to represent health-related information captured by sensors. These applications include Digital Family Portrait (later referred to as DFP, Mynatt et at, 2000) designed by the Graphics, Visualization and Usability Center of the Georgia Institute of Technology, Fish 'n' Steps (Lin et at, 2006) designed by Siemens Corporate Research, Inc. and UbiFit Garden (Consolvo et at, 2007) designed by Intel Research, Inc. All of these applications use sensors to collect health or wellness data and rely on a particular approach to visualizing the resulting data set, namely they use metaphors of real world events or objects to assist in comprehension.

An alternative approach to facilitating analysis of health data captured by ubiquitous computing applications is by providing social scaffolding mechanisms. One example of such applications is Mobile Access to Health Information (MAHI, Mamykina et al, 2006) designed and developed by the Georgia Institute of Technology and Siemens Corporate Research, Inc. In contrast to DFP, Fish'n'Steps, or UbiFit Garden, MAHI uses relatively simple data presentation techniques. However, it includes a number of features that allow diabetes educators help individuals with diabetes acquire and develop skills necessary for reflective analysis of the captured data.

Evaluation studies of the applications we describe here showed that all of them were successful in reaching their respective design goals and led to positive changes in behaviors or attitudes of their users. While these studies did not specifically focus on data comprehension, such comprehension was the necessary first step in achieving these positive results. In addition, our own experiments comparing different types of visualizations showed that not all of them are equally effective. However, we believe that novel visualizations and social scaffolding have their unique advantages and disadvantages that need to be considered when making a choice as to which strategy to follow. In the rest of this chapter we describe the applications mentioned above in greater detail and talk about the results of their deployment studies. We then describe our attempts to evaluate the effectiveness of different types of data visualization. We conclude with the analysis of comparative advantages and limitations of the two approaches.

VISUALIZING HEALTH INFORMATION

As the world's elderly population increases in numbers, chronic diseases common to older adults stretch the capacity of traditional healthcare. As a result, aging adults and other individuals affected by chronic diseases must take an increasingly proactive stance towards personal healthcare, adopting roles and responsibilities previously fulfilled by professionals. One such responsibility is the monitoring of longitudinal medical records for patterns that may indicate important changes in conditions or that may signal an impending crisis.

Shifting medical monitoring activities to lay individuals is not without consequence. According to a recent report of the Committee on Health Literacy (Nielsen-Bohlman et al, editors, 2004), "nearly half of all American adults ─ 90 million people ─ have difficulty understanding and acting upon health information." Often at issue are the methods with which this health information is visually represented. Traditional techniques represent data using graphs, charts, or tables, all of which can pose impassable barriers to individuals of advanced age or lower socio-economic status and education. However, these individuals have the highest risk of developing chronic diseases, and thus the greatest need to be meaningfully engaged in self-care.

The problem of assisting individuals in comprehending complex and extensive datasets is at the heart of the field of Information Visualization. Building upon a set of principles first developed in the late eighteenth century, modern day visualizations range from common graphs and bar charts to space-time narratives and data maps (Tafte, 1999). Common to these methods is the notion of abstractly representing data so that large quantities of information can be depicted and compared in a condensed space. However, whereas these visualizations may be suitable for educated users, some researchers question their appropriateness for individuals of advanced age and lower education and seek alternative visualization techniques.

People rely on a number of methods when faced with the need to understand complex phenomena. One such method is the use of metaphors, whereby a complex concept is related to a simpler situation exhibiting similar properties. Metaphors permeate modern languages and deeply impact human cognition, lay as well as scientific (Lakoff and Johnson, 1981). Within the world of computer interfaces, metaphors can be found at the core of graphic user interfaces; the ubiquitous "desktop" metaphor is familiar to millions of computer users. Lately, metaphors served as an inspiration to a number of applications that visualize health related information for lay individuals that we discuss below.

Metaphor-Based Visualizations

Throughout history, analogies with real world objects and situations have served as powerful inspiration for visual communication. For example, maps have been grounded in real-world geographic analogies for over a thousand years, making them one of the most persistent and ubiquitous forms of analogical, pictorial communication in the Western world.

In the eighteenth century, Lambert and Playfair, among others, popularized new forms of graphical representation: statistical charts used for communicating economical and political data (Tafte, 1981). The techniques they pioneered later developed into plots, which utilize Cartesian coordinates, time-series, or relational graphics. Whereas previous data visualizations relied heavily on real-world analogies, these new charts required one to learn mappings between particular visual properties (such as position, color, shape or size), and the information represented by these encodings.

Computing technologies naturally lend themselves to relational visualizations because they make it easy to decouple data from representation. In fact, much of the power of computer-based visualizations lies in their ability to produce abstract, high density, relational visualizations efficiently for a wide range of data sets. However, these techniques require a certain level of abstract thinking and appreciation of basic mathematical concepts (Tversky et al, 1991).

While relational visualizations permeate computer-based Information Visualization, there exist alternatives, more commonly explored within the fields of ambient or peripheral displays. For example, InfoCanvas (Stasko et al., 2004) visualizations utilize real world imagery to map information but allow users to create arbitrary mappings. Further departing from the relational tradition, visualizations such as People Garden (Xiong and Donath, 1999), or the Presence Display (Huang and Mynatt, 2003) relay information, such as the flow of conversations or individuals' presence in the office, by using metaphors that compare the information with familiar real world situations.

Metaphors allow individuals to understand one set of experiences in terms of another through a relation of the form "A is B," where B is said to be the source of the metaphor and A is the target. Common examples of metaphors include "time is money," or "life is a journey." According to Lakoff and Johnson (Lakoff and Johnson, 1981), human thought processes are largely, although implicitly, metaphorical. Through the use of metaphors, complex or abstract concepts, such as emotions or thought processes, become more accessible through their relation to concrete objects and situations. Visual metaphors are means to visually represent a linguistic metaphor. One of the most familiar examples of visual metaphors, or metaphor-based data visualizations, is a genealogical tree, which represents a history of a family as a tree with each branch depicting a particular "branch" of the family. The roots of this visualization can be traced to "life is a tree" metaphor common in many languages (Lakoff and Johnson, 1981)

Although there exist examples of symbolic or metaphorical visualizations in User Interfaces, they are rarely seen as superior to relational alternatives in facilitating analysis and comprehension. Instead, they are often valued for aesthetic properties or their ability to blend into the surrounding environment. At the same time, the historical importance of metaphors suggests they may possess particular strengths for audiences or situations which are lacking skills necessary for interpreting relational graphics.

Recently, however, there emerged a number of applications that utilize real-world imagery to convey health and wellness related information to lay individuals. These applications came from different research organizations and were designed by different research teams, perhaps without explicitly targeting usage of metaphors as an inspiration for the design. However, the conceptual similarity in the approaches adopted by these applications is intriguing, and positive results of the deployment studies described by the researchers recommend metaphor-based visualizations as a promising approach for health monitoring applications. We discuss several such applications: Digital Family Portrait by the Georgia Institute of Technology (Mynatt et al, 2001), Fish 'n' Steps by Siemens Corporate Research (Lin et al., 2006) and UbiFit Garden by Intel Research (Consolvo et al., 2008). These applications represent only a limited selection, however we believe together they form a relatively representative sample of this new class of software designed for health and wellness monitoring.

Digital Family Portrait

Digital Family Portrait (DFP, Mynatt et al., 2000) is a pioneering application designed by researchers at the Graphics, Visualization and Usability center of the Georgia Institute of Technology that helps adult children remain connected with their aging parents living remotely. DFP is inspired by the observation that many decisions to transition to assisted care facilities are initiated by adult children who want to ensure wellbeing of their parents. In modern times, when children and parents rarely live together and are often separated by hundreds of miles, they lack the usual lightweight indicators of each other's daily activities. For example seeing

Figure 1. Digital Family Portrait. The picture of the aging parent is surrounded by a digital frame with icons indicating the amount of activity in the parent's house in the last 14 days. Each butterfly represents a day of activity (the current day is indicated with a lighter background color); the size of the butterflies shows the amount of activity captured with motion detection sensors

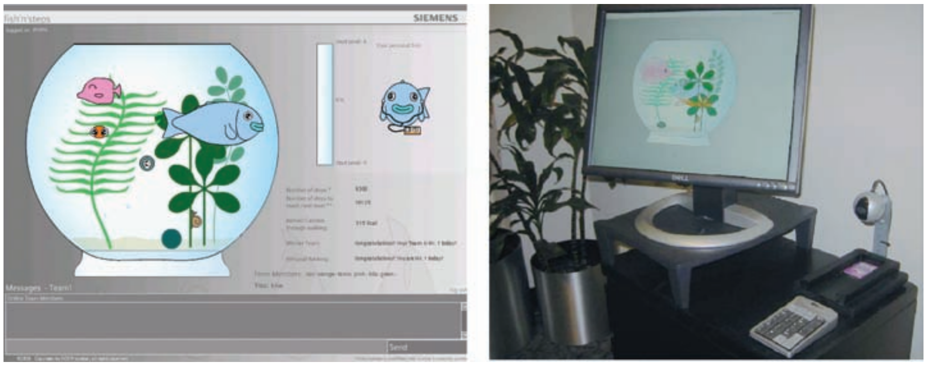
that mom picked up the newspaper in the morning or the light in the kitchen window around dinner time might be sufficient to conclude that things are in order if you live in a house next door. DFP uses modern sensing technology to recreate the feeling of collocation without undue intrusion on the privacy of the aging parents. A number of motion detection sensors placed around the parent's house capture a rough picture of daily activities. The design of the display further supports the notion of lightweight unobtrusive awareness: a digital frame of a parent's picture is enhanced with icons indicating the general amount of activity in the parent's house. The choice of icons includes butterflies, trees, or other simple and aesthetically pleasing images; each icon represents one day, and its size represents the amount of activity (Figure 1). Thus, while each icon taken by itself is not sufficiently informative, together they form a pattern and allow the users to notice changes in the amount of activity overtime.

DFP was deployed with one family for an extended period of over a year. It is easy to imagine that the volume of sensory data collected during this time could be quite overwhelming and difficult to interpret. However, the simple, yet articulate visualization made it easy for both users to cope with the data volume and extract useful aggregated information. During the time of the study, both the parent, Helen, and the child, Will, participating in the study learned to rely on the display for awareness. Helen volunteered that because of the display she felt less lonely, knowing that Will is looking over her. Will found several creative ways for using the display, such as anticipating Helen's return from travel, or inferring when she was out doing errands. While the more detailed and more typical visualization of Helen's movements around the house could provide more detailed information, simple butterflies contributed to the desired piece of mind and sense of awareness.

Fish 'n' Steps

Fish'n'Steps designed by Siemens Corporate Research, Inc. (Lin et al., 2006), is an application that combines ubiquity and simplicity of pedometers, wearable devices that measure one's

Figure 2. Fish'n'Steps. One participant's display after approximately two weeks into the trial in the Fish'n'Steps team-condition, also the public kiosk and pedometer platform, which rotated through each of the team fish-tanks. The components of the personal display include: 1) Fish Tank - The fish tank contains the virtual pets belonging to the participant and his/her team members, 2) Virtual Pet – The participant's own fish in a frontal view on the right side next to the fish tank, 3) Calculations and feedback - improvement, burned calories, progress bar, personal and team ranking, etc., 4) Chat window for communicating with team members



step counts, with the engagement of social computing games. Individuals enrolled in the game use pedometers to measure their daily step count. Fish'n'Steps then links the number of steps taken each day to the growth and emotional state of a virtual pet "belonging" to each individual: a fish in a fish-tank. Additional incentives incorporate social dynamics, such as competition between teams of players.

"Fish'n'Steps" was built as a distributed software application that included several functioning components as well as some "Wizard of Oz" components. Simple commercially available pedometers, Sportline 330, were used to measure the step count of individual participants. To collect data from pedometers, individuals placed their pedometer on a platform at a public kiosk, and took a picture of their pedometer screen, including the unique pedometer ID. The picture was captured and sent to a member of the research team who entered the appropriate data into a database.

The fourteen-week deployment study with nineteen participants showed that the game served as a catalyst for promoting exercise and for improving game players' attitudes towards physical activity. Furthermore, although most player's enthusiasm in the game decreased after the game's first two weeks, analyzing the results using Prochaska's Transtheoretical Model of Behavioral Change (Grimley et al, 1994), suggested that individuals had, by that time, established new routines that led to healthier patterns of physical activity in their daily lives. Once again, as with DFP, the simple visualization allowed to condense large volumes of data captured with pedometers and present a coherent aggregated picture of users' overall activity levels. Such compelling visual presentation had an additional benefit of creating a resemblance of emotional attachment and motivated a number of users to increase their activity.

UbiFit Garden

Another application that utilizes a similar idea was designed by researchers at Intel Research (Consolvo et al., 2008). UbiFit Garden is a mobile application designed to monitor and encourage physical activity by its users. On-the-body sensing component monitors individuals' physical

Figure 3. UbiFit Garden's Glanceable Display. a) at the beginning of the week; b) after one cardio workout; c) a full garden with variety; and d) a full garden on the background screen of a mobile phone. Butterflies indicate met goals

activity and can reliably differentiate between various types of exercise. The display, designed for a mobile phone, represents levels of activity through flowers in a garden: the number of flowers and types of flowers in the garden indicate amount and variety of different types of exercise. Butterflies above flowers signify achievement of activity goals.

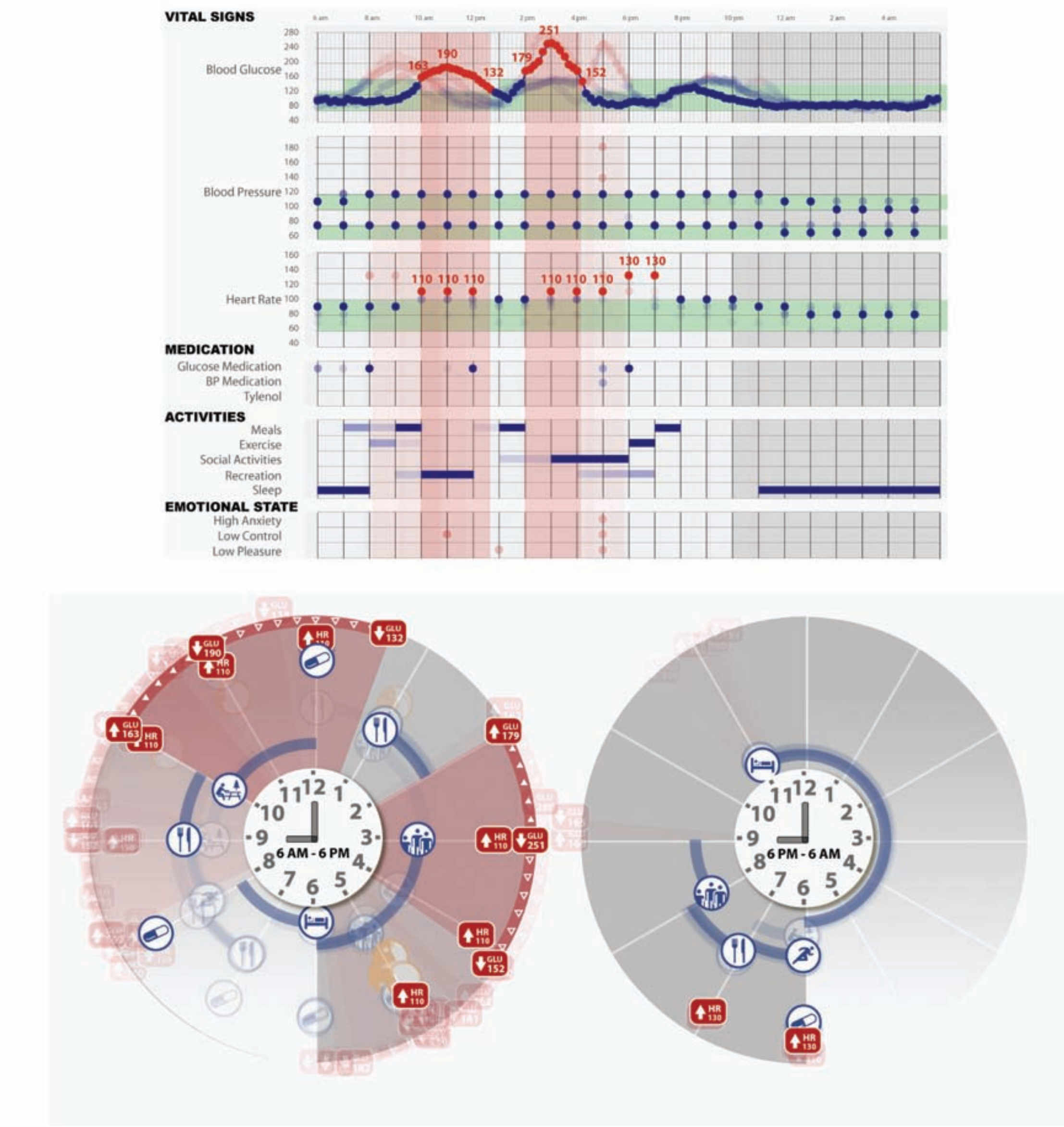
As with the previous two applications, UbiGarden uses simple, familiar imagery to convey specific information in a way consistent with using linguistic metaphors. While the initial deployment studies of UbiFit Garden focused primarily on the activity sensing side of the application, the display received a positive reaction from the users. Once again, large volumes of data were condensed to a simple coherent picture that was informative, aesthetically pleasing, and had an additional capability of inspiring emotional reaction and consequently motivating users.

Evaluating Metaphor-Based Interfaces

The deployment studies of the three applications described above have demonstrated their overall utility for the users. However, they did not specifically focus on the effectiveness of their chosen approach to visualizing the data through the use of metaphors. More generally, while there exist many examples of studies examining relative benefits of different visualizations, to the best of our knowledge none of them focuses specifically on visualizations that use metaphors. To address this limitation we conducted two small pilot studies that examined these questions. In these studies we specifically focused on data comprehension with different visualization types measured by an individuals' ability to answer pointed questions regarding the depicted data using the classic criteria of comprehension such as error rate and time required to answer the questions.

In the first of the studies we designed two visualizations to present diabetes-related data usually targeted by diabetes monitoring applications, such as records of blood sugar values and records

Figure 4. Comparing Relational and Metaphorical Visualizations. Both visualizations (top and bottom) show a day worth of activity records and health indicators (emotional state, blood glucose values, etc.) The visualization on top utilizes more traditional, relational techniques, such using coordinate systems. The visualization below uses a metaphor of a clock to show temporality of the data and uses icons to signify different activities



of daily activities. The first visualization used a more traditional, relational approach (Figure 4, top image); the second visualization used a number of metaphors to represent temporal aspect of the records, and for the design of the icons (Figure 4, bottom image). In a controlled experimental setting the participants were exposed to both visualizations for a limited amount of time and asked to answer a series of questions regarding the data.

Thirty-five participants were paid $125 to participate in a two-hour experimental session. Participants with diabetes were recruited from two age groups, younger adults (17 participants, mean age 36.24 years, range 25-40) and older adults (eighteen participants, mean age 69.18 years, range 60-75). Each participant had been living with diabetes for at least 2 years. Within age groups, our goal was to have individuals who differed in their ability to interpret graphs and data trends. Accordingly, one group consisted of high school graduates with little formal statistical knowledge, and no specialized experience in interpreting data trends or graphs. Another group consisted of individuals with Bachelors or Masters Degree, and some formal statistical training, with the expectation that they would be more capable of using graphs and extracting data from them. To further evaluate their ability to interpret traditional graphical presentations and validate our sampling methods, each participant was given a test taken from the graph understating portion of the Graduate Record Examination (GRE) (ETS, 2004). Participants were split into high (2-4 correct answers) and low (0-2 correct answers) Graphical Facility (GF). This produced an approximate median split, with 16 low and 19 high GF participants. Sex was not a variable of interest, but each group was approximately gender-balanced. We expected that age and Graphical Facility would influence the subjects' success with different visualizations, with subjects of younger age and higher GF performing better with relational graphics and subjects of older age and lower GF performing better with metaphorical graphics.

As expected, younger adults with higher GF required less time to interpret relational visualizations, whereas older adults with lower GF required less time to interpret metaphorical visualizations, without significant reductions in accuracy. In addition, younger adults with high GF showed strong preference towards the relational interface, though this was a general preference among all participants. The only group that showed slight preference towards metaphorical visualization was older adults with lower GF, although that trend was not significant. Somewhat surprisingly, in addition to age and GF, sex appeared to be an important factor in accuracy of the interpretations; the accuracy of the female participants was significantly higher on the metaphorical visualization. Further research is required to account for this finding.

In the second study, we expanded the scope of our investigations to include four different types of visualizations. The first of them (Bar Chart) utilized the familiar bar chart approach; the second one (Relational Graphic) used colors, shapes and forms but without coordinate systems to code information, the third one (Symbolic) used real world symbols and images to depict information, but the symbols were chosen arbitrarily, without any metaphorical connections, and the last one (Metaphorical) used metaphors to communicate information (see Figure 5 below). To account for the possible design bias some of these visualizations were designed by members of our team and some borrowed from the works of others (Huang and Mynatt 2003, Stasko et al, 2004). Based on our previous findings we specifically focused on individuals of advanced age (above 65) with various levels of education. As in the previous study, we expected that individuals with higher levels of education will perform better with more traditional graphics (Bar Chart and Relational), whereas individuals with lower levels of education will perform better with metaphorical visualizations.

Nine participants were recruited from senior centers to participate in the study. Participants' age ranged from 65 to 85 (mean age 70.8), with the majority of the participants being female (7 out of 9). Six participants completed high school and had some college experience, whereas three did not complete high school. The testing took place at the senior centers, and the participants were compensated $50 for participating in the 1½ hour session.

During the session, participants were presented with visualizations one at a time, with an

Figure 5. Comparing Bar Graphs, Relational, Symbolic and Metaphorical Visualizations. The four images represent different ways to visualize planned meeting attendance. Bar Graph (top left) shows three meetings as three separate bar charts with length of bars corresponding to attendance, non-attendance or no decision. Relational (top right) shows the same three meetings as flowers with colors of petals showing attendance (green), non-attendance (red) or no decision (white). Symbolic (bottom left) shows the same three meetings as three windows in a grocery shop with objects in the window showing attendance (watermelons), non-attendance (flowers) or no decision (apples). Metaphorical shows three meetings using metaphors of coffee tables with cups filled with coffee for attendance, cups turned upside down for non-attendance and empty cups for no decisions

explanation accompanying each visualization on the screen. After reviewing explanations, the participants answered four multiple choice questions about each visualization. The questions required participants to interpret the visualization (e.g., “How many people are planning on attending meeting 1?”); identify overall trends in the data (“There is an overall high attendance of the meetings”); or form an inference (“Meeting 2 seems the most interesting based on the planned attendance”). Participants’ accuracy and time per question were recorded. A subjective rating for ease of questions, ease of visualization, and comparative quality of visualizations was captured via a paper questionnaire after each visualization was presented. Time required for answering each question and the accuracy of the answers were captured by the researchers.

For Accuracy, the results showed a significant main effect of the visualization type across education levels [$F(3, 18) = 13.68$, $p < 0.001$]. Pair-wise comparison showed that metaphorical and symbolic visualizations were comparable with bar-charts, while relational graphics led to significantly less accurate answers [$F(1, 6) = 22.65$, $p < 0.01$]. Further analyses revealed a significant interaction between Visualization Type and Education [$F(3, 18) = 5.36$, $p < 0.01$; the means are presented in Table 1]. For individuals with higher education, metaphorical visualizations led to slightly inferior performance as compared to bar graphs. This trend reversed for those with

Table 1. Results presented in the form of mean accuracy for responses and standard deviations

Higher Education			**Lower Education**	
	Mean	St.D	Mean	St.D
Bar Graph	0.63	0.49	0.56	0.50
Relational	0.28	0.45	0.38	0.49
Symbolic	0.63	0.49	0.40	0.49
Metaphorical	0.56	0.50	0.67	0.48

lower education: These participants performed best with metaphorical visualizations; however, the differences in performance within this group were not significant.

There were no significant effects on response time, perhaps owing to large individual differences between participants.

These findings demonstrate considerable differences for older adults in their comprehension of information visualized in different ways. Although the small sample size of this study prohibits strong claims and conclusions, the trends identified in the experiment deserve further investigation. Across educational levels, relational graphics proved to be the most challenging for the older adults. In addition, education proved to play an important role in helping individuals benefit from traditional forms of presentation, such as bar graphs and relational graphics.

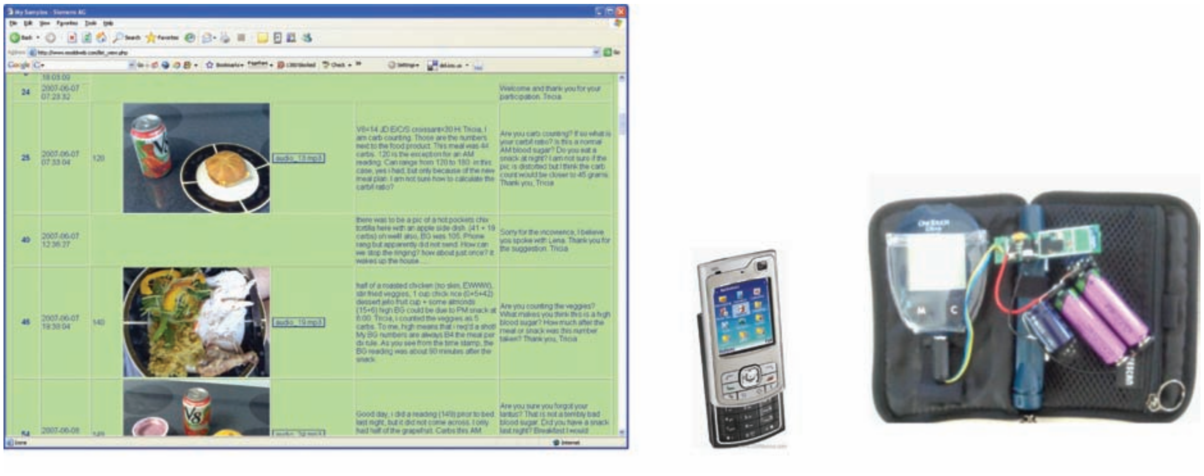
With these two small pilot studies we only scratched the surface of this issue, and uncovered new research questions. For example, in our experiments the participants received a limited exposure to each of the visualizations. Consequently, there remains a question of whether metaphorical visualizations will have similar benefits even after users gained substantial experience with them or their advantages are short-lived. However, even these preliminary results show that at least for individuals of advanced age and lower education metaphorical visualizations are a promising approach to depicting information.

SOCIAL SCAFFOLDING FOR DATA ANALYSIS

The applications we describe above successfully helped their users cope with large volumes of data captured by sensors. However, due to the significant level of data aggregation, these applications may have limited utility in facilitating detailed data analysis. Below we describe a complimentary approach for the design of health monitoring application that focuses not on a particular type of data presentation, but on helping users acquire and develop data analysis skills by observing and imitating experts.

There are a variety of ways people learn and acquire new skills. Some researchers argue that the acquisition of new skills in personal and even professional worlds is different in nature from formal schooling. Observations of a number of professional (butchers, tailors) and non-professional (Alcoholics Anonymous) communities of practice by Lave and Wenger (Lave and Wenger, 1991) led them to conclude that learning in these communities occurs through observation and imitation in a style known as apprenticeship. They argue that knowledge in these communities is preserved by core members or masters, who mastered the necessary skills in the course of their careers. New members join these communities at the periphery, and engage in observation and imitation of the masters, while often performing small and well-defined tasks. With time and acquisition of new skills, novices move from the periphery closer to the center of the community

Figure 6. Components of MAHI: MAHI website (screenshot of the actual site usage). The columns include: 1) record number, 2) date and time of capture, 3) blood glucose value, 4) picture(s), 5) audio, 6) participant's comments posted directly to the website, 7) educator's comments posted directly to the website; MAHI phone; Glucose meter with Bluetooth adapter



until they in turn become masters and keepers of community's practices.

In our work, we adopted the view of learning as a social activity that happens through observation and imitation. We incorporate features that facilitate these activities into the diabetes-monitoring application, MAHI (Mobile Access to Health Information). MAHI was developed in collaboration between the Graphics, Visualization and Usability Center of the Georgia Institute of Technology and Siemens Corporate Research, Inc.

MAHI is a distributed mobile application that includes a conventional blood glucose meter, such as LifeScan's OneTouch Ultra, a Java-enabled cell phone, such as Nokia N80 and a Bluetooth adapter, such as a modified and custom-programmed Brainboxes BL-819 RS232 Bluetooth Converter to support communication between the glucose meter and the phone (see Figure 6). Individuals with diabetes can use MAHI in two modes, as a diary and as an experience sampling tool. As a diary, MAHI allows individuals to capture their diabetes-related experiences, such as records of activities or questions and concerns they may have through voice notes and photographs (using a cell phone camera) taken with a straightforward and easy-to-use user interface. As an experience sampling tool, MAHI initiates recording sessions when individuals use their blood glucose meter. At that time, MAHI establishes a Bluetooth connection between the meter and the phone, allowing the phone to query the meter for the recently captured readings and prompt individuals to record the reasons for using the glucose meter, and the context of usage by capturing voice notes and photographs. The captured records are packaged by MAHI and transferred to a MySQL database hosted on a dedicated web-server.

The last component of MAHI is a web-based application built using PHP that offers access to dynamic, password-protected websites where individuals and their educators can review captured records, and engage in a dialog by providing comments, feedback and additional questions in a message board style.

Deployment Study

The deployment study was conducted in collaboration with the St. Clare's Hospital Diabetes

Education Center in Dover, NJ. The education program includes a number of personalized sessions with certified nurses and certified diabetes educators and registered dieticians to establish personal care goals, and weekly diabetes education classes, in which the students are familiarized with the physiological nature of the disease and different aspects of care. The two recruitment criteria included age (below 65) and experience owning and using a cell phone (over 1 year) to minimize confounds due to cell phone usability.

The research team invited all the newly enrolled students of the center to participate in the study as part of their educational program; 49 new students volunteered to participate. The study used a between-subjects design. Half of the participants (25) were assigned to the experimental group, provided with mobile phones, glucose meters and Bluetooth adapters and were asked to use MAHI during the four weeks of the program. Another half (24) were assigned to a control group and received all of the benefits of the diabetes education but did not use MAHI. General demographics questionnaires conducted prior to the study showed no significant differences between the experimental and the control groups in regards to age, gender, marital status, educational level, or the severity of their general medical condition and their diabetes.

Once the classes started, the individuals in the experimental group were expected to use MAHI independently, with no additional meetings with the research team beyond their attendance of the classes. During the class time, their glucose meters with Bluetooth attachment were collected for battery exchange. At the same time, the individuals were given an opportunity to ask questions, and discuss their experience with the researchers. The researchers attended and audio recorded all the classes that had recruited participants. Once the classes were completed, the individuals were invited for another qualitative interview and reimbursed $30.

Results

As with other applications mentioned earlier in this chapter, the deployment study of MAHI focused on the general utility of the application for individuals with diabetes and its ability to assist them in the management of their disease. We evaluated the impact of MAHI along three different dimensions: individuals' analytical state, or changes in their understanding of their disease, emotional state, or changes in their attitudes towards the disease and changes in their actual behavior. These three factors can help to recreate a comprehensive picture of one's diabetes management. The actual measures for each of these factors were selected together with the personnel of the Diabetes Education Center and included the following:

- **Analytical state:** A multiple choice questionnaire testing basic diabetes understanding developed by the Diabetes Education Center
- **Emotional state:** The two measures used included the standard Health Locus of Control (Wallston et al 1976) and Diabetes Quality of Life (Burrough et al, 2004) questionnaires
- **Behavior:** As part of the educational program, the personnel of the center helped new students to establish their individual management goals, specifically diet goals based on their established habits and desired results. The achievement of these goals was evaluated by the registered dietician during the post-study interview

In addition, we used the Grounded approach Theory (Strauss and Corbin, 1990) to analyze qualitative data, which included qualitative interviews with the participants and online conversations between participants and educators captured in MAHI. The complete findings of this study are described elsewhere (Mamykina et al, 2008). In this chapter we briefly summarize the results that demonstrate the overall effectiveness of MAHI and specifically focus on ways individuals engaged with the application and learned to analyze the data.

The results of quantitative measures indicated that both groups achieved significant improvements along all three anticipated dimensions. In regards to the specific benefits of MAHI, we found that using the application significantly contributed to individuals' improvement along two particular dimensions. These included achievement of personal diet goals, established at the beginning of the study, and acceptance of a more proactive and responsible stance towards diabetes management indicated by adoption of the Internal Locus of Control. Both of these findings are encouraging since they demonstrate that MAHI not only helped individuals meet their diabetes management goals but also helped them change their attitude towards the disease, a good indicator that the behavioral changes achieved during the study will endure overtime (Wooldridge et al, 1990).

These positive results can serve as an indicator that individuals were in fact able to comprehend the data collected by MAHI and draw meaningful conclusions from it. The analysis of online conversations and interviews with the participants gave us some cues as to what influenced individuals' comprehension. As we expected, the educators played a decisive role in helping individuals engage with the applications and learn the necessary analytical skills.

Many online conversations followed a similar pattern. They started with the identification of a specific problem, most commonly a surprisingly high blood glucose value noticed either by the participant or by the educator. After articulating the problem, the educator engaged in the analysis of the possible causes of the problem in individual's behavior by reviewing records captured by MAHI and filling gaps in the data through extensive question and answer exchanges captured on MAHI website. These exchanges played a critical role in illustrating to the participants the expert way of engaging with the data, formulating relevant questions and hypotheses and testing initial conclusions. For many participants these exchanges became the most valuable experiences of the study:

> *Half the time I didn't even answer her questions. But I knew that those were questions for me; this is how I should be thinking. Now I can look at these records and I know what to look for and how to look for it.*

Thus empowered by the expert example, the participants could incorporate the newly learned strategies into their own data analysis techniques and experiment with the new approaches. During this time, the educators observed participants' progress and provided feedback and recommendations until there was sufficient evidence that the participants adopted the new skills and no longer required any scaffolding. This three-step approach including demonstration of the new skills by the expert, internalization of the skills by the student with coaching from the expert and subsequent removal of the scaffolding have striking resemblance with the teaching style that Collins, Brown and Newman named "cognitive apprenticeship" (Collins, Brown and Newman, 1989). Through observing the experts and imitating their techniques the participants were able to master the volumes of data collected by MAHI and learn to draw meaningful conclusions from it.

DISCUSSION

In the last decade novel sensing technologies enabled the development of applications that help individuals with chronic diseases monitor their health and activities. These applications can generate large volumes of data that need to be processed and analyzed. At the same time, many of these applications are designed for non-professional use by individuals of advanced age and/or lower educational levels. These users may find the data collected by the applications challenging and overwhelming, rather than helpful and may require additional assistance in interpreting it.

We discussed two different approaches to designing computing applications that not only collect the relevant health and wellness data but also find creative ways to engage individuals in the analysis and assist with interpretation of the data. These approaches include the visualization of data using simple real world imagery and metaphors, and social scaffolding mechanisms that help novices learn by observing and imitating experts. Both of these approaches have a number of advantages and limitations that we discuss below.

Presentation of data, in particular data captured by health and wellness monitoring applications that use various sensors, has a number of clear benefits, as is demonstrated by the applications we described above. Their interfaces were able to condense large volumes of data inevitable with any monitoring application to a clear and comprehensible picture that was easy to understand by lay individuals, specifically by individuals of advanced age and lower educational level, who may otherwise have difficulties adopting novel technologies. These interfaces are aesthetically pleasing and consequently more appropriate for non-professional environments, such as homes, or for personal mobile devices. In addition, such visualizations as the ones utilized by Fish ‘n’ Steps and UbiFit Garden can inspire emotional response and further reinforce the behavior change they are designed to inspire. Finally, they tend to be intuitive enough to be used without any training and often require only a simple explanation.

With these advantages, however, come a number of limitations. The study of Fish ‘n’ Steps demonstrated that the emotional attachment can have a negative side: some participants limited their participation in the game because they found crying fish too upsetting. The researchers noted that adopting only positive reinforcements and avoiding negative ones might be a safer strategy. In addition, mapping with visual as well as linguistic metaphors is not precise and could be misinterpreted. Finding an appropriate visual metaphor for all and any data might be a serious challenge: all three applications described here focus on wellness and activity data, which might have more direct mappings to metaphors than more abstract clinical data, for example. Finally, because these visualizations help to condense large volumes of data they inevitably lead to data loss and thus may not be appropriate if the goal of the application is detailed data analysis.

Similarly, MAHI demonstrated that social scaffolding mechanisms can be successful in helping individuals engage with the data and learn to independently interpret it. This approach does not lead to any reduction in the data, consequently it can be used with relatively complex data displays that facilitate detailed analysis. It also avoids the necessity to search for metaphors, which may be challenging in cases of abstract data.

At the same time, the clear limitation of this approach is that it requires a significant commitment and time investment from the expert and depends on the personality of the expert. In MAHI studies, the expert providing advice was a member of the research team and was highly motivated to engage the participants, which may not always be the case. However, if further analysis of conversational patterns between experts and participants reveals a certain level of consistency in experts’ approaches, there is hope that the expert’s role can be fully or at least partially substituted by automated agents. Conversational agents in healthcare is already a vibrant and active research area and future research will show whether these agents can play a role in autoidentifaction applications as well.

REFERENCES

Amft, O., Stager, M., Lukowicz, P., & Troster, G. (2006). Analysis of chewing sounds for dietary monitoring. [Springer-Verlag Berlin Heidelberg]. *Pervasive*, *2006*, 56–72.

Burrough, T. E., Desikan, R., Waterman, B. M., Gilin, D., & McGill, J. (2004). Development and validation of the diabetes quality of Life brief clinical inventory. *Diabetes Spectrum.*, *17*(1), 41–49. doi:10.2337/diaspect.17.1.41

Collins, A., Brown, J. S., & Newman, S. E. (1989). Cognitive apprenticeship: Teaching the crafts of reading, writing, and mathematics. In L. B. Resnick (Ed.), *Knowing, learning, and instruction: Essays in honor of Robert Glaser* (pp. 453-494). Hillsdale, NJ: Lawrence Erlbaum Associates.

Consolvo, S., Froehlich, J., Harrison, B., Klasnaja, P., LaMarca, A., Landay, J., et al. (2008). Activity Sensing in the Wild: A Field Trial of UbiFit Garden. *Proc. Of CHI 2008*. Florence, Italy

Cooper, A. (1995).The Myth of Metaphor. *Visual Basic Programmer's Journal*.

Grimley, D., Prochaska, J. O., Velicer, W. F., Vlais, L. M., & DiClemente, C. C. (1994). The transtheoretical model of change. In T.M. Brinthaupt & R.P. Lipka, *Changing the self: Philosophies, techniques, and experiences. SUNY series, studying the self* (p. 201 – 227). Albany, NY: State University of New York Press

Huang, E. M., & Mynatt, E. D. (2003). Semi-public displays for small, co-located groups. In *Proceedings of the ACM Conference on Human Factors in Computing Systems, CHI 2003* (pp. 49-56).

Intille, S. S. (2003). Ubiquitous Computing Technology for Just-in-Time Motivation of Behavior Change (Position Paper). In *Proceedings of the UbiHealth Workshop' 2003*.

Lakoff, G., & Johnson, M. (1981). *Metaphors We Live By*. Chicago: The University of Chicago Press.

Lave, J., & Wenger, E. (1991). *Situated Learning: Legitimate Peripheral Participation.* New York: Cambridge University Press

Lin, J., Mamykina, L., Delajoux, G., Lindtner, S., & Strub, H. (2006). Fish'n'Steps: Encouraging Physical Activity with an Interactive Computer Game, UbiComp'06, Springer-Verlag Berlin Heidelberg

Mamykina, L., Mynatt, E. D., Davidson, P. R., & Greenblatt, D. (2008). MAHI: Investigation of Social Scaffolding for Reflective Thinking in Diabetes Management. In *Proceedings of ACM SIGCHI Conference on Human Factors in Computing, CHI 2008*.

Mamykina, L., Mynatt, E. D., & Kaufman, D. (2006) Investigating Health Management Practices of Individuals with Diabetes. In Nielsen-Bohlman et al (Eds.), *Proceedings of the ACM SIGCHI conference on Human factors in computing systems, CHI'06*, Montreal, Canada

Mynatt, E. D., Rowan, J., Craighill, S., & Jacobs, A. (2001). Digital family portraits: supporting peace of mind for extended family members. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 333-340). Seattle, Washington, United States.

Nielsen-Bohlman, L., Panzer, A. M., & Hindig, D. A. (Eds.). (2004). *Health Literacy: A Prescription to End Confusion*. Washington, D.C.: The National Academic Press.

Stasko, J., Miller, T., Pousman, Z., Plaue, C., & Ullah, O. (2004). Personalized peripheral information awareness through information art, in [Nottingham, U.K]. *Proceedings of UbiComp*, *04*, 18–35.

Tafte, E. R. (2001). *The Visual Display of Quantitative Information*. Cheshire, Connecticut: Graphics Press.

Tversky, B., Kugelmass, S., & Winter, A. (1991). Cross-cultural and developmental trends in graphic production. *Cognitive Psychology*, *23*, 515–557. doi:10.1016/0010-0285(91)90005-9

Wallston, B. S., Wallston, K. A., Kaplan, G. D., & Maides, S. A. (1976). Development and validation of the health locus of control (HLC) scale. *Journal of Consulting and Clinical Psychology*, *44*(4), 580–585. doi:10.1037/0022-006X.44.4.580

Wooldridge, K., Graber, A., Brown, A., & Davidson, P. (1992). The relationship between health beliefs, adherence, and metabolic control of diabetes. *The Diabetes Educator*, *18*(6), 495–450. doi:10.1177/014572179201800608

Xiong, R., & Donath, J. (1999). PeopleGarden: creating data portraits for users. In *Proceedings of the 12th Annual ACM Symposium on User interface Software and Technology* (Asheville, NC, United States, November 07 - 10, 1999). UIST ‘99, pp. 37-44.

KEY TERMS AND DEFINITIONS

Chronic Disease Management: A set of practices that allow individuals with chronic diseases to control the development of their disease and avoid or delay development of complications. For example, for individuals affected with diabetes, disease management usually involves close monitoring of blood sugar levels, adjusting diet and maintaining an exercise routine.

Health Monitoring: A collection of techniques that allow collection of data pertaining to individuals’ health. This collection could be performed manually or with the use of computing technologies. For example, in case of diabetes, health monitoring may include capture of blood sugar levels, records of individuals’ diets and exercise routines.

Information Visualization: A set of techniques for visually presenting certain data or concepts. Common examples of information visualization include graphs, plots, various maps or illustrations. Recently this term became associated with a branch of computer science that focuses on computer-based techniques for generating such presentations. These computer-generated visualizations could be static or interactive and are usually meant to assist in analyzing and comprehending large volumes of data.

Metaphor-Based (or Metaphorical) Visualizations: Presentations of complex data that use common linguistic metaphors and real-world imagery as a their basis. One of the most familiar examples of metaphorical visualizations are genealogical trees that use a “life is a tree” metaphor implicit to many languages to depict a history of a family, using branches of the tree to represent “branches” of a family.

Relational Graphics: Visualizations of data that rely on abstract mapping between the data and particular visual properties, such as position in space, color, shape or size. Examples of relational graphics include different types of graphs, such as line, bar or pie, and most charts.

Social Scaffolding: A set of techniques and methods that allows teachers or experts to support novices or students in their learning process. Common examples of socials scaffolding include coaching, when a coach is observing a student’s performance and provides feedback or learning by example, when an exert demonstrates certain techniques to students.

This work was previously published in Auto-Identification and Ubiquitous Computing Applications: RFID and Smart Technologies for Information Convergence, edited by J. Symonds; J. Ayoade; D. Parry, pp. 74-90, copyright 2009 by Information Science Reference (an imprint of IGI Global).

Chapter 2.6

A Distributed E-Healthcare System

Firat Kart
University of California, Santa Barbara, USA

Gengxin Miao
University of California, Santa Barbara, USA

L. E. Moser
University of California, Santa Barbara, USA

P. M. Melliar-Smith
University of California, Santa Barbara, USA

ABSTRACT

In this chapter we describe a distributed e-healthcare system that uses service oriented architecture as a basis for designing, implementing, deploying, invoking and managing healthcare services. The e-healthcare system that we have developed provides support for patients, physicians, nurses, pharmacists and other healthcare professionals, as well as for medical monitoring devices, such as blood pressure monitors. The system transmits e-prescriptions from physicians to pharmacists over the Internet. It offers multimedia input and output, including text, images and speech, to provide a human-friendly interface, with the computers and networks hidden from the user.

INTRODUCTION

According to Carmen Catizone of the National Association of Boards of Pharmacy (Catizone, 2002), there are as many as 7,000 deaths from incorrect prescriptions in the United States each year. A Washington Post article (Weiss, 1999) indicates that as many as 5% of the 3 billion prescriptions filled each year are incorrect. In the United States Institute of Medicine report, To Err is Human: Building a Safer Health System, Kohn et al. (USIOM, 2000) discuss human errors in the workplace:

> *Human beings, in all lines of work, make errors. Errors can be prevented by designing systems that make it hard for people to do the wrong thing and easy for people to do the right thing.*

The report sees the need to improve the quality of healthcare systems, ease the access to healthcare and healthcare information, and reduce the cost of delivery of healthcare. The Healthgrid review (Healthgrid Association & Cisco Systems, 2004) concludes that large healthcare systems have difficulties in managing personal data, standardizing the data, extracting content-based knowledge, and federating databases.

Computing and networking technology can contribute greatly to the quality of healthcare. The slow adoption of such technology in healthcare is caused in part by the highly decentralized nature of healthcare and in part because healthcare professionals are often uncomfortable with computers and networks, and feel that such technology is not central to their healthcare mission, even though they acknowledge that accurate record keeping and communication are essential to good healthcare.

In this chapter we present a distributed e-healthcare system that we have developed. The system is intended for use by patients, physicians, nurses, pharmacists and other healthcare professionals, as well as by medical monitoring devices. It aims to provide user interfaces that busy healthcare professionals and fearful patients find attractive and convenient to use, as well as more effective and efficient communication between them.

A patient can make an appointment with his/her primary care physician on the Web. The physician can refer the patient to a specialist electronically, if he/she is unable to treat the patient. When the physician prescribes medication, the system communicates an e-prescription over the Internet from the physician to the pharmacy, decreasing the probability of incorrect or lost information. The patient can check his/her prescription status on the Web and arrange for pickup or delivery of the medication.

BACKGROUND

Extensive work has been undertaken on the development of electronic healthcare information systems. Much of the work on such systems has focused on record keeping and databases based on the notion of the electronic medical record (Bourke, 1994; USIOM, 1997; Taylor et al., 2004; Tsiknakis et al., 1997). Work has also been done on access and security (Anderson, 1996; Andersen et al., 2001), as well as on social implications of recording and communicating healthcare information (Bloomfield, 1991). Less work has been done on human-computer interfaces and usability by healthcare professionals and patients, which our e-healthcare system aims to address.

Governmental and private organizations have promoted the use of electronic technology for healthcare, but these organizations typically incline towards centralized or centrally administered systems (Andersen et al., 2001; Detmer, 2003). Because of the fragmented nature of healthcare in the United States and the increasingly international nature of healthcare services and patients, more distributed and interoperable e-healthcare systems based on open international standards are needed (Grimson et al., 2000).

Beyer et al. (2004) discuss the limitations and challenges of developing an architecture for an integrated healthcare network. They identify flexibility, adaptability, robustness, integration of existing systems and standards, semantic compatibility, security and process orientation as key issues in developing a healthcare network. Song et al. (2006) present a survey of computer-aided healthcare workflow. They define workflow properties and provide a summary of requirements for common healthcare practices.

Omar and Taleb-Bendiab (2006) have utilized the service oriented architecture, in conjunction with grid computing technology, for a sensor and actuator framework that monitors the health status of a patient and provides feedback. Our e-healthcare system provides more extensive services that involve patients, physicians, nurses and pharmacists, as well as medical monitoring devices, whereas their system focuses specifically on the use of medical monitoring devices.

Care2x (2007) is an open-source, Web-based university project that implements a modern hospital information system for training medical students and healthcare engineering students. It includes a central data server and a health exchange protocol, and is implemented using the Apache Web server, the PHP scripting language and the mySQL database system. Our e-healthcare system focuses on the interactions between patients, physicians, nurses, pharmacists and medical monitoring devices outside the hospital setting, rather than on a health research data network or healthcare training for the hospital environment.

Subramanian et al. (2006) have developed a model for patient-centered healthcare services using a mobile device to push/pull data to/from a data analysis engine based on the service oriented architecture. Also relevant is the work of Budgen et al. (2007), who have developed a data integration broker for healthcare systems that uses a software service model to collect and integrate data from autonomous healthcare agencies.

THE DISTRIBUTED E-HEALTHCARE SYSTEM

Design

The distributed e-healthcare system that we have developed is based on the service oriented architecture (Srinivasan & Treadwell, 2005), and uses both Web servers and Web services (W3C, 2004) and also Atom/RSS (Bray, 2005). The service oriented architecture is an appropriate model for developing a distributed e-healthcare system, because it supports an open, networked ecosystem of multiple providers and users. Web servers and Web services support collaboration and enable interactions over the Internet by using standard protocols and conventional interfaces to facilitate access to the application logic and information. Atom/RSS provides syndication of content over the Web and enables synchronization of data in different databases.

Our distributed e-healthcare system comprises a Patient module, a Clinic module and a Pharmacy module. It uses desktop/server computers, hand-held mobile devices such as PDAs and smart cell phones, and medical monitoring devices such as blood pressure monitors. To provide more convenient input and output for healthcare professionals, the system employs various multimedia technologies, such as speech software for speech recognition (SRI, 2007) and speech synthesis (AT&T, 2007).

The Patient, Clinic and Pharmacy modules use security and privacy mechanisms to protect the patients' information in the e-healthcare system. Personal healthcare information is confidential, so access to that information must be restricted to authorized users. Users of the system are authenticated, and session information is kept in a log of service calls. Resources in the system are attached to the resource creator, and privileged users can view/modify the data in the system. For applications deployed on devices like PDAs/smart cell phones, authentication and session management are strictly enforced.

Patient Module

The Patient interface of our e-healthcare system, shown in Figure 1, allows a patient to request an appointment with a physician for a specific date/time, by communicating with the clinic Web service. Initially, a patient must make an appointment with his/her primary physician. The primary physician can refer the patient to a specialist, and the patient can arrange an appointment with the specialist.

The patient can see his/her previous appointments, and check the status of a prescription associated with an appointment. The e-healthcare

Figure 1. Patient interface

Welcome Firat Kart
Your last login: June 11, 17:24:50

You have 3 appointments in the next 7 days

Physician	Date	Time
Cavit Kart	Tuesday, June 12	10:00
Cavit Kart	Wednesday, June 13	15:00
Cavit Kart	Friday, June 15	13:30

system sends reminders about appointments with the physician, the status of prescriptions at the pharmacy, and messages from the physician or the pharmacist to the patient.

Medical monitoring devices, deployed with wired or wireless network support, are used to report periodically, or in an emergency, the status of the patient. Such devices do not send any patient-identifying information. Information is transmitted along with the serial number of the device, and the association with the particular patient is made by the clinic Web service. Unless the patient registers the device on the medical devices Web page, information from the device is discarded.

In our e-healthcare system, the Patient interface is Bluetooth-enabled to a blood pressure monitoring device, which transmits information from the patient to the patient's laptop or desktop computer. That information is communicated over the Internet to the clinic Web service for examination by the physician. The physician and the patient can see the historical data from the blood pressure monitor as a list and/or in a chart.

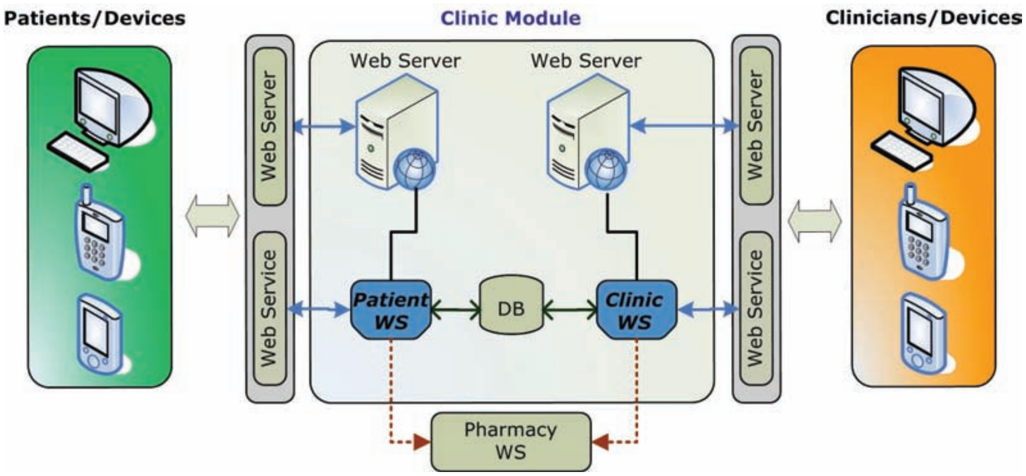
Clinic Module

The Clinic module, shown in Figure 2 provides support for routine activities of the healthcare professionals at the clinic. It maintains healthcare-related information, such as the physician's appointments, the patients that he/she has examined, notes related to the patients, etc. Access to a patient's private information is restricted and secured, as discussed previously.

The Clinic module exposes Web server and Web service interfaces for the clinic staff, the patients and the medical monitoring devices. The Web server interface is intended for users who prefer to use a Web browser to access the e-healthcare services at the clinic. The Web service interface can be used by humans or devices to communicate with, and deliver information to, the e-healthcare system. Applications that are implemented in Java use the Web service to communicate with the Clinic module. The Web server uses the Web service to access the data.

The Clinic module allows a physician or a nurse to create and view a patient's profile, and to add, delete and edit information (height, weight, blood pressure reading, temperature,

Figure 2. Clinic module



diagnosis, etc) about the patient associated with the particular patient profile. The clinic server application runs as a Java servlet and provides Web pages for the physician and the patient to access via the hypertext transfer protocol (HTTP) over the Internet. The patient information is stored in a database at the clinic, including the patient's profile, appointments related to the patient, and prescriptions related to the patient. The clinic Web service communicates with the database over a wired or wireless local-area network using Java database connectivity.

The Clinic client application runs on a handheld mobile device, such as a PDA or a smart cell phone, and exploits multimedia input and output, including speech software in order to provide a human-friendly interface for the physicians and nurses. The Clinic client application also allows the physician to create an e-prescription for the patient corresponding to a particular appointment.

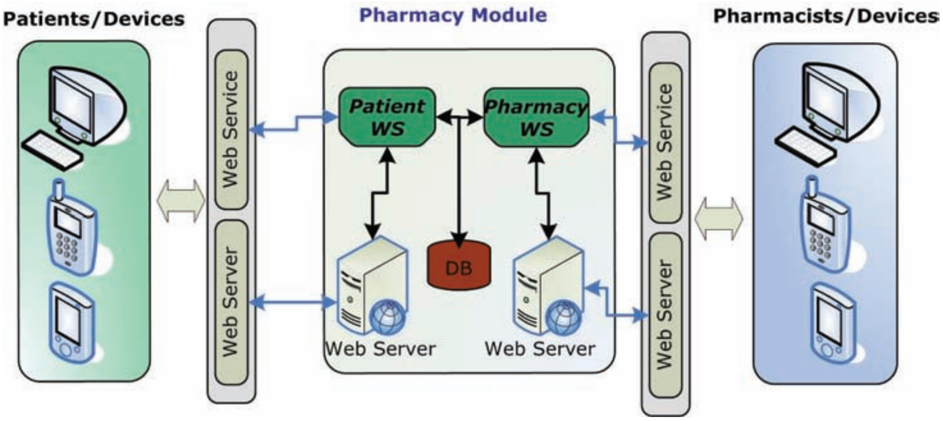
The clinic Web service discovers information about the pharmacies in the area, augments the e-prescription with the name of the pharmacy to which the physician is to send the e-prescription, and sends the e-prescription for the particular patient to the particular pharmacy using the Pharmacy Web service. To locate the pharmacy closest to the patient's home or the clinic, the clinic Web service uses the Yahoo! LocalSearch (Yahoo, 2007) Web service.

The physician can use the Web Server interface to access the e-healthcare system using a browser from a desktop/laptop computer or a PDA/smart cell phone. The physician can use the PDA to enter/retrieve information about the patient during/after an appointment and access this information any time, any where. The use of a PDA with a small keyboard makes it difficult for the physician to input information about the patient. Consequently, in addition to the graphical interface, we have enabled the PDA with speech software. Speech recognition software (SRI, 2007) allows the physician to enter/retrieve information by speaking. Feedback to the physician is provided by means of speech synthesis software (AT&T, 2007). Such speech software eases the task of the physician in completing tasks and encourages the use of the PDA.

Pharmacy Module

The Pharmacy module, shown in Figure 3, exposes Web server and Web service interfaces. The Web server interface allows the users to access the e-healthcare system at the pharmacy using a Web browser. The Web service interface

Figure 3. Pharmacy module



provides access for applications deployed at the pharmacy and can also be used by humans and devices. The Pharmacy module provides services to the pharmacists, patients and devices used at the pharmacy.

The Pharmacy module allows a pharmacist to view the outstanding e-prescriptions from the physicians and to view the e-prescriptions for a particular patient. The Pharmacy server application runs as a Java servlet and provides Web pages for the pharmacist, the physician and the patient to access via the hypertext transfer protocol (HTTP) over the Internet. The e-prescriptions for the patient are stored in a database at the pharmacy for the pharmacist's and the patient's reference. The pharmacy Web service communicates with the database over a wired or wireless local-area network using Java database connectivity.

When the physician submits a new e-prescription to the pharmacy, the Clinic module communicates directly with the Pharmacy module over the Internet. Removing human intervention from the communication between the physician and the pharmacist, and maintaining the information electronically, reduces the possibility of human errors.

The pharmacist can view the outstanding e-prescriptions for the patients, as the Pharmacy module receives them from the physicians. The Pharmacy Web service updates the status of the e-prescriptions as the pharmacist fills them.

When the pharmacist has filled an e-prescription, the Pharmacy Web service sends a notification to the Patient Web service. The patient can also determine, via the Web Server or Web service, whether an e-prescription has been filled and is ready for pick up or delivery. When the patient has collected the medication, the Pharmacy module sends an acknowledgement to the Clinic module, so that the physician knows that the patient now has the medication.

According to the National Community Pharmacists Association, a pharmacy in the United States dispenses an average of 204 prescriptions per day (Alexandria, 2006). Most of these prescriptions are renewals of existing prescriptions. Therefore, the Patient interface also has access to services that provide renewals of existing prescriptions, custom alerts, etc.

Implementation

We have deployed the Web servers and Web services of our distributed e-healthcare system on 3 GHz computers with 2 GB memory. We have deployed the client applications on 2 GHz

Figure 4. Physician's PDA displaying the e-prescription manager and a list of medications

e-Prescription Manager

Listening now, say 'help' anytime

Patient:
Firat Kart

Pharmacy:
Walgreens

5900 Calle Real
Goleta, CA
(805) 967-5977

Medications:
Lovastatin, 20 mg, once a day, 5 refills
Metformin, 500 mg, 3 times a day, 5 refills

Medication: Metformin

Refills: 5 until July 30 2007

Sig: 500 mg,
3 times a day

computers with 2 GB memory. The client applications communicate with the Web servers or Web services over the wide-area Internet.

For the PDA we used the OQO device, which is a full-featured 3" x 5" personal computer. The OQO device is powered by a 1 GHz Transmeta Crusoe processor, which is powerful enough to run both an embedded speech recognition engine and our clinic client application for the physician. The device features a 800 x 480 resolution screen that is capable of providing the physician with detailed graphical information. The PDA can communicate with a desktop or server computer using wireless (WiFi) communication. The PDA displaying the e-prescription manager and a list of medications is shown in Figure 4.

While it is possible to use any programming and/or scripting language to implement a service oriented architecture or a distributed e-healthcare system, we decided to use the Java programming language for its ability to be deployed on small wireless devices as well as on powerful server computers.

In the following subsections we discuss the particular software technologies that we employed in our distributed e-healthcare system and the considerations that we used in making these choices.

Web Services

Our Web services use the Apache Axis2 Framework (which is the core engine for Web services built on Apache Axiom) and the Apache Tomcat server (Apache, 2007).

Most developers using Web services need to work with data in the form of Java objects, rather than XML documents. Last-generation frameworks, such as Axis and JAX-RPC, implemented their own forms of data binding to convert between XML and Java objects, which was a limited solution for developers. Axis2 is designed to support plug-in data binding using a wide-range of data binding frameworks. To ease the development and debugging of our distributed e-healthcare system, we used plain old Java objects (POJO), based on the Spring Framework (SpringF, 2007).

The data binding support uses customized extensions to the Axis2 WSDL2Java tool. This tool generates Axis2 linkage code based on

WSDL service descriptions in the form of stubs on the client-side and message receivers on the server-side. The client-side stub acts as a proxy for making calls to the Web service, defining method calls that implement the Web service operations. The server-side message receiver acts as a proxy for the client, by calling the actual user-defined Web service method. The client applications use the auto-generated stubs to make Web service calls and create/parse the XML representations of the Java objects.

Speech Software

Our e-healthcare system uses speech software for speech recognition and speech synthesis, as described below.

The e-healthcare system uses the DynaSpeak speech recognition engine from SRI (2007). DynaSpeak supports multiple languages, adapts to different accents, and does not require training by the user prior to use. It incorporates a hidden Markov model (HMM) for separating speech from interfering signals with different statistical characteristics. DynaSpeak is ideal for embedded platforms, because of its small footprint (less than 2 MB of memory) and its low computing requirements (66 MHz Intel x86 or 200 MHz Strong Arm processor). DynaSpeak can be used with either a finite-state grammar or a free-form grammar. We chose to use the finite-state grammar, because it offers greater control over parsed phrases than the free-form grammar does.

The e-healthcare system also uses the Natural Voices speech synthesis engine from AT&T (2007). Natural Voices provides a simple and efficient way to produce natural sounding device-to-human voice interaction. It can accurately and naturally pronounce words, and speak in sentences that are clear and easy-to-understand, without the feeling that a computer is talking to the human. Natural Voices supports many languages, male and female voices, and the SAPI, VoiceXML and JSAPI interface standards. Using Natural Voices, we created text-to-speech software for the prototype device that runs in the background and accepts messages in VoiceXML format.

Medical Monitoring Devices

Our distributed e-healthcare system supports the use of medical monitoring devices, deployed with wired or wireless network support, to report periodically, or in an emergency, the status of the patient. Such medical monitoring devices can include networked electronic blood pressure monitors, glucose monitors, weighing scales, pillboxes, etc.

Currently, our e-healthcare system is enabled with the A&D blood pressure monitor device (A&D, 2007), which transmits readings using a Bluetooth radio. After pairing the Bluetooth device with a Bluetooth adapter on a laptop or desktop computer, the blood pressure monitor transmits data to the specific service. Having received this information, the Client application uploads the readings to the Clinic module for storage and enables access to this information by healthcare professionals and patients.

The output from the blood pressure monitoring device on a patient's laptop or desktop computer is shown at the top of Figure 5. The blood pressure history of the patient as a clinic Web service is shown at the bottom of Figure 5.

Atom/RSS

Enabling physicians, nurses and pharmacists to use PDAs or smart cell phones requires those devices to be able to communicate with the Clinic and Pharmacy modules on their desktop or server computers using a wireless or wired network. It is possible that, at certain times and places, network communication is not available. For example, in an emergency situation, such as a hurricane or an earthquake, a physician cannot expect to have a network connection to his/her desktop or server computer. Physicians, nurses and pharmacists

Figure 5. At the top, output from the blood pressure monitor on a patient's computer. At the bottom, the blood pressure history of the patient as a clinic Web service

Data listing
June 10, 21:57:32
June 10, 21:55:58
June 03, 19:20:17

Device model: Model 767
Serial number: 204110109100
Bluetooth address: 00:04:3e:43:0e:9d
Date & time: June 10 2007, 21:57:32 PDT
Measured data: Systolic: 108
Diastolic: 56
Pulse rate: 69
Mean Arterial Pressure: 67

Status: Bluetooth is on, waiting for data

must be able to access, and modify, healthcare information offline.

Atom/RSS (Bray, 2005) are syndication technologies, based on XML, that enable the sharing and communication of information between heterogeneous platforms by augmenting that information with meta-data tags so that the information is self-describing. They allow a publisher to make information available on the Web for consumers, so that they can retrieve the information subsequently. The information is delivered from the publisher to the consumer as an XML file, called an Atom/RSS feed.

We have developed a Consistent Data Replication and Reliable Data Distribution infrastructure (Kart, Moser & Melliar-Smith, 2007) that replicates information from one computer to another computer. We can use that infrastructure to replicate information from the physician's desktop or server computer to his/her PDA, thus allowing the physician to view that information when it is offline.

In our infrastructure, Atom feeds are used to synchronize the information on the physician's PDA with that on his/her desktop or server computer. At the start of the day, our software on the PDA retrieves the necessary updates from the clinic Web service on the desktop or server computer via a wired or wireless network. Any modifications to the information on the PDA are stored locally on the PDA. At the end of the day, our software on the PDA generates an update feed for the clinic Web service on the desktop or server computer to read.

FUTURE WORK

Our distributed e-healthcare system currently focuses on the relationships between patients, physicians, nurses and pharmacists. We plan to extend the technology to provide other healthcare services and to accommodate other healthcare professionals. For example, a nurse can use the e-healthcare system to check that a medication and dosage are appropriate before administering the medication to the patient. After the nurse has done so, the e-healthcare system informs the physician that the medication has been administered. Similarly, using the e-healthcare system, the physician can communicate the required laboratory tests for the patient electronically to the laboratory. After the laboratory technician determines the test results, the e-healthcare system returns the results electronically to the physician.

The Pharmacy and Clinic applications can be interfaced to applications used by pharmacists, such as Epocrates Rx (Epocrates, 2007), that provide information on appropriate medications and dosages, and that warn of interactions between medications. The Patient application can be extended to provide reminders to the patient to take medications at appropriate times. A medication dispensing device (e-pillbox), such as that provided by MedSignals (2007), can prompt and monitor the regular and timely consumption of medications, a significant weakness in current healthcare. Such a device can also notify the Physician application when the patient has taken a medication.

Communication between the physician and the patient between the patient's visits to the clinic is also lacking in current healthcare systems. Our distributed e-healthcare system can be extended to provide such communication, so that the physician can monitor the progress of the patient and the patient can report symptoms or receive reassurances. This sort of monitoring can reduce the number of unnecessary visits of the patient to the clinic and can increase the number of patients that should have been, but were not, seen by the physician. If physicians lack communication with patients, hospitals are in even worse shape because they have little contact with patients once they have been discharged. Our distributed e-healthcare system can enable hospitals to remain in communication with their discharged patients and to monitor the progress of their recovery.

We plan to investigate the use of PDAs and smart cell phones to provide continuing communication about the health of the patient. We also plan to investigate wearable monitoring devices that continuously monitor the health of the patient and report any deterioration.

CONCLUSION

We have presented a distributed e-healthcare system that uses the service oriented architecture as a basis for designing, implementing, deploying, managing and invoking e-healthcare services. The service oriented architecture facilitates the development of a distributed e-healthcare system by supporting an open, networked ecosystem of multiple providers and users who can collaborate, using Web servers, Web services and Atom/RSS. Multimedia input and output, particularly graphics and speech, make the e-healthcare system seem less computer-like and more attractive to users who are not computer-oriented.

REFERENCES

A&D. (2007). *Blood pressure monitor*. Retrieved from http://www.lifesourceonline.com

Alexandria, V. (2006). *Number of independent pharmacies on the rise, impact of medicare part D looms on the horizon*. Retrieved from http://www.ncpanet.org/media/releases/2006/~number_of_independent_pharmacies_on_the_04-28-2006.php.

Andersen, R., Rice, T. H., & Kominski, G. F. (2001). *Changing the U.S. health care system: Key Issues in health services, policy and management*. Josswey-Bass.

Anderson, R. J. (1996). *Security in clinical information system*s. British Medical Association.

Apache. (2007). *Axis2, Axiom, Tomcat*. Retrieved from http://ws.apache.org/

AT&T. (2007). Natural Voices speech synthesis software. Retrieved from http://www.research.att.com/ ~ttsweb/tts/

Beyer, M., Kuhn, K. A., Meiler, C., Jablonski, S., & Lenz, R. (2004). Towards a flexible, process-oriented IT architecture for an integrated healthcare network. *Proceedings of the 2004 ACM Symposium on Applied Computing*. Nicosia, Cyprus (pp. 264-271).

Bloomfield, B. P. (1991). The role of information systems in the UK National Health Service: Action at a distance and the fetish of calculation. *Social Studies of Science*, *21*, 701–734. doi:10.1177/030631291021004004

Bourke, M. K. (1994). *Strategy and architecture of health care information systems*. Springer.

Bray, T. (2005). *RSS 2.0 and Atom 1.0 compared*. Retrieved http://www.tbray.org/atom/RSS-and-Atom.

Budgen, D., Rigby, M., Brereton, P., & Turner, M. (2007). A data integration broker for healthcare systems. *IEEE Computer*, *40*(4), 34–41.

Care2x. (2007). *Hospital information system*. Retrieved from http://www.care2x.org

Catizone, C. (2002). Colorado state board of pharmacy news. Retrieved fromhttp://www.nabp.net

Detmer, D. E. (2003). Building the national health information infrastructure for personal health, health care services, public health and research. *BMC Medical Informatics and Decision Making*, *3*, 1–40. doi:10.1186/1472-6947-3-1

Epocrates. (2007). *Prescription software*. Retrieved from http://www.epocrates.com

Grimson, J., Grimson, W., & Hasselbring, W. (2000). The SI challenge in health care. *Communications of the ACM*, *43*(6), 48–55. doi:10.1145/336460.336474

Healthgrid Association & Cisco Systems. (2004). *Healthgrid whitepaper*. Retrieved from http://whitepaper.healthgrid.org.

Kart, F., Moser, L. E., & Melliar-Smith, P. M. (2007). Reliable data distribution and consistent data replication using the atom syndication technology. *Proceedings of the International Conference on Internet Computing*. Las Vegas, NV, (pp. 124-132).

MedSignals. (2007). *Electronic pillbox*. Retrieved from http://www.medsignals.com.

Omar, W. M., & Taleb-Bendiab, A. (2006). Service oriented architecture for e-health support services based on grid computing. *Proceedings of the IEEE International Conference on services oriented Computing,* Chicago, IL (pp. 135-142).

Song, X., Hwong, B., Matos, G., Rudorfer, A., Nelson, C., Han, M., & Girenkov, A. (2006). Understanding requirements for computer-aided healthcare workflows: Experiences and challenges. *Proceedings of the 28th International Conference on software engineering*. Shanghai, China, (pp. 930-934).

Spring Framework. (2007). Retrieved from http://www.springframework.org/

SRI. (2007). *DynaSpeak speech recognition software*. Retrieved from http://www.sri.com/

Srinivasan, L., & Treadwell, J. (2005). *An overview of service oriented architecture, Web services and grid computing*. Retrieved from http://h71028.www7.hp.com/ERC/downloads/SOA-Grid-HP-WhitePaper.pdf

Subramanian, M., Ali, A. S., Rana, O., Hardisty, A., & Conley, E. C. (2006). Healthcare@Home: Research models for patient-centered healthcare services. *Proceedings of the 2006 International Symposium on Modern Computing* (pp.107-113).

Taylor, K. L., Colton, C. M., Baxter, R., Sparks, R., Srinivasen, U., Cameron, M. A., & Lefort, L. (2004). A service oriented architecture for a health research data network. *Proceedings of the International Conference on Scientific and Statistical Database Management,* Santorini, Greece (pp. 443-444).

Tsiknakis, M., Chronaki, C. E., Kapidakis, S., Nikolaou, C., & Orphanoudakis, S. C. (1997). An integrated architecture for the provision of health telematic services based on digital library technologies. *International Journal on Digital Libraries*, *1*(3), 257–277. doi:10.1007/s007990050021

U.S. Institute of Medicine. Dick, R.S., Steen, E.B. & Detmer, D.E. (eds.) (1997). *The computer-based patient record - an essential technology for health care*. National Academy Press.

U.S. Institute of Medicine. Kohn, L.T., Corrigan, J.M. & Donaldson, M. (eds.). (2000). To *err is human: Building a safer health s*ystem. National Academy Press.

Weiss, R. (1999). Medical errors blamed for many deaths: As many as 98,000 a year in U.S. linked to mistakes. *The Washington Post*.

World Wide Web Consortium. (W3C) (2004). *Web services architecture*. Retrieved from http://www.w3.org/TR/ws-arch.

Yahoo! (2007). *LocalSearch APIs*. Retrieved from http://developer.yahoo.com/search/local/.

KEY TERMS

Atom/RSS: Two different, but related, families of feed formats that are used to publish frequently updated digital content on the Web. Both feed formats are based on the eXtensible Markup Language (XML).

E-Healthcare System: A healthcare system based on the application of information and communication technologies that provides a wide range of healthcare services to its users including physicians, nurses, pharmacists and patients. Typically, these services are provided over the Internet.

Electronic Medical Record (EMR): A medical record in digital format.

E-Prescription: Electronic transfer of a medical prescription in digital format from an physician to a pharmacist, in contrast to the current paper-based method.

Service Oriented Architecture (SOA): A software architecture that uses loosely coupled services to support the requirements of business processes and users. Resources on the Internet are made available as services that can be accessed without knowledge of their underlying platform implementation.

Speech Recognition: The process of interpreting human speech for transcription, or as a method of interacting with a computer or device, using a source of speech input, such as a microphone.

Speech Synthesis: The artificial production of human speech. Speech synthesis technology is also called text-to-speech technology because of its ability to convert text into speech.

Web Server: A computer or computer program that accepts hypertext transfer protocol (HTTP) requests from clients (Web browsers), and that serves them HTTP responses along with optional data content, typically Web pages such as HyperText Markup Language (HTML) documents and linked objects, such as images.

Web Service: A software service that executes typically on a remote computer and that can be accessed by clients over the Internet. A Web service is based on standards such as the eXtensible Markup Language (XML) and the Simple Object Access Protocol (SOAP) and, thus, provides interoperable interactions over the network.

This work was previously published in Handbook of Research on Distributed Medical Informatics and E-Health, edited by A. Lazakidou; K. Siassiakos, pp. 117-128, copyright 2009 by Medical Information Science Reference (an imprint of IGI Global).

Chapter 2.7

Planning Successful Telemedicine and E-Health Systems

Michael Mackert
The University of Texas at Austin, USA

Pamela Whitten
Michigan State University, USA

Emily Krol
The University of Texas at Austin, USA

ABSTRACT

Telemedicine and e-health applications have the potential to improve healthcare organizations' ability to provide advanced services in a cost-effective manner. Given the failure rate of information technology projects in general (25%), successfully launching a new telemedicine or e-health system can be a daunting prospect–especially for organizations without experience with these new technologies. This chapter provides examples of important aspects of pre-project planning that can help set the stage for success in implementing new telemedicine and e-health applications; importantly, the lessons provided in this chapter are provided by discussing both systems that have achieved success and others that have faced significant difficulties. Key points discussed include: the benefits of involving important stakeholders and users in the planning process, effectively contracting with external technology vendors, and successfully managing expectations. Improved pre-project planning can contribute substantially to the eventual project outcome, so this is a step that cannot be overlooked.

INTRODUCTION

As healthcare providers and organizations seek to minimize costs while providing quality healthcare to patients, telemedicine and e-health applications offer promising solutions to these challenges. This chapter will explore pre-project aspects of telemedicine and e-health systems as well as implementations

DOI: 10.4018/978-1-60566-356-2.ch027

that contributed significantly to the technology's success or failure. Lessons learned in exploring these varying factors can be broadly applied to other Information Technology (IT) projects in the healthcare context. These lessons are important, as research has demonstrated that 25% of all IT projects fail (Keil & Mann, 2000).

Telemedicine refers to the provision of healthcare via telecommunication technology – healthcare provided at a distance. Some of the earliest telemedicine work was carried out by Wittson and colleagues in 1961, through the establishment of a video-based telepsychiatry service that linked providers in Nebraska at the Psychiatric Institute in Omaha with a distant psychiatric hospital (Wittson, Affleck, & Johnson, 1961). Since the 1960s, the number of telemedicine projects and services operating in the United States has grown so large it is no longer possible to quantify the exact number (Whitten & Kuwahara, 2003).

Telemedicine has evolved to include a wide array of services, including home-based monitoring of patients with chronic diseases (Hopp et al., 2005; McManus, 2004), providing hospice services via videophones (Bensink & Irving, 2004; Whitten, Doolittle, Mackert, & Rush, 2003), and Picture Archiving Systems (PACS) used to store and transmit images for teleradiology and similar applications (Raman, Raman, Raman, & Beaulieu, 2004). Telemedicine has been used in an assortment of medical applications, including dermatology (Burgiss, Clark, Watson, & Haynes, 1997; Chen, See, & Shumack, 2002), pathology (Joel, Leong, & Leong, 2004; Mireskandari, Kayser, Hufnagl, Schrader, & Kayser, 2004), radiology (Aas & Geitung, 2005; Crowe & Sim, 2004), psychiatry (Greenwood, Chamberlain, & Parker, 2004; Kuulasmaa, Wahlberg, & Kuusimaki, 2004), and physical therapy (Rizzo, Strickland, & Bouchard, 2004). Telemedicine researchers continue to explore innovative and efficacious methods of providing healthcare at a distance, so the capabilities of the technology will continue to improve.

While certainly related to telemedicine, e-health is a different field and type of application. Eysenbach (2001) provides a well-recognized definition of e-health:

> *e-health is an emerging field in the intersection of medical informatics, public health and business, referring to health services and information delivered or enhanced through the Internet and related technologies. In a broader sense, the term characterizes not only a technical development, but also a state-of-mind, a way of thinking, an attitude, and a commitment for networked, global thinking, to improve health care locally, regionally, and worldwide by using information and communication technology.*

The Internet has become increasingly ubiquitous, with recent reports indicating that 70% of American adults use the Internet at least occasionally (Pew Internet and American Life Project, 2007). A large majority of those using the Internet (8 in 10) have used it as a source of health information, and every day six million Americans seek health information on the Internet (Fox, 2006; Schloman, 2003). In this context e-health, much like telemedicine, can be a useful tool and model for thinking about improving healthcare – both to advance the quality of care and contain costs. Examples of promising e-health applications include websites designed to enable provider consultations (Heinzelmann & Kvedar, 2004), providers communicating with patients via e-mail (May, Finch, Mair, & Mort, 2005), online patient support groups (Arrington, 2004).

Given the potential for telemedicine and e-health, it is not surprising that healthcare providers and organizations are enthusiastic about these technologies. But the fact remains that adoption and usage of these systems is often disappointing, as even those systems that might be considered successful during the research phase often fade once initial grant funding disappears (Grigsby et al., 2002).

The overall purpose of this chapter is to provide useful examples of decisions made in the earliest stages of planning telemedicine and e-health applications that have contributed to the eventual success or failure of the described projects. This includes points about the benefits of involving important stakeholders and users in the planning and development process, effectively contracting with external technology vendors, and successfully managing expectations. Most of the examples come from four telemedicine and e-health projects:

- **TeleKidcare:** TeleKidcare is a school-based telemedicine system that makes use of interactive videoconferencing technology to provide medical consultations to children in Kansas schools.
- **Upper Peninsula Telehealth Network (UPTN):** The UPTN is a telemedicine and telehealth network operating in the Upper Peninsula of Michigan. The project has evolved over time from pilot testing the potential for telemedicine in 1994 to a network of 42 sites (Marquette General Health System, 2007).
- **Bedside Teleconsultations in Nursing Homes:** This system was designed to provide medical consultations directly to rural nursing home residents' bedsides. From August 2003 to March 2006, though, the project struggled through the process of installation, testing, and troubleshooting; the system was never used to complete an actual clinical consultation.
- **e-Health Solutions for Low Health Literate Patients:** Health communication researchers and professionals are exploring new methods for communicating health information to this hard-to-reach audience. One promising strategy is interventions designed specifically to meet the needs of low health literate individuals.

Overviews of each case and project provide the proper context for understanding the key points about a particular factor that contributed significantly to the final project outcome. References to other reports of these cases are provided where appropriate.

PRE-PROJECT PLANNING: INVOLVING KEY STAKEHOLDERS

Many pre-project decisions can have a large impact on the eventual success of a new telemedicine or e-health system, and one such decision is which stakeholders should be involved in the planning process. The exact list will vary depending on the system being designed, but stakeholders could include:

- Doctors
- Nurses
- Medical support staff
- Administrators
- Patients
- Caregivers
- Technology support staff
- Policymakers
- Members of the community

There are a variety of reasons stakeholders should be involved in the planning process for a new telemedicine. One of the main reasons is that involving stakeholders – especially the end users of a system – in the planning process can help increase likelihood of implementation once the system is eventually installed. Instead of feeling like they are having a new system forced upon them, involvement in pre-project planning can make end-users can feel involved throughout the development process of the system and increase their investment in its success. Involving stakeholders can also help avoid problems integrating the technology into the organization, one of the most common issues with telemedicine systems (May, Finch, Mair, & Mort, 2005).

One good example of involving key stakeholders in the planning process comes from the TeleKidcare system, a school-based telemedicine system deployed in Kansas (Whitten & Cook, 1999; Whitten, Cook, Kingsley, Swirczynski, & Doolittle, 2000; Whitten, Kingsley, Cook, Swirczynski, & Doolittle, 2001). The TeleKidCare system uses interactive videoconferencing for consultations with Kansas University Medical Center (KUMC) physicians and health offices in elementary and secondary schools. It was originally designed to provide electronic consultations for acute medical problems, however it has evolved to offer other services, such as management of behavioral problems. TeleKidcare has grown from four original pilot sites in 1998 to over thirty schools in urban and rural areas.

Mackert and Whitten (2007b) recently explored the factors that have contributed to the success of TeleKidcare, and the importance of involving stakeholders emerged as one of the most significant elements of the long-term success of the system. As project planners sought to design the TeleKidcare system, they involved a variety of key stakeholders. One project planner described this process:

> *[We conducted] interviews with people up and down the school districts, interviews at each school, meetings with the principals, meetings with the teachers… I can't exaggerate how many meetings there were.*

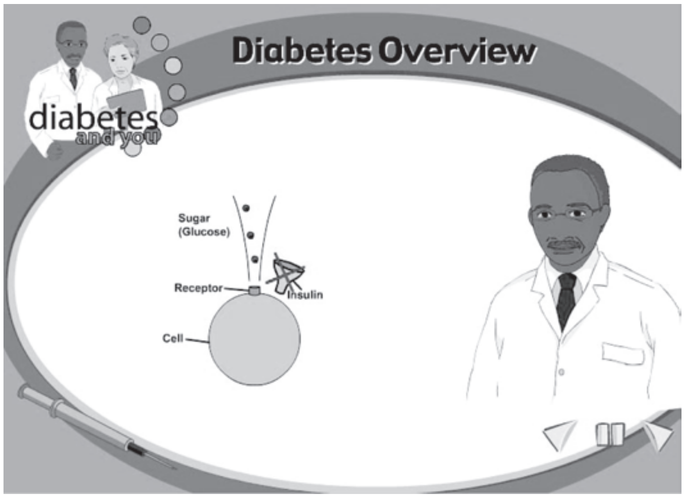
> *It was strategic in terms of who we included, in the early planning [the other project manager] and I sat down to talk about who all should be involved in the planning, who should be on the planning team. We had a few big meetings with everyone and then smaller meetings. We had a pediatrician and a nurse and someone from psychology and someone from telemedicine and someone from billing and someone from the school district.*

As stated earlier, a key benefit of involving stakeholders in the planning process is that it can personally invest users in the system's success. TeleKidcare planners made a concerted effort to involve school nurses, the eventual end users of the system, in the planning and development process. This helped ensure TeleKidcare would work – both the technology itself and the processes around building TeleKidcare into the school nurses' duties.

The importance of having the right stakeholders in place went beyond involving school nurses in the planning process. TeleKidcare managers carefully selected new sites for the system, focusing on those schools with the greatest chance of success. Components of a school with potential to make significant use of TeleKidcare were a nurse with the appropriate skills to use the system in their work, as well as school administrators who could appreciate the value of TeleKidcare in their school.

Success of a telemedicine system is largely dependent on those who are invested in the project. When key stakeholders are involved throughout the planning process, it helps increase acceptance of the end result among all interested parties. Careful consideration of who key stakeholders are is vital, as overlooking an important person or group of people can result in serious problems when attempting to deploy new technology in the healthcare organization. KUMC's work with TeleKidcare is a great example of how involving stakeholders can help set the project up for eventual success.

Figure 1. Diabetes and You



PILOT TECHNOLOGY WITH ACTUAL USERS

As engineers and technicians build and deploy a new telemedicine system, they often have a clear picture of how the system should and will work for end users. Not surprisingly, these individuals have little trouble operating the systems they design. The actual end users' first experience with a new system can be quite different, however. Because of this, it is extremely important to pilot test new applications with end users.

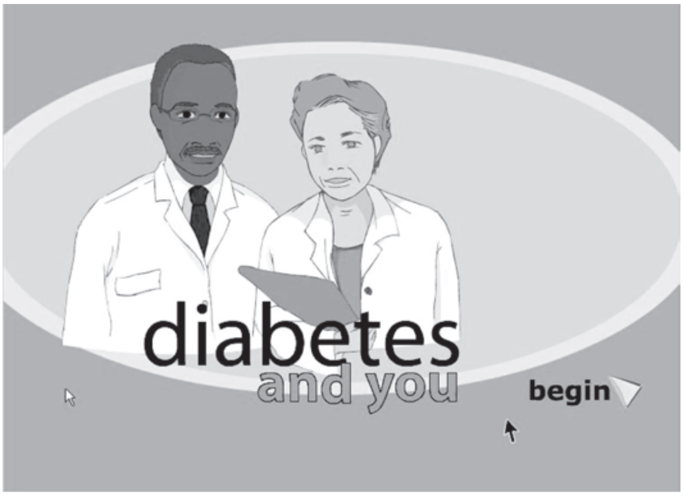
A particularly illustrative example of this principle comes from the study of e-health interventions designed to provide health information to low health literate audiences. Low health literacy – which focuses on the ability of individuals to obtain, process, and act on health information – is a growing problem that costs healthcare systems through incorrect use of medications, unnecessary emergency room visits, and poor management of chronic diseases (Nielsen-Bohlman, Panzer, & Kindig, 2004). Zarcadoolas et al. (2006) discuss the fact that health literacy is more complex than the ability to read, consisting of functional literacy, scientific literacy, civic literacy, and cultural literacy.

As health communication professionals seek better ways to provide information to low health literate audiences, one promising strategy appears to be websites designed specifically to meet the needs of low health literate audiences. Research has demonstrated the potential for these websites to provide information about diabetes and childcare to low health literate individuals (Whitten, Love, Buis, & Mackert, in press) and more general audiences (Mackert, Whitten, & Garcia, in press).

These websites were designed to be meet the needs of low-literate users by providing information primarily via audio delivered by animated health providers. The content was assembled by a team of healthcare researchers and professionals, and the websites themselves were designed in Flash. The goal of the designers was to make the sites accessible even to those users with little or no computer experience, so much of the navigation was accomplished via VCR-style controls (Figure 1). The first website, "Diabetes and You," included instructions for users on how to use their mouse to click on the rewind, play, pause, and forward buttons to move through the website.

After several rounds of design and review among the research team, the website was pilot tested with low health literate users recruited at

Figure 2. Diabetes and You introduction screen



food banks and a Medicaid healthcare clinic. Most participants had at least some computer experience, but others required brief instructions on the use of the computer and the mouse.

While most users were able to navigate the website with little difficulty, many of the participants with no computer experience became extremely confused during the introduction. For users who just received instruction on how to use a mouse, the website designers' decision to put an animated mouse arrow on the screen to demonstrate navigation (e.g., "Click the forward arrow to proceed.") was extremely confusing; these individuals were just introduced to the concept of the mouse moving the arrow on the screen, then the website introduced a second arrow of which they had no control (Figure 2).

It is unlikely that the "Diabetes and You" design team could have foreseen this particular difficulty faced by novice computer users. Given their own computer proficiency, the design and demonstration of the navigation system (including the "extra" mouse arrow on the screen) was not confusing. Only in testing the website with actual users was this design flaw exposed, and the next generation website did not include such a design element.

A similar issue came about when designing the navigation system. Website designers used a picture of a traffic warning sign as an icon to lead into the "Signs and Symptoms" section of the website. One of the healthcare professionals who helped design content for the intervention insisted that a picture of a pancreas be used as the icon for that section of the website. Eventually the website designers included a picture of a pancreas in an early version of the website, which immediately confused users (who thought it looked like a sponge). The website designers went back to using the traffic warning sign as an icon for the "Signs and Symptoms" section, and this became another example of how experts can often have a difficult time completely understanding the knowledge and expectations of users.

It can be difficult for system designers to completely understand the needs of eventual users and anticipate all of the unusual or unexpected things they might do in using a system. As such, there is simply no substitute for testing systems with potential users. The earlier, and more frequently, this can happen during the development process, the better.

LET USERS DETERMINE THE BEST WAYS TO USE A SYSTEM

As a new telemedicine or e-health system is being designed and tested, it may seem natural to begin developing procedures and best practices for actually using the technology. Indeed, there must be some sort of procedures in place so that users can be trained and prepared to integrate the system into their existing work practices. As discussed earlier, involving actual end users in the development and testing processes will help ensure that training and usage manuals reflect how the system will actually be used.

It is important, however, that any formal or official procedures for using the technology be flexible enough to let users appropriate the technology in useful and unexpected ways. As the development and pilot testing process is never going to be perfect or encompass all potential situations in which a system might be used, administrators and project planners must empower end users to determine the best ways to use technology once it is in the field.

As an example, the school nurses involved with the TeleKidcare system discussed earlier routinely found uses for the system that were not anticipated. Unanticipated applications of the technology included:

- Nurses use the equipment as a diagnostic aid in their offices, such as using the system locally to see things on the television screen using the otoscope.
- Nurses use the system to contact other school nurses for second opinions on cases where they need assistance.
- Nurses continue to use the school videoconferencing network that was originally set up for training purposes. Over time this has become an informal mentoring network to help new TeleKidcare nurses get up to speed and successfully adopt the technology.
- Nurses used TeleKidcare for a videoconference between a KUMC physician and parents of a sick child, so the physician can explain the necessity of bringing their child to the doctor for ailments that cannot be handled via telemedicine.

One nurse described this last situation:

We also have TeleKidcare for those hard cases where [the doctors] are not able to diagnose a child, and I know that sometimes their limitation is that this child probably can't be diagnosed with telemedicine. But I'll bring the parent in so they can have a consultation with the physician. Sometimes they need to hear it from the physician that this child has a medical issue that needs to be seen by a doctor [in person].

Clearly, part of the continued success of TeleKidcare has been due to the fact that administrators are very open to the idea of nurses innovating and appropriating the technology. Given the fact that adopting new technology into existing work practices can be a challenge, it definitely is not for everyone. One nurse spoke of this fact, saying:

It's not for everybody. We have a nurse right now that's at a preschool, and she has an opportunity to go to a telemedicine school, and she said she doesn't want [to move]. So it's not for everybody. I think the nurses that are interested and believe in it, the ones that see the outcomes, are the ones that are really more involved. I have one nurse right now that has telemedicine, she's split between schools and it's too much work. I think it just depends on that individual – how much she believes in it, and how much work she's willing to put into it.

Recognizing the importance of having the ideal nurse in the school to let TeleKidcare achieve significant utilization, the presence of a capable nurse becomes one of the major considerations when looking at a new potential TeleKidcare site. TeleKidcare administrators' awareness of the importance of a capable school nurse can help them avoid bringing telemedicine to schools that would not use the system to its full potential.

While some systems will need to be used by all staff, the case of TeleKidcare highlights the fact that targeting the correct early adopters and users can make a significant difference in project success. Even for a more large-scale technology implementation (e.g., an Electronic Medical Records system), such systems can be implemented on a clinic-by-clinic or department-by-department basis; targeting the clinics or departments most likely to successfully adopt the technology – and appropriate it in novel ways – can help the following clinics and users get up to speed more quickly.

One of the most effective ways that administrators and planners can encourage this type of use is to provide users with a rough framework of how the system "should" work. In making this framework available to users, and explaining to them that the goal is to provide flexibility in bringing the technology into their work, users can feel empowered to experiment with telemedicine and determine what works best for them and their patients. This is particularly true in a system with multiple sites, where the organizational culture and processes at different sites might vary dramatically. One of the TeleKidcare project managers spoke of this fact:

It takes an extensive amount of planning. It takes a lot of research, and actually going out and doing site visits and seeing what's going to work. What works in Kansas City, Kansas, does not work anywhere else. What works in one community does not work in the next. So I think it's a lot of planning and a lot of interviewing, a lot of seeing what resources are out there [at the schools and in the community]. So what we have to do is make a template [of] how to do things. [We can] say, "This is how we do things up in Kansas City. This is, so far, what we have seen to be the best working process."

Now we're introducing in Bellingham, which is a whole other process. We might have to adapt it a little bit to that community, or have them take our template and [adapt] it for themselves. It just depends on if the community is using our resources or they're using the local ones.

Essentially it comes down to the simple fact that overly-rigid models for technology use are likely to achieve only what they were designed to accomplish – consistent usage in the specified manner in expected situations. Project managers and planners who are willing to let users experiment with telemedicine, though, are more likely to oversee a more creative and active system.

EFFECTIVELY CONTRACTING WITH EXTERNAL TECHNOLOGY VENDORS

Contracting with external technology vendors may be a necessity, especially for healthcare organizations with little experience deploying telemedicine and other advanced e-health systems. This is not necessarily a bad thing, as partnerships between healthcare organizations and technology vendors can be extremely collaborative and effective.

As one example, Kinsella et al. (2004) describe the customization of a home monitoring device designed for elderly patients. The study described how a home health agency worked at length with its technology vendor to test the product and customize it for its patients. The authors insightfully note that "using this disciplined planning and implementation approach required more effort and time than simply installing technology" (Kinsella, Lee, & Ecken, 2004, p. 287).

While successful cases demonstrate that such partnerships can indeed work, it can be more instructive to consider partnerships that have not worked. Mackert and Whitten (2007a) provide an overview of one such failed partnership, between university researchers (and their partner nursing homes) and the primary regional telecommunication services provider (named Company X for the purposes of this report). The proposed project would have linked four rural nursing homes with urban specialists, providing videoconference consultations directly to nursing home residents' bedsides. The problems encountered in this project provide a number of important lessons.

Because of the status of the telecommunication industry at the time, most local markets were dominated by a single service provider. Given the likelihood that Company X would eventually supply transmission lines for the system (no matter what company or companies might provide hardware and networking within the nursing homes), researchers involved Company X in the process of preparing the grant. Cost estimates provided by Company X made it possible to ensure service would be available at project sites and prepare the budget for the grant. This was an important aspect of submitting a competitive grant application and planning a successful system. A manager from Company X spoke of their interest in assisting in the process of planning the system and applying for the grant:

And I know his [the company's leader on the RFP response] intention, which is often the case, is that we try to engage ourselves within the planning process, so it makes it easier to respond to the bid. And I know [he] had tried to do that.

Then we even worked a little bit with [a member of the researchers' institution] in purchasing. Simply because he wasn't real familiar with the video, you know the whole network and everything like that.

Once awarded the grant, researchers published a Request for Proposals (RFP) to invite interested companies to compete for the project contract. This was a very straightforward process, as the system architecture had already been planned for the purpose of submitting the grant. Companies were thus forced to compete for the work based primarily on price, as opposed to creativity in meeting the overall objectives of the researchers. After reviewing three responses to the RFP, Company X received the contract; this was due to the lower price of their proposed solution and their unique ability to provide a turnkey, end-to-end solution. Speaking at the end of the project about the RFP process, though, one manager from Company X stated:

I think the thing that we probably find makes things go better generally is if the RFP process specifies just some general characteristics that you [the customer] would be looking for in order to partner with somebody on the project. Then the design becomes a little bit more collaborative, both sides sitting down as we're doing the design and just working through exactly what the applications are and being able to interact and say, "Okay, here's your choice. If you want to move at this speed, here's what we'd recommend. If you want this [other] speed, here's what we'd recommend."

I would say just generally we find that people are very collaborative in the design process, and sit down and give and take through how we want this designed versus just being given the system [design or requirements]. That generally tends to work out a little better.

Aside from the RFP process, another issue arose due to the nature of the contract between the researchers and Company X. The contract was relatively straightforward for a fixed sum of money to complete a working system. There were no incentives in place to encourage more efficient work by Company X, nor penalties for poor performance or failure to deliver a working system. The simple contract was a result of receiving and spending research grant funds. However, the simplicity of the contract provides interesting insights into why more efficient contracts are required.

Most important is the simple fact that a technology vendor is likely to have technical expertise well beyond that present in the healthcare organization. While this expertise is the reason that the healthcare organization is partnering with the technology vendor in the first place, this imbalance in expertise can make it challenging for the healthcare organization to effectively monitor the vendor's performance on the contract and validate their expertise. One member of the research team spoke of this issue in relation to a specific piece of hardware required for the network:

When [Company X] had talked about that product they really talked about it as if they knew what they were doing. And I think that as things progressed we had a hard time just getting it, and then technical support was nonexistent and it really turns out that they [Company X's engineers] didn't have very much experience with that product at all. That was quite surprising to me.

There's always a place for beta and field trial, and every vendor is going to work on equipment that they've never worked with before, but they didn't up front clearly disclose the fact that they didn't have a lot of experience with that product.

In situations where there is a significant imbalance in the technical expertise of the two organizations, it is necessary for contractual incentives to encourage efficient performance on the part of the vendor. At that point the technology vendor will carefully monitor its own performance, a necessity given the healthcare organization's relative inability to do so.

The results of this particular project should not discourage healthcare organizations from partnering with external technology and telecommunication service providers, of course, but it does point to the fact that such partnerships can be more complicated than expected. The process of finding and contracting with a technology vendor requires planning and thorough consideration of how a healthcare organization can put the right incentives in place to encourage vendor performance.

SETTING REALISTIC EXPECTATIONS

One of the easiest mistakes to make when beginning a new telemedicine application is to be overly ambitious in what the project can realistically accomplish. This is particularly true when writing a new grant and looking to initiate a project that will create excitement among the healthcare organization and funding agencies. Specifically, it is tempting to suggest that a new telemedicine system will serve large numbers of patients at lower costs than traditional models of healthcare.

The case of the UPTN, operating in the Upper Peninsula (UP) of Michigan since 1994, provides an instructive example of why it might be better to set realistic expectations up front. The UP of Michigan is an extremely rural area with an aging population, severe weather, and transportation challenges. Marquette General Health System (MGHS), the largest healthcare provider in the UP, was initially interested in telemedicine as a way to eliminate lost productivity as providers traveled back and forth to educational events.

The project manager who began investigating telemedicine recalled early efforts to stay "under the radar" with the preliminary attempts to secure pilot grant funding. While MGHS management did not outright discourage these efforts, they were clear that this would be nothing more than a test, a bridge to be crossed if and when grant funding was awarded.

These early pilot efforts and grants were viewed as a chance to test the technology, and the potential for telemedicine to help address needs that MGHS had identified. Rather than assuming a telemedicine application will solve specific problems and investing heavily in it, testing it first provides a more realistic model for building telemedicine and e-health capacity.

To provide an interesting counterpoint to MGHS's efforts with the UPTN, a second network was initiated in Michigan in the mid-1990s as the result of an organizational strategic plan. A grant supported the first three years of network operation, with long term sustainability addressed through significant network fees. This network has survived and succeeded with educational and administrative services, yet clinical applications have not developed and site expansion has been limited. Since this research did not explicitly study the second telemedicine network operating in Michigan, its troubles developing clinical applications and adding new sites could certainly be due to a variety of other factors. Still, the difference in strategy for initiating and building these two networks reflects a fundamental difference in the two operations, and could reasonably be believed to explain at least some portion of the networks' differing outcomes over time.

The UPTN has consistently grown within its means, gradually adding new services and independent sites. The alternative strategy – trying to do too much, too quickly – could be more prone to network collapse if system usage cannot justify the high costs of a larger system when grant funding expires.

Mackert and Whitten (in press) discuss a variety of reasons the UPTN has succeeded, but this realistic attitude in the early stages of the project can provide an important lesson to others. Successfully managing expectations must be a key managerial imperative in launching a new telemedicine or e-health system, particularly if the healthcare organization and its employees have little experience with such technology. The UPTN's early pilot work and eventual growth – which was similar to the TeleKidcare's small number of pilot sites and subsequent expansion – speaks to the benefits of "starting small," letting users achieve early success with realistic goals, and make it possible for the system gain momentum over time.

CONCLUSION

There are many factors that contribute to the eventual success or failure of telemedicine and e-health projects. Some of these can simply be beyond the control of healthcare organizations, such as a large regional or national telecommunication services provider not able to provide sufficient bandwidth to a remote facility. But many of the factors that determine the fate of such systems can indeed be controlled – or at least managed – by healthcare organizations, including organizational culture, work processes, and putting the proper incentives in place to encourage the adoption of new technology.

Effective management of telemedicine and e-health systems does not begin once the system begins to service end users. Quite the contrary, some of the most important decisions to be made in implementing such a system must be made long before the technology will help provide healthcare to patients. What is the best way to work with an external vendor in deploying the technology? How can end users of the system be involved in design and pilot testing? How should users be trained to use the system? How can the expectations of organization members and patients be managed effectively? Finding good answers to such questions will help set a new telemedicine project on the path to success.

Healthcare organizations certainly have good reason to consider telemedicine and e-health systems in determining the best ways to provide high quality healthcare under continuous pressures to reduce costs. Given the potential, it is easy to imagine how the system will operate when it is up and running smoothly. The important thing for project managers to recognize, however, is that it can be a long journey from deciding to initiate such a project to completion. Successfully managing the earliest stages of such an endeavor can make it much more likely that their final vision will indeed be realized.

ACKNOWLEDGMENT

Funding for this research was provided by United States Department of Commerce Technology Opportunities Program and the Michigan Department of Community Health.

REFERENCES

Aas, I. H. M., & Geitung, J. T. (2005). Teleradiology and picture archiving and communications systems: Changed pattern of communication between clinicians and radiologists. *Journal of Telemedicine and Telecare*, *11*(Suppl 1), 20–22. doi:10.1258/1357633054461589

Arrington, M. I. (2004). The role of the Internet in prostate cancer survivors' illness narratives. In P. Whitten & D. Cook (Eds.), *Understanding health communication technologies* (pp. 181-186). San Francisco: Jossey-Bass.

Bensink, M., & Irving, H. (2004). Telemedicine and pediatric palliative care. In R. Wootton & J. Batch (Eds.), *Telepediatrics: Telemedicine and child health* (pp. 225-232). London: Royal Society of Medicine Press.

Burgiss, S. G., Clark, E. J., Watson, H. W., & Haynes, B. K. (1997). Telemedicine for dermatology care in rural patients. *Telemedicine Journal*, *3*(3), 227–233.

Chen, K., See, A., & Shumack, S. (2002). Website discussion forums: Results of an Australian project to promote telecommunication in dermatology. *Journal of Telemedicine and Telecare, 8*(Suppl 3), S3:5-6.

Crowe, B., & Sim, L. (2004). Implementation of a radiology information system/picture archiving and communication system and an image transfer system at a large public teaching hospital: Assessment of a success of adoption by clinicians. *Journal of Telemedicine and Telecare*, *10*(Suppl 1), S25–S27. doi:10.1258/1357633042614339

Eysenbach, G. (2001). What is e-health? *Journal of Medical Internet Research*, *3*(2), e20. doi:10.2196/jmir.3.2.e20

Fox, S. (2006). *Online health search 2006*. Washington, D.C.: Pew Internet & American Life Project.

Greenwood, J., Chamberlain, C., & Parker, G. (2004). Evaluation of a rural telepsychiatry service. *Australasian Psychiatry*, *12*(3), 268–272. doi:10.1111/j.1039-8562.2004.02097.x

Grigsby, J., Rigby, M., Hiemstra, A., House, M., Olsson, S., & Whitten, P. (2002). The diffusion of telemedicine. *Telemedicine Journal and e-Health*, *8*(1), 79–94. doi:10.1089/15305620252933428

Heinzelmann, P., & Kvedar, J. (2004). Internet-based specialty consultations: A study of adoption challenges. In P. Whitten & D. Cook (Eds.), *Understanding health communication technologies* (pp. 261-267). San Francisco: Jossey-Bass.

Hopp, F., Whitten, P., Subramanian, U., Woodbridge, P., Mackert, M., Goldsmith, A., et al. (2005, April). *Opportunities and barriers in home telehealth: Perspectives from the Veterans Health Administration.* Paper presented at the Tenth Annual Meeting & Exposition of the American Telemedicine Association, Denver, CO.

Joel, F., Leong, W. M., & Leong, A. (2004). Digital imaging in pathology: Theoretical and practical considerations and applications. *Pathology*, *36*(3), 234–241. doi:10.1080/00313020410001692576

Keil, M., & Mann, J. (2000). Why software projects escalate: An empirical analysis and test of four theoretical models. *MIS Quarterly*, *24*(4), 631–664. doi:10.2307/3250950

Kinsella, A., Lee, K., & Ecken, B. (2004). Designing technology: A case of vendor and provider partnership. In P. Whitten & D. Cook (Eds.), *Understanding health communication technologies* (pp. 284-288). San Francisco: Jossey-Bass.

Kuulasmaa, A., Wahlberg, K. E., & Kuusimaki, M. L. (2004). Videoconferencing in family therapy: A review. *Journal of Telemedicine and Telecare*, *10*(3), 125–129. doi:10.1258/135763304323070742

Mackert, M., & Whitten, P. (2007a). The relationship between healthcare organizations and technology vendors: An overlooked key to telemedicine success. *Journal of Telemedicine and Telecare*, *13*(S3), S50–S53. doi:10.1258/135763307783247419

Mackert, M., & Whitten, P. (2007b). Successful adoption of a school-based telemedicine system. *The Journal of School Health*, *77*(6), 327–330. doi:10.1111/j.1746-1561.2007.00214.x

Mackert, M., & Whitten, P. (in press). Long term success of a telehealth network: A case study of the upper peninsula telehealth network. *International Journal of Healthcare Technology and Management*.

Mackert, M., Whitten, P., & Garcia, A. (in press). Evaluating e-health interventions designed for low health literate audiences. *Journal of Computer-Mediated Communication*.

Marquette General Health System. (2007). *Upper Peninsula Telehealth Network of Michigan*. Retrieved on January 26, 2007, from http://www.mgh.org/telehealth/index.html

May, C., Finch, T., Mair, F., & Mort, M. (2005). Towards a wireless patient: Chronic illness, scarce care, and technological innovation in the United Kingdom. *Social Science & Medicine*, *61*(7), 1485–1494. doi:10.1016/j.socscimed.2005.03.008

McManus, S. G. (2004). A telehealth program to reduce readmission rates among heart failure patients: One agency's experience. *Home Health Care Management & Practice*, *16*(4), 250–254. doi:10.1177/1084822303262542

Mireskandari, M., Kayser, G., Hufnagl, P., Schrader, T., & Kayser, K. (2004). Teleconsultation in diagnostic pathology: Experience from Iran and Germany with the use of two European telepathology servers. *Journal of Telemedicine and Telecare*, *10*(2), 99–103. doi:10.1258/135763304773391549

Nielsen-Bohlman, L., Panzer, A., & Kindig, D. (Eds.). (2004). *Health literacy: A prescription to end confusion*. Washington, D.C.: National Academy of Sciences.

Pew Internet and American Life Project. (2007). *E-patients with a disability or chronic disease*. Washington, D.C.

Raman, B., Raman, R., Raman, L., & Beaulieu, C. F. (2004). Radiology on handheld devices: Image display, manipulation, and PACS integration issues. *Radiographics*, *24*(1), 299–312. doi:10.1148/rg.241035127

Rizzo, A. A., Strickland, D., & Bouchard, S. (2004). The challenge of using virtual reality in telerehabilitation. *Telemedicine Journal and e-Health*, *10*(2), 184–195. doi:10.1089/tmj.2004.10.184

Schloman, B. (2003). Quality of health information of the Web: Where are we now? *Online Journal of Issues in Nursing*, *8*(1), 26–34.

Whitten, P., & Cook, D. (1999). School-based telemedicine: Using technology to bring health care to inner-city children. *Journal of Telemedicine and Telecare*, *5*(S1), 23–25. doi:10.1258/1357633991932423

Whitten, P., Cook, D., Kingsley, C., Swirczynski, D., & Doolittle, G. (2000). School-based telemedicine: Teachers', nurses', and administrators' perceptions. *Journal of Telemedicine and Telecare*, *6*(S1), 129–132. doi:10.1258/1357633001934429

Whitten, P., Doolittle, G., Mackert, M., & Rush, T. (2003). Telehospice carries end-of-life care over the lines. *Nursing Management*, *34*(11), 36–39. doi:10.1097/00006247-200311000-00015

Whitten, P., Kingsley, C., Cook, D., Swirczynski, D., & Doolittle, G. (2001). School-based telehealth: An empirical analysis of teacher, nurse, and administrator perceptions. *The Journal of School Health*, *71*(5), 173–180.

Whitten, P., & Kuwahara, E. (2003). Telemedicine from the payor perspective. *Disease Management & Health Outcomes*, *11*(5), 291–298. doi:10.2165/00115677-200311050-00002

Whitten, P., Love, B., Buis, L., & Mackert, M. (in press). Health education online for individuals with low health literacy: Evaluation of the diabetes and you Website. *Journal of Technology in Human Services*.

Wittson, C., Affleck, D., & Johnson, V. (1961). Two-way television group therapy. *Mental Hospitals*, *12*, 22–23.

Zarcadoolas, C., Pleasant, A., & Greer, D. (2006). *Advancing health literacy: A framework for understanding and action*. San Francisco: Jossey-Bass.

KEY TERMS AND DEFINITIONS

E-Health: Health services delivered through the Internet and related technologies.

Health Literacy: The ability to obtain, process, and then act appropriately on health information.

Telemedicine: Provision of healthcare services at a distance via telecommunication technology.

This work was previously published in Handbook of Research on Information Technology Management and Clinical Data Administration in Healthcare, edited by A. Dwivedi, pp. 433-446, copyright 2009 by Medical Information Science Reference (an imprint of IGI Global).

Chapter 2.8

Shared Healthcare in a Regional E-Health Network

Kari Harno
Helsinki University Central Hospital, Finland

ABSTRACT

Healthcare information exchange is transforming the practice and structure of healthcare delivery. This chapter introduces the building of a regional e-health network between public healthcare providers as well as the necessary legal foundation and governance for this successful deployment in a Finnish Hospital District. An overview is presented of prerequisite building blocks, such as policies supporting the knowledge-intensive e-health services and the creation of a partnership between shareholders enabling regional e-health delivery. The roadmap to a national e-health network is paved on the premises of these experiences and lessons learned are transferred to described concepts when migrating to a national e-health network. Understanding these principles and critical success factors (i.e., the role of stakeholders, governance, and financing) is essential for guidance to implement viable cross-organizational information exchange. In this context ICT not only fulfills the objective of cost containment, but also creates positive impacts on patient care and service quality.

DOI: 10.4018/978-1-60566-356-2.ch024

BACKGROUND

Knowledge is fueling growth and social development in every region of the world. Finland has successfully evolved from a resource driven economy to a knowledge driven economy spearheaded by information and communication companies such as Nokia. However, it is the use of ICT rather than its production that is decisive in the long-term economic growth.

The transformation may be explained by global financial and economic restructuring, but also by less typical national policies including a strong welfare state and in particular the very strong emphasis on education (Dahlman, 2005). The welfare state is not a unitary concept, but rather a mixture of values, accomplishments and aspirations varying somewhat from country to country (Giddens, 2007). The traditional welfare state is essentially a collective insurance system, which has been slow in adapting to changes initiated by the knowledge driven economy and specifically the use of information technology.

Health policies in most countries have been more or less oriented to here-and-now problems as they occur and health care provider interests tend to prevail over those of clients. Present day healthcare is provided by information-based organizations requiring clear, simple common objectives that translate into actions, so as to optimize the joint performance.

The productivity of the public sector, organized and performing in this fashion, has been declining in the 21st century (Mäkitalo & Ruottinen, 2006), although productivity is the key to meet the increasing financial requirements of the welfare society that stem from the consequences of the demographic changes in Europe.

In the post-industrial welfare society we should be expecting empowered clients through a series of mechanisms, such as availability of information, personalization of services and choice (Giddens, 2007). The average person's ability to access data and communicate electronically is proliferating exponentially. In Finland, 80% of the population is using the Internet and every second citizen owns a PC. Although more than 100 personal health records (PHR) and related technologies have proliferated in the United States and abroad, only a small proportion of the population uses PHRs (Connecting for Health, 2006). Therefore, this leapfrog change to consumer directed healthcare is expected to take some more time and in the meantime we need to adopt provider-sponsored clinical data networks in healthcare.

TRANSFORMATION OF HEALTHCARE WITH ICT

It is widely acknowledged that one of the greatest challenges facing healthcare information technology today is the effective sharing of clinical and administrative information among healthcare providers. Although timely sharing of patient data has been slowed down by issues such as security, privacy and confidentiality, lack of standards has created obstacles to achieving interoperability between different information systems.

Information Sharing in Networks and Healthcare Practice

Knowledge-based organizations are composed mainly of specialists who develop their own performance through feedback from colleagues and also from clients. Hospital care in university clinics mirrors this kind of knowledge-intensive service model with highly educated specialists and coordinated practice. Members of these networks are separated from primary care physicians through organizational boundaries, but also to some degree by practice and identity that divide.

Looking at learning we see the analogy in two types of work-related networks that, with the boundaries they inevitably create, are critical for understanding learning, work, and the movement of knowledge (Brown & Duguid, 2002). First, there are the networks that link people to others whom they may never get to know but who work on similar practices. These are the "networks of practices" and they are notable for their reach which may be fortified by information technology. There is some reciprocity in consultations across such a network. Although these networks produce little new explicit knowledge, they are operationally very efficient in supplementing tacit and collective learning to this process.

These networks represent practices between hospital and primary care physicians or other professionals. Healthcare information sharing by ICT is most suited to support, develop and strengthen the networks of practice. However, healthcare has been slow in undertaking such exchanges because supporting reach and information sharing extracts resources and knowledge from hospital care and results in the reduction of demand for hospital services. Therefore, such loosely coupled networking systems may make the hospital vulnerable and therefore formal agreement and strategic alliance negotiations are necessary early on.

Second, there are the more tight-knit groups formed, again through practice, by people working together on the same or similar tasks. These are what we call "communities of practice". Here coordination is tight, ideas and knowledge is distributed in productive and innovative fashion. While information technology and information sharing is very good in reach, it may suit less well to the dense interaction already in place between practices in the same clinic.

New Integrated Models for Organizations

According to Angelo Rossi Mori (2008), two approaches to innovation are possible in healthcare (http://emea.himss.org/enewsletters/index.htm#f1). The first deals with healthcare informatics and the second approach stems from new organizational models for an economically sustainable evolution of healthcare, such as chronic disease management. The ICT solutions should cope with continuity, collaboration and communication among the actors and this will support the synchronization of activities across facilities.

The traditional functional structure in health care provider organizations should first shift to a structure that medically integrates the care of patients with particular medical conditions and is able to coordinate care over the continuum (Porter & Teisberg, 2006). This is what health information exchange de facto is presently capable of advancing and a growing number of providers are moving to this model, although some argue that this will tend to fragment health care delivery.

Why has Transformation in Healthcare Been Slow?

Tax-funded health care systems are considered easier for the government to steer and reform. However, some core problems hindering the transformation stem from structural changes. Healthcare in Finland was radically decentralized in 1993 when central government relinquished to the municipalities many of its regulatory and management powers in relation to the delivery of health and social services, and changed to a non-earmarked, block-grant system for providing state financial support to local government (OECD, 2005).

Responsibility for healthcare lies in the hands of the municipalities, making the national government dependent on their cooperation. It is the 300+ municipalities, and the 20 hospital districts which represent them, which have been given the main lead in the financing, provision and management of health. Decentralization on the scale found in Finland strengthens local decision-making and ownership at the cost of problems in diseconomies of scale and lack of expertise. In the field of ICT it may be expected to result in lack of common definitions and standards, lack of national data base, lack of national transparency and comparability and barriers to diffusion of some innovations (OECD, 2005).

Barriers in healthcare may also be seen to be due to cultural differences between professional groups and as resistance to development of new organizational models (Harno, 2006). The proposed regional technologies would have allowed the construction of a new working environment, supporting the collaboration between multidisciplinary team members (patient and professionals), defining common care targets according to predefined and stratified plans for patient management and providing access to tools to optimise the resources available. However, the municipalities could not come to terms at this stage with the hospital district on governance and funding of the new registry.

The municipalities were free to invest in technology at a time, when local ICT progress and interoperability issues would have demanded guidance. Although the level of investments in information and communication technologies has been relatively low (approximately 2% of all expenditure) in the healthcare sector, the lack of direction and standards led to a broad spectrum of one-off systems with little technical interoperability. The first ICT strategy (Ministry of Health and Social Welfare, 1995) underlined the importance of creating seamless care between providers, but lacked an action plan and was issued too late to halt the progress in municipalities initiated already in 1981.

As a consequence of this, by 2001 diverse electronic patient record systems were in active use in 63% of primary care providers. In 2005 96% of primary healthcare centres were using electronic patient records and it was the main way of recording patient data in 99,4% of them (Hämäläinen, 2007). Even in the private health sector 88% of the clinics were applying EPRs in daily practice. By the end of 2007, the coverage of electronic patient records in public primary and specialized care organizations in Finland was expected to approach 100%.

GOVERNMENT ACTIONS IN FINLAND

The role of the state as the norm-setting and regulatory authority has been strengthened during the 21st century and the responses in different nations to healthcare challenges are also slowly but surely converging (Busse & Schlette, 2007). Examples of this are the introduction of country-wide hospital plans, as well as the national IT plan ARGE ELGA in Austria (Hofmarcher & Rack, 2006) and the increase in state-level legislative action regarding health IT in the USA (http://www.ehealthinitiative.org/2007HIESurvey). While there was virtually no legislation at the state level related to health IT prior to 2005, in 2005 and 2006 thirty-eight states introduced 121 bills specifically focused on health IT, and of those 36 bills passed into law in 24 states. Since the beginning of 2007 a total of 208 bills have been introduced across all 50 states that refer to the adoption or implementation of health IT.

A specificity of the Finnish model in rapid structural transformation beginning in the mid nineties has been the early application of a systems view, i.e. acknowledgement of the importance of interdependencies among stakeholders in various stages of innovation process and funding these simultaneously. In healthcare such instruments have been only recently assigned (Kuitunen & Haila, 2007) and national investors of healthcare are currently coordinating their efforts and setting the stage for emulating the innovative business environments into healthcare.

In Finland, the Act on Experiments with Seamless Service Chains (2000) provided the legislative foundation for the building of regional co-operation in matters of information management, with the aim that information concerning the client in social welfare or healthcare can be transferred electronically from one organization to another. This provisional Act included technical requirements for the regional *e*Health network, for citizen access services by an *e*Card, and requirements for applying care managers and seamless chains in health and social care.

As a result of the Act on Seamless Service Chains the design of a regional record locator service (RLS), a database that originated in the networking project Macropilot in Satakunta (1999), was launched. In HUS the service was originally developed as part of an EU funded Inter-Care project together with participating vendors. Although the project system was originally in use since 2001, the present version was implemented in 2003. The Government provided start-up funding for the connecting organizations in the piloting hospital districts such as the Helsinki and Uusimaa Hospital District and its UUMA project in the Uusimaa province.

CASE UUMA: HEALTHCARE INFORMATION EXCHANGE

The Hospital District of Helsinki and Uusimaa comprise 23 hospitals in the province of Uusimaa, which includes the capital city Helsinki, in Southern Finland. It includes three leading academic and research hospitals in Finland. As a joint authority it provides specialized care services to the 1.4 million citizens in its 32 member municipalities. The Hospital Information System and *e*Business applications in use within the Hospital District are described in a sector report by *e* – business w@tch in 2006 (www.ebusiness-watch.org).

One of the present academic hospitals (Peijas Hospital) was digitalized already in 1990 and by the end of 2008 the electronic patient records project (ESPA) will have accomplished that health care information is accessible from any of the 15.000 PCs or by any of the 22.000 health care professional users in the Hospital District. Although municipal health centres were digitalized earlier, most of them were applying different electronic patient records in their care. The promotion of regional procedures using ICT was seen necessary to support continuity of care.

Definitions

Integration has been defined by the HIMSS EHR Implementation Toolkit Task Force as the process of bringing together related parts into a single system in order to make various components function as a connected system (HIMSS, 2008). The degree of integration may vary and seven integration levels have been identified. Our focus has been creating comprehensive regional health information exchange (RHIOs), i.e. legally separate organizations sharing encounter information with each other and approaching high degree of interoperability. Based on the degree of interoperability we have achieved level 6.

Interoperability means the ability of information and communication technology (ICT) systems and of business processes they support to exchange data and to enable the sharing of information and knowledge (http://www.i2-Health.org/) originating from the European Interoperability Framework (European Interoperability Framework, 2004).

Messaging Processes Integrating Primary and Secondary Care with *e*Referrals

We have set up a wide-area referral network between primary care and three university hospitals. This network was initially launched in 1990, but it took several years to promote significant exchange of information beyond the conventional media. In 2002 67.000 *e*Referrals were transferred between the Helsinki University Hospitals and primary care. The solutions extended from the initial VPN use to EDIFACT standard and finally transition to standardized HL7 messages utilizing C-way message transfer systems (HUSway) through a single Network Access Point (HUSnap). In 2007, 200.000 *e*Referrals and approximately the same range of discharge *e*letters were exchanged between primary and secondary care providers.

The electronic referral not only speeds up the transfer but also offers an option for communication between the primary care physician and the hospital specialist. By sharing information and knowledge remote eConsultations between primary and secondary care physicians evolve into a new virtual working space for integrated delivery of *e*services between the health care providers. Besides transferring data or information between providers, networking partnerships have to be structured by mutual agreements.

The underlying model of the electronic referral process is:

- The referrer initiates an e-request
- The organization receives it
- The organization allocates it for reply
- The responder replies to the initiator

The *e*referral module has been in production for over ten years and has gone through extensive assessment studies by us (Harno, 2000) or analyzed by third parties (Roine, 2001; Wootton, 2001). In these studies the *e*referral system has decreased the need for secondary care services by reducing first visits to outpatient clinics by 36% and in less urgent cases by 50%. The system allows more patients to be treated at less expense. Because all patients are thoroughly examined beforehand, the numbers of repeat visits as well as direct costs remain lower. We have shown convincingly that the interactive use of an *e*Referral system improves access to an adequate level of care and even large scale use results in more timely appointments. By prospective follow-up studies we have been able to prove that the quality of health care using remote *e*Consultations is consistent with outpatient face-to-face visits.

Regional *e*Health Network

The core of the regional *e*Health service is the Navitas record locator service (Harno & Ruotsalainen, 2006). The record locator service (RLS) is a service that queries the locations of patient records within the eHealth network. The purpose of the RLS is to allow the physician or other healthcare professional to retrieve data on a patient from other institutions that the patient has visited. The physician sends a query to the RLS, which returns a list of record locations acquired from the patient information system, but not the data itself. The view provided by the RLS is a read-only view, structured in a user-friendly and visual way.

At the first stage, the RLS only informs the doctor that her patient has medical records at one or more institutions. The contents of these records are not revealed by the RLS. Retrieval of data contained in the electronic health records is a separate process of the RLS and requires the patient's informed consent. This exchange of information occurs directly between the requesting physician and the institution that stores the record by clicking a link, a window will open up to display the actual clinical information.

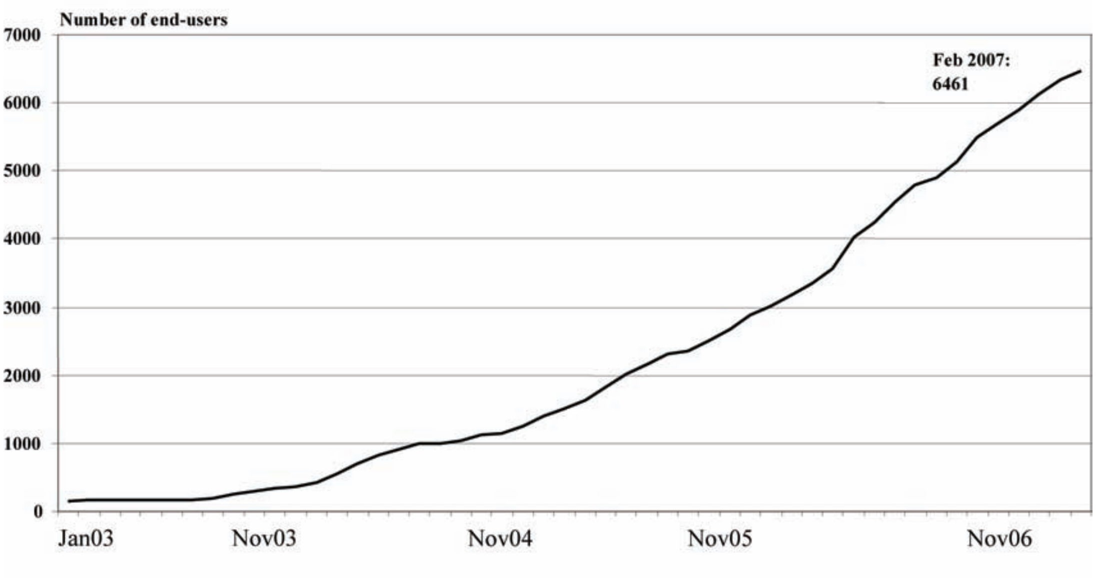
The RLS is a centralized database containing links to patient data stored in their legacy systems. Provider access is possible by web browsers and patient information includes (primary care/hospital) visits, critical data, EOE (laboratory and imaging), images and reports, laboratory results, referrals and discharge letters. All data is sorted according to social security coding, which is standard procedure in Finland. Standard API connections between primary care information systems and the RLS data are installed. The documents are produced in CDA R1, more recently in CDA R2 format, and messages transferred in a standard pattern (XML/HL 7).

Each participating organization has its own electronic health record. Besides the EHR, HUS has many other clinical information systems e.g. the laboratory system and HUSpacs, which have all been connected to the RLS. At the moment there are 15 different patient information systems in some 55 organizations connected to the RLS. A specific adapter software has been installed locally into each of the systems through which links are fed into the RLS.

Navitas has a regional user database and centralized authentication and authorization services; this enables the participating organizations to have complete control over their own users. The health care professionals can access Navitas from their personal workstations using a web browser. The data transfer is encrypted and only private, dedicated networks are used to transmit the data.

The service was originally launched in 2003 and presently most (29/31) of the municipalities in the Hospital District, as well as 24 HUS hospitals, are connected to the RLS and apply it for regional exchange of information. Currently there are 6.800 professional users in both secondary and primary care (Figure 1). Two private health care clinics and non-profit hospitals are connected to the RLS for eReferrals, discharge letters and image exchange. In addition, two other Hospital Districts are linked with the Hospital District of Helsinki and Uusimaa through the eReferral and discharge system.

Figure 1. Cumulative increase of end-users in health care provider organizations of the hospital district of Helsinki and Uusimaa since the first implementation of the Regional eHealth Network in January 2003



Health Information Exchange

The municipalities and hospitals were not initially networking except when referring patients to the hospitals or when mailing discharge letters to primary care. The return of discharge summaries was meagre and varied according to specialty from 10% to 50% return for referred patients, but increased to 100% after the deployment of the *e*Referral system. Our preliminary study demonstrated that multi-professional teamwork and secure information flow in the network was needed for community patients with several health problems (Valta, 2003). The most relevant information was the patient medical history, contact information, information support for home care and availability of services.

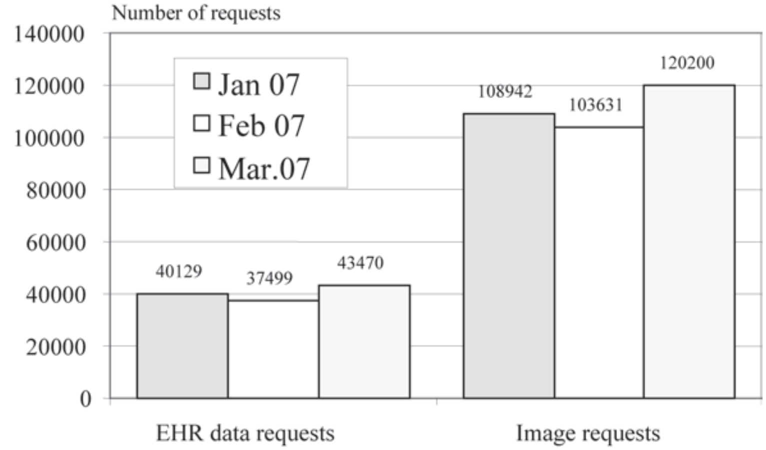
In 2007 roughly 50% of the data exchange in the Hospital District between primary care and RLS consists of imaging. The monthly volume of images transferred is 140.000 and the rest of the RLS information exchanged was distributed among the EHR information available through the RLS with over 60.000 monthly requests (Figure 2). Over 7.000 daily HIE requests were recorded. The technical and non-technical barriers appear to be overcome, since the downtime for the regional network in 2007 was less than 99, 99%. However, downtime of legacy EPR systems inaccessible during those intervals was not included.

Recently, the *e*Health Initiative reported that in 2007 34% of the respondents were exchanging laboratory data and 32% data related to outpatient episodes. Exchange of emergency department episodes, outpatient laboratory results, and radiology results are 30%, 28% and 28%, respectively.

Funding and Business Case Development

The governmental funding was intended for investments on the infrastructure, but not for operational costs. This funding solved our initial concern in 2002, which was still four years later in the USA the most significant challenge for health information exchange initiatives. 90% of

Figure 2. Number of monthly requests for healthcare information exchange by healthcare professionals to the regional Record Locator Service segmented according to their distribution for either images in the regional PACS archive or EHR data in legacy systems.



the organizations participating in the fourth annual survey of health information exchange at the state, regional and local level perceived creating sources of upfront funding to be either a very or moderately difficult challenge.

The creation of information exchange in health care requires both capital for investments and means to support the financial requirements of ongoing operations. To achieve a national health information network in the USA would cost according to expert estimates $ 156 billion in capital investment over 5 years and $ 48 billion in annual operating costs (Kaushal, 2005). Approximately two thirds of the capital costs would be required for acquiring functionalities and one third for interoperability.

The start-up support uncovered the next challenge – developing a sustainable business model. In the USA many communities are unable to collaborate, because of intense regional competition, disinterest by key stakeholders and overtly fragmented or large, local healthcare markets (Glaser, 2007). This may appear obvious within a market-oriented healthcare system, where reimbursement system rewards both volume and fragmentation and serves as a disincentive for sharing health information across healthcare stakeholders.

However, even the municipalities responsible for public provision and funding of healthcare were concerned about the business model for the regional *e*Health network. Although there was some evidence that implementing an *e*Referral and *e*Consultation system improves health care processes between secondary and primary care and contains health care costs (Harno, 2000), it was still unproven whether the regional *e*Health network would be able to reduce operational costs and improve clinical performance.

The paradise of shared information and a more egalitarian working environment just wasn't there in the beginning, because standards support for HL 7 messaging between EPR's and record locator services, on the one hand, and patient data in hospital information systems, on the other hand, were partly missing. This was not inspiring initial pilot organizations to invest, because there were only limited returns for their costs to be expected.

The business model for the regional eHealth network had to be based on transactional cost calculations originally made for the picture archiving system (PACS) implemented in the

Hospital District. HUSpacs, the PACS of the Hospital District of Helsinki and Uusimaa (HUS) is one of the largest regional PACS installations in the world. In total, over 1,000,000 examinations are handled per year, representing around 20 terabytes of imaging data completed on about 300 connected modalities.

Information technology was driving the transaction costs of centralized image storage and transfer down to such an extent that regionalizing health care information exchange could be estimated to contain costs. Radiology in all the hospitals of HUS was transformed filmless by 2004. Since the pricing of film development and delivery to primary care became more expensive than adding user licenses to the regional eHealth network for viewing these images, the business case was proven to be healthy and sustainable.

The funding is no longer dependent on non-operating revenue from the Ministry of Social Affairs and Health, and the financial sustainability appears viable, since it derives its revenues for ongoing operations from HUS (29%) and municipal primary care (71%).

It is therefore somewhat surprising that the viability of RHIO 1.0 in the USA appears questionable, because the majority of the about 200 RHIOs is expected to vanish in the years ahead, unable to address the challenges (Glaser, 2007). It is anticipated, that the majority of the clinical data exchange in RHIO 2.0 will be the result of targeted initiatives undertaken by organizations that have very specific business goals.

Low-hanging fruits from economic scale benefits to public health care providers were reaped by centralizing imaging and laboratory services in HUS, i.e. all metropolitan area municipal laboratories have been transformed to point-of-care testing and sample collecting points, while sample analyzes have been centralized and automated in HUS laboratories.

Horizontal integration by concentrating specialized services like orthopedics and urology within the three university hospitals was accomplished three years after the electronic health record was first deployed in HUS. This change was pursued not only for cost containment, but foremost to improve the quality of care, since surgeons need a certain number of operations to maintain skill levels in operational procedures.

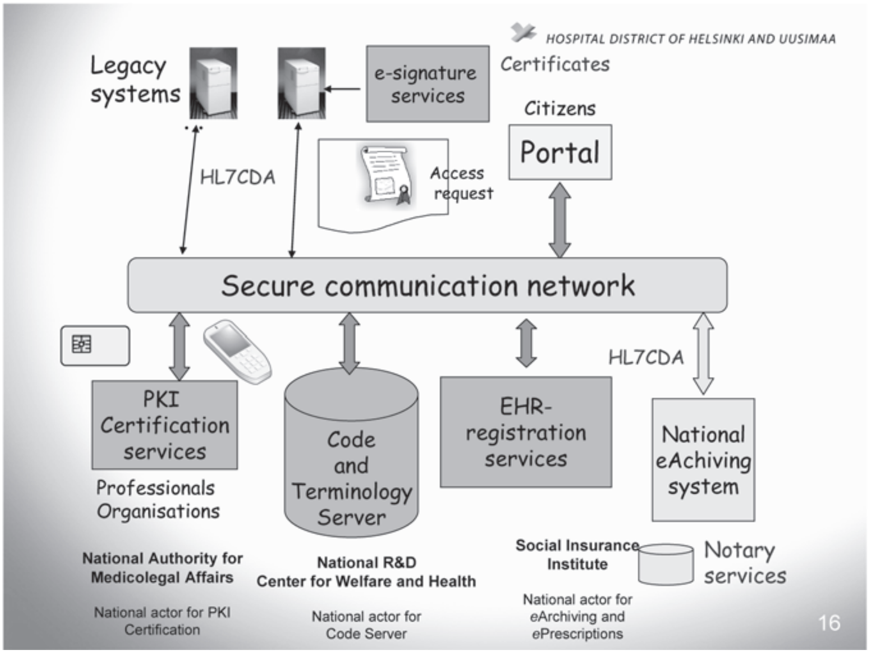
Now four years after the *e*Health network was launched the metropolitan municipalities are planning to allow their citizens to visit the closest emergency or laboratory unit because healthcare information exchange no longer inhibits these processes. Patient-centered processes are finally substituting traditional organizational focused services with the aid of healthcare information exchange.

Governance

The Regional Health Information Organization (RHIO) is the provider-centric organization creating and managing the regional healthcare data exchange in regionalized networks. These networks are often referred as RHIOs and this would connect multiple provider institutions in a region. The collaboration of regional healthcare stakeholders come together to address issues of governance, funding, privacy policies, data sharing agreements and the management of the exchange technology infrastructure (Lang, 2007) .

The essential building blocks for the creation of a RHIO between stakeholders, i.e. sufficient social capital and ability, are needed to create partnerships and effective working relationships. In Finland, the Act on Seamless Service Chains regulated data sharing and privacy policies. Formalizing the governance within a loose group of collaborators (in 2001 five municipalities and the Joint Authority) was pursued by a contractual arrangement. This contract laid out common values and policies to bond the parties, created a framework for the governing bodies and addressed the funding between stakeholders. However, consensus had to be achieved between the stakeholders, because the RHIO possessed

Figure 3. A schematic description of the architecture for the Finnish National eHealth Network



no independent decision making power over the municipalities or Joint Authority.

NATIONAL HEALTH INFORMATION EXCHANGE

Steps Taken by the National Health Project 2002-7

To promote better access to patient information, the Ministry of Social Affairs and Health has produced national specifications on the requirements for content and structure of information systems concerning open interfaces, data protection, information security and architecture. Security, privacy, authentication, and system management were centralized. Local providers submit data to, and request data from, the central repository (national *e*Archive) using the centralized network (secure communication network) with 24/7 availability (Figure 3). The service-oriented architecture (SOA) and Web services form the network-interaction standards.

Effective sharing of clinical and administrative information had been progressing slowly, but so far no uniform presentation of data enabling disparate stakeholders to apply their legacy systems and have consistent presentation of data existed due to lack of common terminology and different classifications. Therefore, the National Health Project also focused on national certification and distribution of common classification and codes, as well as on uniformed structured core data in EPR's (Häyrinen, 2004).

The goal for semantic interoperability requires means of moving granular data and a framework to fully understand information. The core data refer to uniformly defined structured data contained in the patient records. These data may be presented in a specified form and encoded using classifications, nomenclature and glossaries that are currently in general use.

The core data are created during treatment events and may be used as a link to clinical data, to view the essential information on the patient, to include in discharge summaries or treatment plans, to create certificates or to link with decision-support-systems. The uniformed structure allows sharing of this information with other providers and building a longitudinal patient record. All vendors in Finland are obliged to include the uniformly structured data set in their products by the end of 2008.

The data elements included in this phase consist of patient identifier, care provider identifier, treatment period and event identifier (seamless chain identifiers), problems and diagnoses list, health risk factors (allergies, smoking and alcohol use), physiological measurements (for example blood pressure, weight), examinations and procedures, medications etc. The list of structured data is intended to be expanded in 2010 to include uniform datasets for dentists, diabetes and cardiovascular disease prevention.

The uniformly structured data builds upon the Clinical Data Architecture (CDA), which Finland adopted as Release 1 form in 2000 and experiments are on way with distributed decision support using CDA Release 2. The national *e*Health network relies on HL7 CDA Release 2, which is a limited subset of HL7 V3 and builds upon other HL7 standards, including HL7 Reference Information Model (RIM).

CDA documents contain data that can be readily integrated into document management systems and record locator services. These documents with the most pertinent information on current and past health status will form the basis for sharing patient information.

Legal Issues and National Actors

Specifications of the national health information architecture and services were drawn in 2006. Most entities of functional requirements such as authentication, authorization, locating health information, auditing and logging were embedded in legal issues which were simultaneously prepared. The government's bill on the processing of personal data relating to health care was passed and came into force in July 2007. The law (http://www.finlex.fi/fi/laki/kokoelma/2007/20070023.pdf) sets the foundation for the deployment of the National Care Records Service and the National *e*Prescription and Transmission Service by 2011.

Three National Actors were appointed responsible for these services: The Social Insurance Institute as actor for *e*Archiving and *e*Prescriptions, The National R & D Center for Welfare and Health as actor for codes and terminology and National Authority for Medicolegal Affairs as actor for PKI certification for professionals and organizations. It will be mandatory for public and private sector healthcare providers to connect to the services from their legacy systems which need to be certified before the patient records will be archived into the national archive.

Limited projecting of *e*Prescriptions between two municipal health centres and local pharmacies will be initiated in August 2008 and in 2009 health records may be transferred between piloting health care providers and *e*Archive.

The national *e*Archive will disclose records if necessary legal and other conditions exist. The centralized eArchive as the point of record sharing in Finland needs careful security and data protection for secure transactions. For identification of health professionals the Public Key Infrastructure (PKI) on a national basis has been implemented for testing in several hospitals. Later a role based access control service will be added. The data structure of data sent to the eArchive should include a new metafile with multi-faced security policy. This metafile should consist of the following information:

- Security policy information
- Unique identification of data producer, patient and organization

- Context and purpose information of the data
- The nature of data
- Information for purposes data can be disclosed
- Information when patients consent is required for disclosure of data

Other National Projects

The National Public Health Institute has started a project to build a health information portal for citizens. The objective is to make online health education and expert advice available to citizens. Citizens will be empowered by providing access to their own clinical information stored in the centralized *e*Archive and unlimited right to check who, when and why, has accessed his or her data. This access is made available by the Social Insurance Institute using the WEB and the citizen portal. The citizens will be more informed of their health and this may result in to an increasing demand for personalized health services.

Finally, this opens an option for a personalized health record (PHR) to be connected with the national eArchive. The services and architecture have been specified, but no decisions have yet been made on the networked PHRs and their role as tools for transformation.

Migration Policies

The process to determine the migratory procedures from regional to national health information network application use is currently under construction and will be finished by July 2008. After necessary conclusions specifications will be drawn. However, the process of information sharing and archiving of EPR documents will be enabled by the centralized *e*Archive instead of the regional eHealth network.

The RLS may be transformed to a centralized indexing service and a shift in the administration of patients' consents for sharing information within the *e*Health Network is to be expected. The role of the regional network could be seen more as an enabler in healthcare delivery of services in orchestrating processes and work flow.

Certification criteria have been adapted by the National R & D Center for Welfare and Health to regulate clinical software document transaction from legacy systems into the National *e*Archive. Clinical software systems should, however, be supervised locally, although centralized procedures have been recommended for systems that pose high clinical risk and provide limited opportunity for competent human intervention (Miller & Gardner 1997).

NEXT STEPS AND FEATURES

The updated strategy and communication architecture for healthcare drawn by the Ministry of Social Affairs and Health has set targets for semantic interoperability. All Finnish EHR-systems must implement a common core data set and communication between EHR-systems will be based on a standardized message system (e.g. HL7CDA-messages, XML-formats and SOAP envelopes).

The purpose is to create a health space where information may be shared safely in multiple care settings and improve both outcomes and safety. Structured text capability in a RAND research project was shown to have the potential to reduce adverse drug events, increase preventive care, increase adherence to evidence based medicine and improve disease management (Benge, 2008). The target is not to increase amounts of information, but rather leaving increasing amounts un- or underrepresented. Efficient communication relies on core data sets with less data, but more contexts.

Personalized care represents the next opportunity to achieve gains when evidence-based treatments are customized to the patient at a deep level of specificity, and behaviour changes generated by decision support delivered at the point of care (Krohn, 2008). To bridge this gap in analytic depth and accuracy, the industry is turning to predictive informatics (PI). For PI to personalize the healthcare, capturing semantically correct data from every relevant source into a centralized data repository are the first steps.

As soon as health care as a whole takes the step from information- to knowledge-based organization, its decision processes, management structure and way to work has to change. At the moment, generation of knowledge models in healthcare has been slow, but the advent of personalized medicine may be anticipated to progress more readily when the knowledge base of genomics is heading our way.

The Nobel Prize-winning economist Ronald Coase developed the notion of transaction costs in the 1930s and according to this theory when transaction costs become low enough, the glue between organizations will dissolve (Brown & Duguid, 2002). Since information technology is relentlessly driving these costs down we may be expecting less formal organizations and more professionals in market relations with citizens.

REFERENCES

Benge, J., Beach, T., Gladding, C., & Maestas, G. (2008). Use of electronic health record structured text and its payoffs. *Journal of Healthcare Information Management*, *22*, 14–19.

Brown, J. S., & Duguid, P. (2002). *The social life of information.* Harvard Business School Publishing Corporation, USA.

Busse, R., & Schlette, S. (2007). *Health policy developments 7/8, focus on prevention, health, and aging, new health professions.* Verlag Bertelsmann Stiftung, Gutersloh.

Connecting for Health. Markle Foundation. (2006). *Connecting Americans to their healthcare. A common framework for networked personal health information*. Retrieved from http://www.connectingforhealth.org/

Dahlman, C. J., Routti, J., & Ylä-Anttila, P. (2005). *Finland as a knowledge economy. Elements of success and lessons learned*. Washington, D.C.: The International Bank for Reconstruction and Development/The World Bank. *e*–business w@tch. (2006). ICT and e–business in hospital activities, ICT adoption, and e-business activity in 2006. *Sector Report*, *10*, 142–147.

European Interoperability Framework. (2004). Interoperable delivery of European e-government services to public administrations, business, and citizens (IDABC). *Program of the European Commision, 5*.

Finnish Legislation. (2007). *Law on the processing of personal data relating to social- and health-care.* Retrieved from http://www.finlex.fi/fi/laki/kokoelma/2007/20070023.pdf

Giddens, A. (2007). *Europe in the global age*. Cambridge, UK: Polity Press.

Glaser, J. (2007). The advent of RHIO 2.0. *Journal of Healthcare Information Management*, *21*, 7–9.

Hämäläinen, P., Reponen, J., & Winblad, I. (2007). *E-Health of Finland.stakes*. Helsinki. Retrieved from www.stakes.fi/verkkojulkaisut/raportit/R1-2007-VERKKO.pdf

Harno, K. (2006). Perspectives in regional disease management and the role of regional data systems. In Z. Kolitsi (Ed.), *Transforming healthcare organizations, regional healthcare service network, interreg IIIc programme* (pp. 46-52). Interreg IIIc, Helsinki University Press.

Harno, K., Paavola, T., Carlson, C., & Viikinkoski, P. (2000). Improvement of healthcare process between secondary and primary care with telemedicine–assessment of an intranet referral system on effectiveness and cost analysis. *Journal of Telemedicine and Telecare*, *6*, 320–329. doi:10.1258/1357633001935996

Harno, K., & Ruotsalainen, P. (2006). Sharable EHR systems in Finland. In L. Bos, et al. (Eds.), *Medical and care compunetics, 121*, 364-370. The Netherlands: IOS Press.

Häyrinen, K., Porrasmaa, J., Komulainen, J., & Hartikainen, K. (2004, March 2). *Uniform structured core data in an electronic patient record, final report.* University of Kuopio and Association of Finnish Local Authorities.

HIMSS. (2008). Building enterprise information sharing: A collection of case studies. *A White Paper by HIMSS EHR Implementation Toolkit Task Force*.

Hofmarcher, M. M., & Rack, H. M. (2006). Austria: Health system review. *Health Systems in Transition*.

Kaushal, R., Blumenthal, D., Poon, E., Jha, A. F. C., Middleton, B., & Glaser, J., & theCost of National Health Information Networking Group. (2005). The costs of a national health information network. *Annals of Internal Medicine*, *143*(3), 165–173.

Krohn, R. (2008). Predictive informatics. *Journal of Healthcare Information Management*, *22*, 8–9.

Kuitunen, S., & Haila, K. (2007). *On the interfaces of health, commerce, and innovation policies. Assessment of the technology program report*. Finland: TEKES.

Lang, R. D. (2007). Provider-sponsored clinical data networks. RHIO values, issues, and concerns on a smaller Scale. *Journal of Healthcare Information Management*, *21*, 2–5.

Mäkitalo, R., & Ruottinen, J. (2006). Fiscal framework and productivity of services. In *Proceedings of the Ministry of Finance, 74*.

Miller, R. A., & Gardner, R. M. (1997). Summary recommendations for responsible monitoring and regulation of clinical software systems. *Annals of Internal Medicine*, *127*, 842–845.

Ministry of Health and Social Welfare. (1995). ICT utilization strategy. In *Proceedings of the Ministry of Health and Social Welfare, 27*.

OECD Reviews of Health Systems. Finland. (2005).

Porter, M. E., & Teisberg, E. O. (2006). *Redefining healthcare. Creating value-based competition on results*. Boston: Harcard Business School Press.

Roine, R., Ohinmaa, A., & Hailey, D. (2001). Assessing telemedicine: A systematic review of the literature. *Canadian Medical Association Journal*, *165*(6), 765–771.

Valta, M. (2003). *On defining the information needs for the development of regional services in social and healthcare networks*. Master's thesis, University of Kuopio, Finland.

Wootton, R. (2001). Recent advances: Telemedicine. *BMJ (Clinical Research Ed.)*, *323*(7312), 557–560. doi:10.1136/bmj.323.7312.557

KEY TERMS AND DEFINITIONS

Core Data Set: Organized and structured data of the most relevant facts about a patient's health information and healthcare prepared by health care providers to enable easy access to information, to foster continuity of care, and to enhance efficiency of health information exchange.

Electronic Health Record: An aggregate electronic record of health-related information on an individual that is created and gathered cumulatively across more than one health care organization.

Healthcare Information Exchange: The electronic movement of health-related data and information among organizations according to agreed standards, protocols, and criteria.

Integration: The process of bringing together related parts into a single system in order to make various components function as a connected system.

National eHealth Network: A network of networks that will connect health care providers, pharmacies, citizens and others who have, or use, health-related data and services including a national data repository for care records and ePrescriptions operated under a legal framework and based upon common standards for interoperability.

Personal Health Record: An electronic, cumulative record od health-relarted information on an individual, drawn from multiple sources, that is created, gathered, and managed by the individual.

Regional eHealth network: Health information exchange within a self-defined region in order to achieve higher quality and greater efficiency in health care delivery.

Regional Health Information Organization: An organization that brings together health care stakeholders within a defined geographic area and governs the electronic exchange of health-related information among them for the purpose of improving health and care.

Seamless Services: Continuity of care between providers.

Shared Care: Closer collaboration between providers and also clinical integration for the development of clinical networks to improve the quality of services.

This work was previously published in Handbook of Research on Information Technology Management and Clinical Data Administration in Healthcare, edited by A. Dwivedi, pp. 383-397, copyright 2009 by Medical Information Science Reference (an imprint of IGI Global).

Chapter 2.9

Tele-Practice Technology:

A Model for Healthcare Delivery to Underserved Populations

Thomas W. Miller
University of Connecticut, USA

Robert D. Morgan
Texas Tech University, USA

Jennifer A. Wood
South Texas VA Healthcare Center, USA

ABSTRACT

Telehealth is viewed as the removal of time and distance barriers in the provision of health care and patient education to underserved populations. Examined is a twenty first century clinical consultation model of health care. Offered are specific applications within a broad spectrum of services utilizing telehealth technology. Important technology shifts for administrative paradigms, clinical models, and educational information technology for healthcare services through telehealth technology are examined. The future of telehealth and its interface with various critical components of society needs to examine the potential benefits over risks in providing healthcare consultations and services through the educational settings available. Addressed is a technology model, which demonstrates the capability of reducing time and distance barriers in the provision of health care and education through telehealth technology. The use of telehealth technology in rural settings is seen as a viable medium for providing needed diagnostic and clinical consultation for underserved and rural.

INTRODUCTION

Examined is the application of telepractice technology in a rural community clinical and educational system. Telepractice is viewed as the removal of time and distance barriers in the provision of health care and patient education to underserved populations (Nickelson, 1996). Offered is a video teleconferencing model of health care for underserved populations and where professional consultation with a team of professionals may benefit rural educational systems and their students. Offered are specific applications within a broad spectrum of services utilizing telepractice technology. Finally, shifts in administrative paradigms, clinical models, and educational information technology for healthcare services through telepractice technology are explored. Distance learning technology has provided society with new applications for clinical and educational consultation that enhance the quality of services offered to rural school systems through telepractice (National Advisory Committee on Rural Health, 2004). Whitten, Cook, Shaw et al. (1998), Sargent (1999), Miller & Miller (1999) Shaw, Goodwin, Whitten, & Doolittle (1999) and Whitten & Cook (1999) Miller, Miller, Sprang, & Kraus (2003), Sammons & DeLeon (2004), Miller, DeLeon, Morgan, Penk, & Magaletta (2006) have all addressed telepractice service application for rural school districts, their students and families. Through this medium of service delivery, children and adults in need of specialized care that might not be readily available to them can receive the specialty consultation of experts using telepractice technology. The purpose of this model is to provide health care practitioners with a consultation model for health related delivery services for children and adults in rural and underserved geographical areas internationally.

Telepractice technology provides an electronic medium for healthcare practitioners and their patients to realize health assessment, diagnosis, intervention, consultation, supervision, education, and information across distances, has become a well recognized vehicle for delivering services and disseminating information to a variety of consumer populations as well as professionals and practitioners (Nickelson, 1998; Miller & Hutchins, 2008)). Given its ability to transcend many of the economic, cultural, and geographic barriers that often prohibit or restrict the provision of health care, the use of telepractice has begun to reshape traditional systems of care. Moreover, due to its unique capacity to negate many of the traditional obstacles in service delivery, telepractice is often a desirable option for the provision of health care to rural, confined, underserved and isolated groups (Miller & Holcomb, 2007).

Well noted is that a large proportion of telemedicine studies have focused on evaluating the effectiveness of telecommunications technology in delivering health services to rural and specialty populations (Wood, 2000). Numerous studies suggest that telemedicine or telepractice applications can be utilized to deliver health care services that are accessible to rural or underserved populations that the quality of care delivered via video teleconferencing is similar to or surpasses that of face-to-face services (Bischoff, Hollist, Smith, & Frank, 2004; Miller, Miller, Kraus, & Sprang, 2003; Norman, 2006) and that both consumers and providers are satisfied with services rendered via video teleconferencing.

From its initial use, one of the major advantages of video teleconferencing has been its ability to improve access to health care services for people living in rural or remote areas where health care professionals are often scarce or absent. In the words of Nickelson (1998), "Telehealth is simply a tool that…makes it easier to practice already established professional skills across distance and to serve individuals and organizations who may not, but for telehealth, have access to such services" (p. 527). This ability to transcend geographic barriers has been the basis for three decades worth of demonstration projects targeted at rural populations. The use of this technology to improve access to health care has since expanded to include other isolated groups, such as inner city families (McLaren, Blunden, Lipsedge, & Summerfield, 1996; Straker, Mostyn, & Marshall, 1976), prison inmates (Ax et al., 2007), and homebound elderly (Maheu, Whitten, & Allen, 2001). Overall, these projects suggest that the use of telehealth is an effective means of improving access to both health care services as well as improving the exchange of information between providers (Blackmon, Kaak, & Ranseen, 1997). Efforts to assess the quality of telepractice services compared to traditional face-to-face services indicate that there is little difference in diagnostic and assessment outcomes across the two treatment modes (Ball & Puffett, 1998; Biggins, 2000; Zarate, et al., 1997 and that telehealth applications may serve to enhance the continuity and efficiency of care (Ghosh, McLaren, & Watson, 1997).

Clinical satisfaction with telepractice applications, the research assessing patient and provider satisfaction with video teleconferencing services reveals uniformly positive results (Miller, 2006; Morgan, Patrick, & Magaletta, 2008; Wood, 2006). In one of the earliest studies of patient satisfaction with telehealth, Solow, Weiss, & Bergen (1971) reported that patient acceptance was impressively high even among highly paranoid patients. Since that time, further research has indicated that satisfaction with telepractice services remains high even when patients are acutely or chronically psychotic or agitated (Kavanagh & Yellowless, 1995).

Clinical satisfaction data are especially relevant in the public sector where services are often lacking. As a response to service deficits, prison systems (e.g., the Federal Bureau of Prisons, the Texas Department of Criminal Justice) have developed sophisticated telehealth networks. It is noted that offenders are generally satisfied with mental health services received via teleconferencing (Leonard, 2004; NIJ, 2002). Of particular importance is that incarcerated mentally ill offenders, historically perceived as resistant to mental health services, reported no significant differences in the working alliance between treatment provider and client, post session mood or treatment satisfaction when receiving psychiatric or psychological services regardless of method of service delivery (i.e., telemedicine vs. face-to-face) (Morgan et al., 2008). Similar findings have been found among parents and children who participate in telepsychiatric consultations (Blackmon, Kaak, & Ranseen, 1997), geriatric clients (Wood, O'Quin, & Eftink, 2004), inner-city families (Straker, Mostyn, & Marshall, 1976), active-duty military personnel (Jerome, 1999), veterans (Wood, 2006), and adults with mild to moderate mental retardation and their mental health care providers (Wood & Hargrove, 2006).

A Telepractice Model for Healthcare

With the noted high level of user acceptability and distinct ability to transcend geographic and social barriers, a visionary telepractice model for public education that focuses on the role of psychology and its interdisciplinary partners can be used to create a national, regional, state and local stratified network of health care professionals and other stakeholders engaged in a nationwide public education campaign (Miller, 2007). The Telehealth Intervention Project (TIP) is a proposed model designed to offer teleconferenced psychological and health related informational and demonstrational sessions focused on a broad spectrum of health related topics. Teleconferening technology is uniquely suited to reach underserved populations and rural practitioners offering relevant evidence-based psychological information to the community. The telehealth network can be used to educate a range of target populations including clients, service providers, educators and community personnel including children and families, school populations, prison inmates, legislators, public officials, and inpatients and outpatients in various public and private sector programs.

As modeled in Figure 1, telepractice provides a sophisticated medium for reaching these targeted populations (consumers and providers) by making psychology a household word. Outlined below are mechanisms (processes) for successfully implementing the Telehealth Intervention Project, a proposed model for implementing a dimension of the public education campaign to reach underserved target groups in need of health and prevention education information nationally.

Use of Telepractice in Health Education and Prevention

Health communication encompasses the study and use of communication strategies to inform and influence individual and community decisions that enhance healthy behaviors and to provide education toward achieving prevention of disease and illness.. It links the domains of communication and health and is increasingly recognized as a necessary element of efforts to improve personal and public health (Kreuter, Strecher, & Glassman, 1999). Health communication can contribute to all aspects of disease prevention and health promotion and is relevant in a number of contexts, including (1) health professional-patient relations, (2) individuals' exposure to, search for, and use of health information, (3) individuals' adherence to clinical recommendations and regimens, (4) the construction of public health messages and campaigns, (5) the dissemination of individual and population health risk information, that is, risk communication, (6) images of health in the mass media and the culture at large, (7) the education of consumers about how to gain access to the public health and health care systems, and (8) the development of telepractice applications (Miller, Burton, & Kraus, 2004; Wood, Miller, & Hargrove, 2005; Miller, 2007).

Utilizing health communication can help raise awareness of health risks (including physical and psychological) and solutions, provide the motivation and skills needed to reduce these risks, help consumers find support from other people in similar situations, and affect or reinforce attitudes. Health communication also can increase demand for appropriate health services and decrease demand for inappropriate health services. It can make available information to assist in making complex choices, such as selecting health plans, care providers, and treatments. At a macro level, health communication can be used to influence the public agenda, advocate for policies and programs, promote positive changes in the socioeconomic and physical environments, improve the delivery of public health and health care services, and encourage social norms that benefit health and quality of life (Piotrow, Kincaid, Rimon et al., 1997).

Effective health communication may also inform health care providers for improved service delivery. The Institute of Medicine criticized current health care training and reported that training of health professionals requires a "major overhaul." Specifically, the IOM stated that health care professionals are not properly trained with regard to changes in patient demographics and health related needs, evolving expectations within health care systems, evolving practice methods and technological advances, or enhanced quality control. Improved health communication among health professionals may alleviate these shortcomings, and telehealth offers a mechanism for improved training that is immediate and accessible. For example, the TIP could be used to offer health professionals an opportunity to discuss physical and psychological issues for targeted populations, interactive education, and face-to-face consultations with specified experts.

Public Education via the Internet

The environment for communicating about psychology and health has changed significantly. These changes include dramatic increases in the number of communication channels and the number of health issues vying for public attention as well as consumer demands for more and higher quality physical and psychological health information. Psychology has the potential of communicating through the home, the school, and the work environment through group, organizational, community, and the Internet interactive telehealth options (Stamm, 1999). For instance, health care providers can take advantage of digital technologies, such as CD-ROM, World Wide Web, and listservs to target audiences, tailor messages, and engage people in interactive, ongoing exchanges about health. Brief sessions via web-based interactive video can provide easier access to needed information and reduce health care cost, travel time, and expenses.

Research indicates that health communication best supports health promotion when multiple communication channels are used to reach specific audience segments with information that is appropriate and relevant to them. Evidence based decision-making suggests that effective psychological health promotion and communication initiatives adopt an audience-centered perspective, which means that promotion and communication activities reflect audiences' preferred formats, channels, and contexts. Targeting specific segments of a population and tailoring messages for individual use are two methods to make reaching home based health promotion care through telepractice activities relevant to audiences. Advances in health informatics are changing the delivery of health information and services and are likely to have a growing impact on individual and community health. Advantages include (1) improved access to personalized health information, (2) access to health information, support, and services on demand, (3) enhanced ability to distribute psychologically accurate information quickly, and (4) just-in-time expert decision support and advice. The health impact of interactivity and customization through teleconferencing technology can achieve making psychology a household word.

Health Information a Telepractice Model

The goals of community based and professional organizations should dovetail with Healthy People 2010 and other similar initiatives worldwide with the focus on using communication strategically to improve health. This can be accomplished through advocacy for: households with Internet access, health literacy, and the quality of Internet health information resources (DeLeon, Crimmins, & Wolf, 2003; Karlinky, 2004; Hilty, 2004). According to the Computer and Internet Use Supplement to the Current Population Survey, U.S. Department of Commerce, Bureau of the Census (US Department of Commerce, 2002), approximately 26 percent of households had access to the Internet at home. Importantly, the greatest growth in Internet access was for lower income households (approximately 25 percent between 1998 and 2001). Continued growth in household access to the Internet is critical to improve psychological health as technical literacy, or the ability to use electronic technologies and applications, will be essential to gain access to health information. This is particularly important for lower income individuals who may be lacking health insurance or financial means for regular health care. Internet availability in the home is an important indicator of equitable access to health information among targeted populations. The health and technology literacy of persons with inadequate or marginal literacy skills data indicate that approximately 90 million adults in the United States have inadequate or marginal literacy skills (Lenhart, 2003). Psychology can play a role in the implementation of this initiative by increasing the proportion of health communication activities that include research and evaluation. Effective health communication programs are built on sound research and evaluation (Casper, 2004; Web Based education Commission, 2000).

The provision of clinical counseling and patient education about health behaviors could enhance adherence and compliance with healthy behavior (both physical and psychological). Culturally appropriate and linguistically competent community health promotion programs, substance abuse treatment, HIV counseling and testing in prisons, worksite promotion of nutrition education and weight management, public access to information and surveillance data, perception of risk associated with substance abuse and tobacco targeting adolescents and young adults are all potential targets for psychology in the home

(Deleon et al., 2003).

Establishing a Telepractice Intervention Program

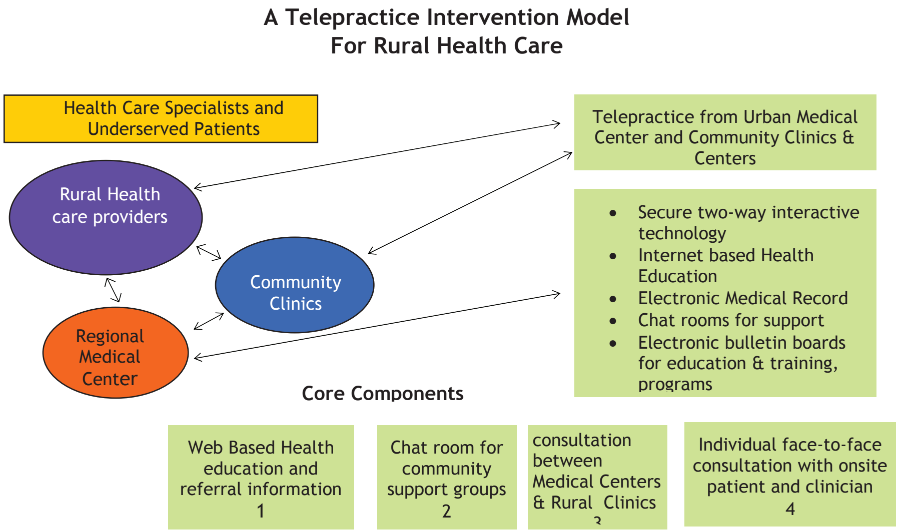
Establishing a telepractice intervention model should begin by identifying existing programs and/or local and national technological resources. Although not formally described as TIP networks, organizations such as the Department of Veterans Affairs and the Texas Department of Criminal Justice are currently using technology to disseminate health care information to providers as well as the consumers they serve. Within the VA, employees have access to an intranet, which contains training modules, informational handouts, clinical guidelines, etc. In addition, employees have the ability to participate in local and national informational broadcasts, videoconferences, and conference calls. With regard to patient care, the VA has developed an Internet-based program called My Health*e*Vet, which serves as a gateway to veteran health benefits and services as well as a tool for enabling veterans to better understand and manage their health. It provides access to trusted health information, links to Federal and VA benefits and resources, a Personal Health Journal, and an online VA prescription refill program. Eventually, veterans will be able to view their appointments, co-pay balances, and access portions of their VA medical records online (My Health*e*Vet, 2006). By examining programs such as these, it is possible to identify the technological resources needed, learn from challenges existing programs have overcome, and to manage various types of informational programs. In addition to reviewing established programs for implementation strategies, it is important to identify existing technological networks, which might be more effectively used to disseminate health information to consumers and providers. For example, many states now include videoconferencing or cable networks in public school systems, public libraries, health care facilities, and other community facilities for efficient connection capabilities. Such existing networks could be utilized to broadcast health information programs targeted toward specific populations or providers. For providers who may not have access to large-scale telehealth resources, there are simple strategies for utilizing existing resources to obtain and disseminate health information. For example, health care providers who wish to obtain information on evidence-based practice or innovative techniques may consult reputable websites or join one of the many professional list serves designed to promote dissemination of information. Providers may also refer their clients to reputable websites (e.g., National Heart Association, National Center for PTSD Research) in order to assist them in gathering information or obtaining support.

The issues for rural health care populations and for rural school systems present additional complexity. Rural school systems are often faced with providing qualified care to their student population and are not able to have ready access to needed expertise. The need for such specialized expertise to address a seriously disruptive student in a rural school setting was more than 500 miles away and transportation was only available by car. Realizing the complexity of problems and the fact that there were no board certified child psychiatrists in the area, it was proposed that through the use of an innovative telecommunications approach, needed clinical consultation could be provided to this school system using telehealth technology. The clinical consultation team included a child clinical psychologist on site working with a school psychologist, an advanced practice nurse, clinical social worker, special education specialist and the consultation of a child psychiatrist by video link from a university based psychiatry clinic through a cost effective model of telehealth. Through the use of this specialized telemetric link using video telephones, the needed interdisciplinary clinical consultation and service could be provided to the rural school system and its staff. The services included diagnostic and treatment planning and classroom observation of the student in question with a secure telehealth video link to the specialist.

Summarized in Figure 1 above is the conceptual model that exemplifies a community based telehealth technology system. Telehealth links in this model exist between health care specialists at the university based medical center, physicians at the rural community clinic and psychologist social worker and advanced practice nurse at the rural district. Within this configuration a secure two-way video link exists for interactive staffing of patients and pediatric emergency care. In addition, Internet based case conferences with a video link can provide necessary and essential face-to-face discussions, video images and streaming video of case materials for review. The combined web based and interactive videoconferencing allows for clinicians and school personnel to exchange information that can be to the benefit of both educational and health care planning and consultation. Each of these segments is noted in the model presented in Figure 1. This model provides children with special needs in rural settings the necessary and appropriate consultation to the benefit of client, clinician and families in our society.

This collaborative partnership between educators and clinicians may be enhanced and facilitated by the use of telehealth using video telephones designated for confidential patient care and planning. School related personnel may wish the consultation of a local or regional specialist and may use Internet video technology through a community clinic. In some cases, the need to have specialized psychiatric consultation services from a medical center-based child psychiatric clinic linked to a community clinic and to a school district may be offered through telehealth technology. In this case, patient health information, patient education materials, clinical records can be shared through electronic medical records sent to consulting clinicians, thus providing them with an opportunity to review information individually and then respond to relevant clinical issues. A clinical staffing of the child involving the referring clinician in the rural setting, the community

Figure 1.



Adapted from: Miller, T.W.; Miller, J.M.; Burton, D. (2003). Telehealth: A model for clinical supervision in allied health. *The Internet Journal of Allied Health Sciences & Practices, 1(2).*

consulting specialists and the university-based specialist can be beneficial and more effective when time and distance barriers are removed via the use of telehealth technology.

The need for telehealth technology is obvious in the face of the major obstacles clinicians face in providing a high standard for health care delivery in a time efficient and cost-effective manner (Miller, 1998; Miller, Miller, Kraus, Burton, Sprang, & Adams, 2003). Emerging systems of managed health care that interface with the educational system have the potential to benefit from the needed services for children as noted in the Young and Iresaon (2003) study. Telehealth is seen as the use of various models of telecommunication, which connect the consumer with the health care provider through live, two-way video transmission, across, distances and which permit diagnosis, treatment, and other health care services. This definition stresses a focus on delivery of services across distances with a sense of concern for ethical provision of services and confidentiality of the health care needs in our society.

The benefits of video teleconferencing technology for clinical health care and for educational settings include: Increased access to clinical consultative services and health education programs for school and community organizations and populations; Improved and expanded psychiatric health care services to underserved areas in rural communities and areas; provision of a feasible and sustainable system of clinician-directed consultations using video conferencing; access to current approved education and training programs for health care providers in settings where access to advanced clinical training may be a barrier due to geographic location; reduction of the isolation for educators and health care providers in rural areas through the development of innovative consultation video conferencing systems that enhance clinical support and consultation regarding the diagnostic, treatment, consultative and educational services available to clinicians and other health care providers in certain geographical regions; and use of telepractice technology in rural communities to decrease the time, inconvenience, expense and risks of travel, as well as other associated problems that distance and isolation cause in obtaining psychological and other health care services.

PRACTICE GUIDELINES FOR TELEPRACTICE

Community based telepractice technology services offers a visionary consultation model for providing standardized and special needs coverage to children by linking metropolitan and flagship university medical centers and specialist services with rural school districts. This definition stresses a focus on delivery of services through distance consultation technology with a sense of concern for the ethical provision of services and confidentiality of the health care needs of the patient provided with such services. As an alternative way of providing traditional health services, telepractice is considered by some to be a solution to America's toughest health care challenges: increasing access to clinical consultation service and involving health care professionals while decreasing the costs involved in providing quality care (Office of Rural Health Policy, 1994). In order to insure standardization of care based on evidence based research and experience, practice guidelines offer a way of incorporating quality care, consistency in educational material and standard models for information technology.

The clinical use of practice guidelines generates algorithms that are used to provide case management based on evidence based research. The goal is to make the client management guideline the accepted professional behavior and a reward in itself. To the extent that this is successful, five components occur: (a) the guideline is widely used and becomes habitual, (b) multidisciplinary professionals can use it to anticipate care events, (c) clinicians can use it as a shorthand or outline to guide their decisions and their communications to others, (d) the logistics for delivering the guideline components are convenient and reliable, and (e) the guideline defines the measure of performance and incorporates information collected that can be used for its evaluation and improvement. The individualized plans clinicians may use also contribute information for guideline revision.

Case management through algorithms presents a systematic perspective. Algorithms try to answer the questions, "What is the best way to systematically handle this problematic condition?" Algorithms have a problem solving orientation coupled with functional specific actions or critical pathways to be taken. If desired results are produced, the problem was managed effectively. If the desired results are not produced, adjustments can be made to achieve the desired results.

The point to be made is that in our professional roles, it is important to be a creative problem solver who can translate relevant research into functional interventions. The model practice guideline summarized in Figure 2 identified the situation that the clinician recognizes that it would be more efficient if telemedicine had a place in the treatment intervention process. Note that a question is asked as to whether a telepracticeoption exists in the patients' locality. If yes then the clinician begins the review with the client of the differences between tradition and telemedicine delivery of care. Informed consent is provided and compliance with all state and federal laws is to be reviewed. Then the clinician assesses the appropriate needs of the medium for what need to be accomplished. Appropriately training the patient in the use of telemedicine and the equipment follows this. Risk management options are offered, Practice session is to occur to assure the patient can use the telemedicine option. The use of web based educational programs is provided. Finally there is a review and monitoring process in place so the clinician can monitor its use. Through this configuration, issues related to liability for negligence or liability for abandonment would be considerable reduced and hopefully eliminated.

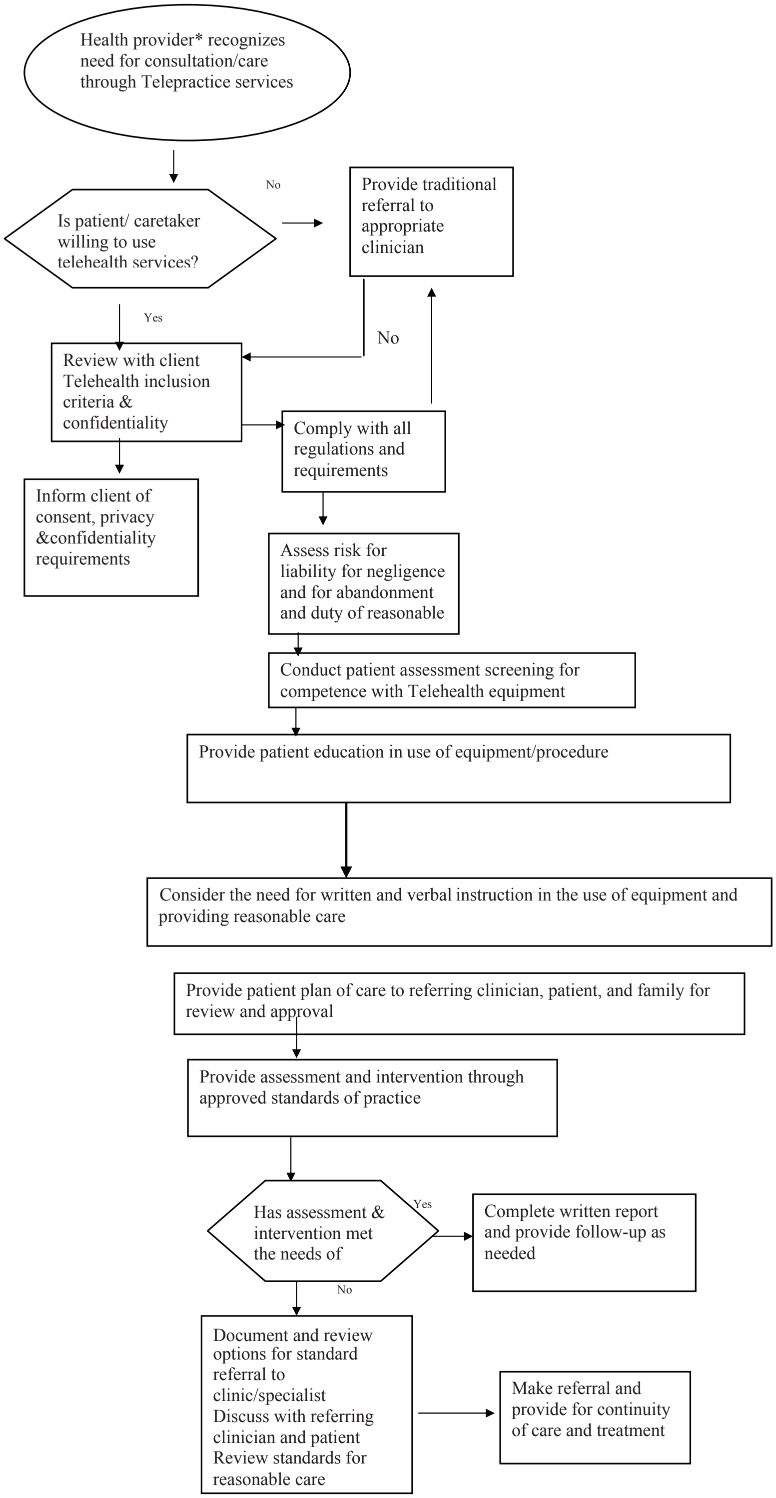
Liability Issues in the Use of Telepractice

Liability is a primary risk factor for clinical healthcare practicioners utilizing telepractice. Risk management strategies should educate psychologists and consumers about telemedicine equipment. Who will provide training, what mechanisms are used to evaluate the effectiveness of training, and how to document deficits in knowledge following completion of initial training. Another concern with respect to liability involves "liability for abandonment." Abandonment may occur when the clinician would unilaterally terminate the relationship with a client or the relationship was terminated without reasonable notice; and termination occurred when further attention was needed. Psychologists using telemedicine technology continuously monitor the clients' ability to participate in telemedicine activities and confirm their understanding of their responsibilities in the use of telemedicine equipment. While there are certain advantages, telepractice is subject to many of the same shortcomings associated with face-to-face care as well as several technology-specific limitations. Most notably, users should be aware of and attend to the following issues prior to establishing a telehealth network or practice.

Security Privacy, and Confidentiality

In an electronically mediated society, concerns regarding security, privacy and confidentiality may take on new meaning with telepracticeOne of the most serious compromises to security and to one's privacy is the unauthorized access to confidential patient health and educational information. Fortunately, these risks may be reduced by utilizing secure or closed networks, encryption programs, and by adhering to the standards set forth in the Health Insurance Portability and Accountability Act (HIPAA) which provides national

Figure 2. Model alogorithm for telepractice consultation & healthcare



standards to reduce health care inefficiencies by encouraging the use of information technology to better secure and protect patient information. In addition, one must consider technological risks that originate from software or computer systems. For example, computer viruses may be designed to destroy data or disrupt computer systems. To avoid these dangers, system managers must continually update virus scan programs, be alert for system glitches, and work to ensure compatibility of all system components (Stamm, 1999; Striefel, 2000).

Transmission Quality

Along with variations in the technical infrastructure and expenses required for various telehealth applications, the quality of data transmission also varies accordingly. When considering options for videoconferencing, providers must take into account both the clinical demands on the system as well as the type of transmission infrastructure required to reliably support a particular application. Videoconferencing systems vary in the type of transmission channel required and thus may operate at different bandwidths. As a measure of a communication channel's ability to carry information, bandwidth directly influences the quality of video transmission. In other words, if detecting fine motor movements is critical, a system with higher bandwidth would be most suitable. On the other hand, lower bandwidths might be more appropriate when movement is not an important factor or when the cost of the infrastructure needed to support higher bandwidth is prohibitive. Among U.S. telehealth programs, the most common transmission rate is currently 384-786 Kbps (Mahue, Whitten, & Allen, 2001).

Level of Use Satisfaction

Regardless of the specific type of technology implemented, the success of a telecommunications system often hinges on its acceptance among participants. As noted by Young and Irenson (2003), once providers and clients become familiar with telehealth technology, there seems to be an acceptable level of satisfaction with the use of this equipment. Adequate and appropriate training based on the intent of the users of such equipment is essential. Beyond training, it is important to normalize the equipment as part of the environment to desensitize those unfamiliar to telepractice practices and technology.

Scope of Practice

The legal and ethical issue of licensure and scope of practice in the use of telepractice may well extend beyond state boundaries or jurisdictions. Licensure requirements, as a limitation to interstate practice, are often cited as a major barrier to the development of services. As with most health care professionals, licensure is on a state-by-state basis, which requires that a practitioner hold a full, unrestricted license in all states him or her practices. For many professionals, acquiring and maintaining multiple licenses is a significant professional and financial burden, which falls particularly hard on rural health care providers who often experience significant travel, lost work time, and other costs in complying with multiple state regulations.

Technology Costs

The cost of acquiring and maintaining the necessary technology including maintenance and update expenses) should be considered. Fortunately numerous options, which vary in price point, exist for creating virtual connections. With availability of the Internet, e-mail, listservs, and chat rooms may serve as a cost effective, accessible medium of communication. Equipment needs are minimal; requiring only a computer and Internet access at each location.

Where practitioners at healthcare delivery sites interested in incorporating technology-mediated face-to-face contact, several types of videoconferencing applications exist. When considering these options, providers must take into account both the clinical demands on the system as well as the type of transmission infrastructure required to reliably support a particular application. Options for videoconferencing applications include, but are not limited to, videophones, PC-based desktop systems, and/or high-quality integrated videoconference units. Given the rapid pace of advances in technology, prices for the above equipment vary from a few hundred to several thousand dollars. Ironically, the cost of developing and maintaining telehealth systems tends to be the highest in the regions where telehealth would be most beneficial (e.g., rural areas) (Nickelson, 1998). Fortunately, federal programs such as the Universal Service Program for Rural Health Providers may help to defray the operating costs of such systems (Stamm, 1999).

In anticipation of legislative changes with respect to the use of telecommunication technology, there have been efforts on the part of the medical and nursing professionals to develop alternative licensure models for their professions. For instance, Texas offers a "special purpose license" for out-of-state physicians who provide telepractice services to Texas residents. Similarly, the Joint Commission on the Accreditation of Healthcare Organizations recently revised its Hospital Medical Staff Standards which now state that practitioners who treat patients via telemedicine are subject to the credentialing processes of the organization that receives the telemedicine service (Joint Commission on the Accreditation of Healthcare Organizations, 2003). Utilizing a different approach, the National Council of State Boards of Nursing has developed a mutual license recognition program which allows nurses who hold a valid license in one state to enjoy a "multi-state licensure privilege" to practice in states that are members of the licensure compact (DeLeon, 2003). Legally and ethically the direct and immediate delivery of patient care is always the responsibility of the on-site licensed professional.

Applications for Telehealth in Rural Educational Settings

Numerous applications hold significant potential for educational settings seeking to meet the health related needs of students through telehealth. These include:

1. Clinical interview and/or evaluation by a clinician specialist; consultations for crisis stabilization in the school setting;
2. Brief screening and assessment prior to comprehensive evaluations for various diagnostic entities;
3. Team assessment and treatment planning may include multiple links with physicians, child psychiatrists, school psychologists, occupational therapists, physical therapists, speech-language pathologists, counselors, nurses, teachers, social workers, and others;
4. Diagnostic testing with the assistance of a technician at the site;
5. Short-term health education and counseling interventions;
6. Vocational assessment, placement and counseling services;
7. Evaluations and diagnostics related to second opinions;
8. Short-term case management for children with special needs;
9. Consultation-liaison services for parents and children;
10. Consultation with primary care physicians and/or specialists, clinicians and educators regarding children with special needs;
11. Continuing medical and health education for administrators, faculty, students, parents and others.

CONCLUDING COMMENTS AND LESSONS LEARNED

Twenty-first century use of electronic based technology for the provision of healthcare services internationally and its interface with various critical components of society needs to examine the potential benefits over risks in providing healthcare consultations and services through the educational settings available. Health care provision through rural school systems utilizing telepractice technology must be vigilant to the challenges and cognizant of the added value when realizing that this technology will reach populations who have been traditionally underserved because of their remote location to needed services.

Examined herein has been a model, which demonstrates the capability of reducing time and distance barriers in the provision of health care and education through telepractice technology. Best practice guidelines have emerged and provide both ethical and legal parameters for practitioners (Miller & Wader, 2002). Vignettes highlighting the usage of this technology through educational settings have been address as has the advantages and potential disadvantages of its use. Several suggested applications have been noted, as have the changing paradigms in delivery of healthcare through community-based services. When consultation with a needed health care professional is not readily available, the use of video teleconferencing technology by healthcare clinicians and providers in rural settings is a viable medium for providing needed diagnostic and clinical consultation for underserved and rural populations globally.

ACKNOWLEDGMENT

The authors wish to acknowledge the support and assistance of Rob Sprang Director of University of Kentucky Telecare, Deborah Burton Ph.D., Charles Lowe Ph.D. Chair Department of Psychology, University of Connecticut and Jeffrey Fisher Ph.D. Director Center for health intervention and Prevention. In addition appreciation is extended to Lon Hays, M.D., Patricia Beckenhaupt RN, MS, MPH, Catherine Russell, Jill Livingston MLS, Lane J. Veltkamp MSW, and Brenda Frommer in the preparation of this manuscript. This article is based on initial research presented in the "Handbook of Research on Information Technology Management and Clinical Data Administration in Healthcare."

REFERENCES

Ax, R. K., Fagan, T. J., Magaletta, P. R., Morgan, R. D., Nussbaum, D., & White, T.

W. (2007). Innovations in correctional assessment and treatment [Special issue]. *Criminal Justice and Behavior, 34,* 893-905.

Ball, C., & Puffet, A. (1998). The assessment f cognitive functioning in the elderly using videoconferencing. *Journal of Telemedicine and Telecare, 4,* 36-38.

Blackmon, L. A., Kaak, H. O., & Ranseen, J. (1997). Consumer satisfaction with telemedicine-child psychiatry consultation in rural Kentucky. *Psychiatric Services, 48,* 1464-1466.

Bischoff, R. J., Hollist, C. S., Smith, C. W., & Frank, P. (2004). Addressing the mental health needs of the rural underserved: Findings from a multiple case study of a behavioral telehealth project. *Contemporary Family Therapy*, *26*.

Casper, L.M., & King, Rosalind, K.B. (2004). Changing families, shifting economic fortunes, and meeting basic needs [Comment/Reply]. *Work Family Challenges for Low-Income Parents and Their Children* (pp. 55-79).

Casper, V. (2004). Beyond feeders and growers: Changing conceptions of care in the Western Cape. *Journal of Child and Adolescent Mental Health, 16*(1), 55-59.

Casper, E. S. (2004). A formative evaluation of a rent subsidy program for homeless substance abusers. *Journal of Service Research, 31*(2), 25-39.

DeLeon, P. H., Crimmins, D. B., & Wolf, A. W. (2003). Afterword-the 21st century has arrived. *Psychotherapy: Theory, Research, Practice, Training, 40*(1-2), 164-169.

Ghosh, G.J., McLaren, P.M., & Watson, J.P. (1997). Evaluating the alliance in video-link teletherapy. *Journal of Telehealth, 3*(suppl. 1), 33-35.

Kavanagh, S., & Yellowlees, P. (1995). Telemedicine: Clinical applications in mental health. *Australian Family Physician, 24,* 1242-1246.

Kreuter, M. W., Strecher, V. J., & Glassman, B. (1999). One size does not fit all: The case for tailoring print materials. *Annals of Behavioral Medicine, 21*(4), 276-283.

Mahue, M., Whitten, P., & Allen, A. (2001). *E-health, telehealth, and telemedicine: A practical guide to start-up and success.* San Fransico: Jossey-Bass.

McLaren, P., Blunden, J., Lipsedge, M., & Summerfield, A. (1996). Telepsychiatry in an inner-city community psychiatric service. *Journal of Telemedicine and Telecare, 2,* 57-59.

Miller, T. W. (2006). Telehealth issues in consulting psychology practice. *Consulting Psychology Journal: Practice and Research, 58*(2), 82-90.

Miller, T.W. (1998). The psychologist with 20/20 vision. *Consulting Psychology Journal: Practice and Research, 50*(1), 25-35

Miller, T. W., Miller, J.M., & Kraus, O.F, Sprang, R. (2003). Telehealth a clinical application model for rural consultation. *Consulting Psychology Journal, 55*(2), 119-127.

Miller, T.W., & Miller, J. (1999). Telemedicine: New directions for health care delivery in Kentucky schools. *Journal of the Kentucky Medical Association, 97*(4), 163 166.

Miller, T.W., & Wader, B. (2002, November 1-2). Best Practices for Psychologist using 21st Century Technology. *Annual Convention Connecticut Psychological Association*, Westbrook, CT.

Miller, T.W., Miller, J.M., Burton, D., Sprang, R., & Adams, J.M. (2003). A Telehealth Model for Clinical Supervision In Allied Health. *Internet Journal of Allied Health, 2*(1), 1-10.

Miller, T.W., DeLeon, P., Morgan, R., Penk, W., & Magaletta, P. (2006). The Public Sector Psychologist with 2020 vision. *Professional Psychology: Research and Practice*, *37-2*, 531-538.

Miller, T. W., & Hutchins, S.A. (2009). 21st Century Teaching technology: Best Practices and Effectiveness in Teaching Psychology. *International Journal of Instructional Media 11*(3), *47-56*.

Miller, T.W. (2007). Telehealth Issues in Consulting Psychology Practice. *Consulting Psychology Journal: Practice and Research, 28*(4), 118-122..

Miller, T.W., & Holcomb, T.F. (2007). Telehealth Applications for Counselors in the Schools. *Kentucky Counseling Association Journal, 26*(1) 6-13.

Morgan, R. D., Patrick, A. R., & Magaletta, P. R. (2008). Does the use of telemental health alter the treatment experience?: Inmates' perceptions of telemental health vs. face-to-face treatment modalities. *Journal of Consulting and Clinical Psychology, 76,* 158-162.

My Health*e*Vet (n.d.). Retrieved June 2, 2006, from https://www.myhealth.va.gov/mhvPortal/anonymous.portal?_nfpb=true&_nfto=false&_pageLabel=mhvHome

Nickelson, D. W. (1998). Telehealth and the evolving health care system: Strategic opportunities for professional psychology. *Professional Psychology: Research and Practice, 29,* 527-534.

Nickelson, D. (1996). Behavioral telehealth: Emerging practice, research, and policy opportunities. *Behavioral Sciences and the Law, 14,* 443-457.

National Advisory Committee on Rural Health and Human Services (2004). *The 2004 Report to the Secretary: Rural Health and Human Services*. Available at: ftp://ftp.hrsa.gov/ruralhealth/NAC04web.pdf

Office of Rural Health Policy, Health Resources and Services Administration (1994).

Reaching: Rural health travel in the telecommunications highway. Rockville, MD: Federal Office of Rural Health Policy.

Norman, S. (2006). The use of telemedicine in psychiatry. *Journal of Psychiatric and Mental Health Nursing, 13,* 771-777.

Sammons, M. T., & DeLeon, P.H. (2004). Whither online counseling: Conceptualizing the Challenges and promises of distance mental health service provision. In R. Kraus, J. Zack, & G. Stricker (Eds.), *Online Counseling: A Handbook for Mental Health Professionals*. New York: Elsevier Press.

Sargent, I. (1999). School based mental health in rural Kansas: A novel use for telepsychiatry. *Telemedicine Journal, 5*(1), 52.

Shaw, P., Goodwin, J., Whitten, P., & Doolittle, G. (1999). Tele-Kid Care: An urban telemedicine service for an underserved pediatric population. *Telemedicine Journal, 5*(1), 25.

Solow, C., Weiss, R., Bergen, B., & Sanborn, C. (1971). 24-hour psychiatric consultation via TV. *American Journal of Psychiatry, 127*, 120-123.

Stamm, B. H. (1999). Creating virtual community: Telehealth and self-care updated. In B. H. Stamm (Ed.), *Secondary traumatic stress: Self-care issues for clinicians, researchers, and educators* (pp. 179-208). Sidran Press: Lutherville, MD.

Straker, N., Mostyn, P., & Marshall, C. (1976). The use of two-way TV in bringing mental health services to the inner city. *American Journal of Psychiatry, 133*, 1202-1205.

Striefel, S. (2000, Summer). Telehealth uses in biofeedback and applied psychophysiology. *Biofeedback, 28*(2). Retrieved February 4, 2004, from http://www.aapb.org/public/

Whitten, B., Cook, D.J., Shaw, P., Ermer, D., & Goodwin, J. (1998). Telekid Care: Bringing health care into schools. *Telemedicine Journal, 4*(4), 335-43.

Whitten, P.S., & Cook, D.J. (1999). School-based telemedicine: Using technology to bring health care to inner-city children. *Journal of Telemedicine and Telecare, 5,*(Suppl 1), S23-5.

Wood, J. A. (2006, April). *Patient and provider satisfaction with telemental health services.* Poster presented at the VA Psychology Leadership Conference, Dallas, TX.

Wood, J. A. (2000). *The effectiveness of videophone technology in bringing mental healthservices to rural residents.* Unpublished master's thesis, Stephen F. Austin State University, Nacogdoches, TX.

Wood, J. A., & Hargrove, D. S. (2006). *Use of videoconferencing to deliver mental health services to adults with mental retardation.* Manuscript submitted for publication.

Wood, J. A., Miller, T. W., Hargrove, D. S. (2005). Clinical supervision in rural settings: A telehealth model. *Professional Psychology: Research and Practice, 36*(2), 173-179.

Wood, J. A., O'Quin, J., & Eftink, S. (2004). A preliminary investigation of the use of videophone technology as a training tool for students working with older adults. *Journal of Teaching in Social Work, 24,* 35-46.

Young, T., & Irenson, C. (2003). Effectiveness of School based Telehealth Care in Rural Elementary Schools. *Pediatrics, 112*(5), 1088-96.

Zarate, C. A., Weinstock, L., Cukor, P., Morabito, C., Leahy, L., Burns, C., & Baer, L. (1997). Applicability of telemedicine for assessing patients with schizophrenia: Acceptance and reliability. *Journal of Clinical Psychiatry, 58*, 22-25.

This work was previously published in International Journal of Healthcare Delivery Reform Initiatives, Vol 1, Issue 3 , edited by M. Guah, pp. 55-69, copyright 2009 by IGI Publishing (an imprint of IGI Global).

Chapter 2.10
Integrated Digital Health Systems Design:
A Service-Oriented Soft Systems Methodology

Wullianallur Raghupathi
Fordham University, USA

Amjad Umar
Fordham University, USA

ABSTRACT

The application of information technology in healthcare has focused primarily on the implementation of specific systems such as electronic health records (EHRs) and clinical decision support systems (CDSSs), mainly for intra-enterprise use. However, for the integrated health system (IHS) to function effectively in a complex inter-enterprise healthcare delivery environment, designers must focus on approaches such as soft systems methodology (SSM) to enable the design of robust integrated digital health systems (IDHSs). A service-oriented architecture (SOA) offers a flexible framework for IDHSs to become de-centralized, fully functional and modular systems with interoperability. This article identifies the design issues in IDHS and explores the potential of an SSM methodology-based SOA for the development of interoperable IDHSs. In the process we compare and contrast the functionalist socio-technical approach to the interpretive SSM. We also describe a prototype SOA application for an IDHS setting and discuss challenges in the application of SOA to healthcare.

INTRODUCTION

The delivery of healthcare services in the United States is a complex, fragmented, and disconnected process, and in 2006, cost almost $2.1 trillion, or 16% of the GDP (Melvin, 2008). Studies published by the Institute of Medicine indicate that the disconnectedness, disorganization and inaccessibility of clinical information adversely affect healthcare quality and compromise patient safety (Institute of Medicine, 2003). In addition, long-standing problems with medical errors as well as inefficiencies increase the costs of healthcare delivery.

The potential of health information technology (HIT) in public and private integrated health systems (IHS) already has been established, and yet implementation of HIT applications has been haphazard. Missing is the necessary planning and attention to the long-term viability of such applications as electronic health records (EHRs), clinical decision support systems (CDSSs), regional health information networks (RHINs), and the national health information network (NHIN). Large-scale implementations, absent consideration of significant design issues such as interoperability and compliance with standards (Chaudhry et al., 2006; Himmelstein and Woolhandler, 2005), can result in the failure of the applications. Note, for example, reports that the U.K. National Health Services program to create a nationwide e-health records system is in trouble, the cost having escalated from 2.6B pounds to at least 13B pounds today (Charette, 2006). So while the call for information technology in healthcare is a positive trend, the need has led to the ad hoc creation of stopgap applications that never will be able to "speak" with other systems that come along.

Newer approaches to design are needed to produce viable IDHSs. A soft system methodology, for example, combined with a decentralized and distributed architecture such as a service-oriented architecture (SOA) offers viability. In this exploratory research, we discuss the application of soft systems methodology (SSM) to the design of IDHSs to support RHINS and the NHIN. The SSM methodology is mapped to the SOA approach (Nadkarni and Miller, 2007) to developing distributed, loosely coupled, interoperable IDHSs. The rest of the article is organized as follows: First, we identify design issues in IDHSs, focusing primarily on interoperability. Then, we discuss the potential of the SOA for IDHS design. Third, we compare and contrast the socio-technical approach to SSM in the context of IDHS-SOA design. Fourth, we apply the SSM to the design process, map the outcomes of the SSM to an SOA framework, and illustrate each stage of the SSM with examples. We also describe a prototype application for an IDHS setting. Fifth, we discuss the challenges in implementing SOA-based IDHSs. And finally, we offer our conclusions and future directions for research.

DESIGN ISSUES IN IDHS

Typically, IDHSs support large integrated health systems that feed into RHINs. For example, the Partners Healthcare Systems—a federation of hospitals in the Boston metropolitan area made up of several hospitals, clinics and laboratories —is a large integrated delivery network. The network uses a combination of centrally or locally managed information system resources. In Indiana, the Regenstrief Institute created the Indianapolis Network for Patient Care (INPC) in 1995 with the goal of improving the medical care of patients. The network is an operational community-wide electronic medical record system that includes an active surveillance component built around real-time electronic laboratory reporting. The Santa Barbara County Care Data Exchange is another pilot example of the trend towards operational health information networks (Overhage et al., 2005). Other examples of integrated health systems include the Taconic IPA (independent practice association) in New York, which uses its physician base as a core for a comprehensive, practice-oriented health information infrastructure that includes clinical information systems and secure networks (Frisse, 2005). Hospitals, clinical laboratories, health plans, and pharmacies subscribe to its network to communicate more effectively with practitioners. IPAs in Colorado, Oregon, and other states are adopting similar models (Frisse, 2005). The Mid-South eHealth Alliance is one more example of a regional comprehensive health information initiative for three counties in Southwest Tennessee.

At the national level, the Department of Health and Human Services released a Strategic

Framework report in July 2004 entitled "The Decade of Health Information Technology: Delivering Consumer-centric and Information-Rich Health Care." The report calls for the creation of a "national health information network" to enable nationwide interoperability as well as regional health information networks (RHINs), which would provide local leadership, oversight, fiduciary responsibility, and governance for the development, implementation, and application of secure health information exchange across care settings (HHS, 2004; Overhage et al, 2005). And yet, prior attempts to build community health information networks (CHINs) in the 1990s have failed. Explanations include inadequate buy in and conflicting missions, lack of trust, the need for centralized databases and desire for control, data ownership issues, lack of financing, and the high cost of network technology (Overhage et al., 2005). This unfavorable history does not augur well for the design of the current IHSs and RHINs. McDonald (1997) also points out electronic patient information—such as laboratory, pharmacy and physician dictation data—reside on many "isolated islands that have been very difficult to bridge." According to the author, each island system contains different data, different structures, and different levels of granularity, and each uses a different code system to identify similar clinical concepts. The external islands differ even more than those within an organization. They tend to use different patient, provider and location identifiers, and the number of these independent systems is legion (McDonald, 1997).

While there have been attempts to build distributed systems in specific domains (e.g. Katehakis et al., 2007; McMurry et al., 2007; Wright et al., 2007), no unified system currently exists for the exchange of comprehensive healthcare information across the wide spectrum of healthcare networks. Regional health information organizations (RHIOs) and a national health information network (NHIN) have been proposed as vital building blocks for providing such a system, but these face many challenges, including delineation and implementation of accepted standards for healthcare data, accurate patient identification and record matching, and the definition of incentives for accelerated deployment of health information technology. The formation of a healthcare data exchange depends on a common set of standards to facilitate communication (Gold and Ball, 2007; Yasnoff et al., 2004). The design and operation of these types of networks therefore, face key challenges.

The next section examines the potential of the SOA for IDHS design.

SERVICE-ORIENTED ARCHITECTURE FOR IDHS

According to Walker (2007), "an SOA is a component model that interrelates the different functional units of an application called 'services,' through well-defined interfaces and contracts between these services. The interface is defined in a neutral manner that should be independent of the hardware platform, the operating system, and the programming language in which the service is implemented."

Here we discuss the drivers for an SOA approach, adapting the discussion from Carter (2007), Raghupathi and Kesh (2007) and Walker (2007):

- **Healthcare delivery is process driven:** Healthcare delivery organizations view HIT responsiveness and flexibility as high-priority. To meet these goals, HIT has to ensure that IT is process driven and responds quickly to changing healthcare delivery conditions. For example, new healthcare (patient) requirements and treatment protocols must be added dynamically to the process models.
- **Promote healthcare delivery as a service:** The goal is to manage the common IHS as-

sets and establish a standard IHS vocabulary for health data used by the SOA framework. For example, a unified common view of patient information can be provided by a web service that makes aggregated patient data accessible; this data would originate from patients' "touch points" at several healthcare delivery participants' systems.

- **Promote reuse:** SOA enables reuse through the "build once and use many times" approach. As the inventory of healthcare delivery services increases, more functions can be created as composite health services.
- **Leverage and modernize legacy systems:** Legacy applications in the IDHS can be upgraded through the use of service encapsulation methods. Upgrading existing applications in this way instead of replacing them allows limited IT resources to be redirected. Healthcare patterns can be developed to simplify the reuse of legacy applications.
- **Incorporate third party products:** By using service interfaces and web services, the architecture accommodates the range of alternatives, including off-the-shelf, custom-built and modified products.
- **Enhance inter-enterprise transactions:** SOA-enabled interoperability with other IDHSs enable extension into regional networks.

Considering the above discussed benefits, an SOA offers a more dynamic and flexible solution to the IDHS design.

SOCIO-TECHNICAL APPROACH VERSUS SOFT SYSTEMS METHDOLOGY

While numerous researchers have proposed a socio-technical approach to health information system design (e.g. Aarts et al, 1998; Berg, 1999; Berg et al, 2003) and distributed systems and network architectures have been discussed in the literature (Blobel, 2006; Kuhn and Guise, 2001), the approach has been interpreted narrowly to imply a man-machine system. Here, building on our prior work (Raghupathi and Kesh, 2007, 2008) and that of other researchers (see Stowell (2008)), for an excellent summary and references on the application of SSM to information systems), we argue for the application of a soft systems methodology for SOA-based IDHS design. A socio-technical approach (Enery and Trist, 1960) is quite appropriate for monolithic electronic health records and clinical decision support systems, which have specific objectives with definite boundaries. However, a "social system" is more desirable in that it captures the essence of complex, distributed systems such as IDHSs and regional health information networks (Raghupathi and Kesh, 2008). We do not imply a reductionist approach, but rather advocate the use of SSM (Checkland, 1981) as a meta model to elicit the high level service requirements. Table 1 compares and contrasts the socio-technical approach (functionalist perspective) and the SSM (interpretive) approach.

At the primitive level, the system may consist of identifiable technical artifacts (Kroes et al., 2006) with the designers focusing on the user interface working within well-defined user requirements and system scope. However, at higher levels in large-scale, heterogeneous systems such as health information networks, the various stakeholders (e.g. health care delivery participants, technical architecture such as IDHS-SOA) and the overall social infrastructure (e.g. the public/citizenry) become an integral part of the overall health system. As Kroes et al (2006) ask, "how are the relations to be conceived between the various technical artifacts that are supposed to glue together these artifacts into a system, a unified whole?" Stowell (2008) also reiterates that "the importance of understanding the relationship between information

Table 1. SOA design: socio-technical approach versus soft system methodology

CONCEPT	**Socio-technical Approach**	**Soft System Methodology**
Conceptual/philosophical basis (Checkland, 1981; Burrell & Morgan;, Deetz, 1996; Jackson, 2000)	Functionalist systems thinking; Organization-as-systems approach	Interpretive systems thinking
Perspective (Adapted from Ulrich, 1980)	Simon's *The Sciences of the Artificial – The Architecture of Complexity*	Churchman's *The Philosophy of Social Systems Design – The Design of Inquiring Systems*
Design Principles		
System type	Relatively simple systems – design enforces hierarchy and order; Electronic health record, clinical database, etc.	Relatively complex systems – cannot be reduced to hierarchies; Integrated digital network, regional health information network, global health grids, etc.
Subjectivity	Designer's primary tool is objectivity: Objectivity is emphasized and systems have specific functionality; Axiomatic models	Designer's main tool is subjectivity: Subjectivism is embraced, designer considers different viewpoints and diverse knowledge; Conceptual learning models
Participant relationship	Unitary	Pluralist
Holism	Is not considered, modularity and components are emphasized; decomposition is an operational principle	Holism is critically considered, the whole is greater than the sum of the parts; difficult to reduce systems that mirror 'social systems'
Reductionism	Is an important design principle and source of design knowledge; complex systems can be described by reducing them to simple process logic	Is not critical to the design process, embracing complexity is encouraged; the uniqueness of system components is considered
Key design challenge (Adapted from Ulrich, 1980)	How to decompose complex systems into simple systems (divide)	How to describe the unique qualities of each subsystem; how to define boundary of networks; "ethics of whole systems"
Advantages & Benefits (adapted from Jackson, 2000)	Optimization of system requirements helps scope a project	Satisfying or 'good enough' solutions inevitable in situations with many stakeholders and conflicting goals
	Does consider limited technological & social aspects	Considers SOA design from a social perspective emphasizing people issues
	Organizations are considered as 'open systems' but intra-organizational	Systems are inter-organizational and boundary spanning
	Workgroups (e.g. development group) are empowered	Entire organizations collaborate in the development of integrated systems
Limitations (adapted from Jackson, 2000)	Underplays teleological or 'purposeful action'; Tendency to 'reify' the organization	Some groups may tend to dominate, for example in 'service' definition'

continued on the following page

Table 1. continued

	Cannot explain the dynamics of change and conflict	May not provide an 'operational model' that is implementable but rather an understanding of the situation
	Tends to emphasize a single point of view (managerial bias)	Diverse stakeholder groups may never agree on 'service' definitions or a acceptable SOA governance model
	Focus is more likely on survival as opposed to integrated goal(s)	Perceived lack of theoretical or conceptual underpinning
Methodology Steps (adapted from Checkland, 1981; Chern, 1976; Jackson, 2000)	*Establish* Compatibility with design objectives; *Define* minimal critical specifications, how development is to be carried out and who should carry it out; *Control* for variances from specifications (e.g. creeping user requirements); *Perform* multi-tasking, parallel development; *Identify* boundary for system development activity, location, control; *Manage* information flow, provide information to work teams; *Support* congruence, organization-system alignment; *Consider* human values and ethics in design; *Use* iterative design process	*Stage 1*: The need for integrated digital health system is recognized, explored and defined in a distributed, 'service-oriented' way. This is in the applied, real world. *Stage 2*: The system requirements under consideration are expressed in a meaningful way, typically in a graphical form. This is called a rich picture. *Stage 3*: This stage is called the 'root definition' stage in which the steps out of the "real" world and into the abstract realm of systems, and is the stage from which all further processes are identified *Stage 4*: Draw a conceptual model from the root definition using system conventions. *Stage 5*: Compare the model to the real world. Stage 6: Develop desirable and feasible system interventions. Stage 7: Identify actions to improve the situation (operationalize the model).

and associated connections within an enterprise cannot be overstressed."

A SOFT SYSTEMS METHODOLOGY FOR SOA-BASED IDHS

IDHSs that provide the underlying IT architecture for IHSs are complex systems that reflect the intricacies of the healthcare delivery process. Participants and stakeholders have varied properties (e.g. non-profit vs. for-profit entities) and diverse objectives (e.g. disease treatment vs. home care), are subject to large-scale changes (e.g. impact of drug discovery on treatment protocol), and have loosely coupled interactions with each other (e.g. health data exchange). Jackson (2003) has proposed the use of such methodologies as systems dynamics, organizational cybernetics, complexity theory and soft systems and postmodern approaches if the "systems of the problem situation tend to be complex (Jackson, 2003)." Considering the overall absence of integrated theoretical models and frameworks to guide IDHS design, there is an urgent need to adopt a systems approach to their development.

The IDHS exists in the context of a complex interconnected health system. Such interconnectedness makes the IDHS difficult to design and implement; however, the use of systems concepts such as holism, boundary management, feedback and control clearly hold promise for the design of IDHS. A modular architecture (e.g. SOA) can express dynamic services. Central to a systems approach is the understanding of the healthcare delivery system as a complex adaptive system, giving rise to dynamic services through a confluence of stakeholder actions. Each stakeholder (participant) is conceived as actor or agent, taking independent action (Warren, 2004).

Traditional approaches to design, such as a database approach, are adequate for "hard systems" such as electronic health records or clinical decision support systems with specific objectives (Raghupathi and Kesh, 2008). But "soft systems" approaches (Checkland and Holwell, 1998; Christie, 2005) are needed to model complex, dynamic systems such as IDHSs. According to Checkland, systems engineering, or the hard systems approach, is only applicable in situations in which goals or needs are precisely defined. Systems engineering looks at 'how to do it' when 'what to do' is already defined." This was found to be the failure of systems engineering, however, when it was applied to ill-defined problem situations (Checkland and Scholes, 1990; Christis, 2005). Ill-defined or messy problems such as IDHS design are characterized by the fact that both the 'what' and the 'how' of problem solving are unclear. Because healthcare delivery organizations, as social systems, have to reach many different goals and needs or have to solve many different problems simultaneously, messy problems will be the routine. In such situations, "many different but plausible definitions of system objectives (are) possible. In this situation, systems engineering methodology appears to break down" (Checkland, 1995). Additionally, "SOAs contain a substantial amount of behavioral content because those initiatives are process-driven and span organizational boundaries. The 'soft issues' of an SOA strategy must address the organizational issues and challenges that may help or inhibit SOA adoption, such as services ownership the business and IT relationship, budgeting practices, and more. Organizational, cultural and process issues thread through several facets of an SOA initiative (Marks and Bell, 2006)." Questions that need to be addressed in an environment characterized by multiple stakeholders, incompatible legacy systems and conflicting organizational goals include: What are "services" in the health care delivery environment? How should health care services be identified? How does the designer model and implement services that are "good enough" for the IHS? How does one define criteria for reuse and granularity levels? How does one rank order the identified candidate services? How should the SOA governance model be described? Who defines the controlling policies?

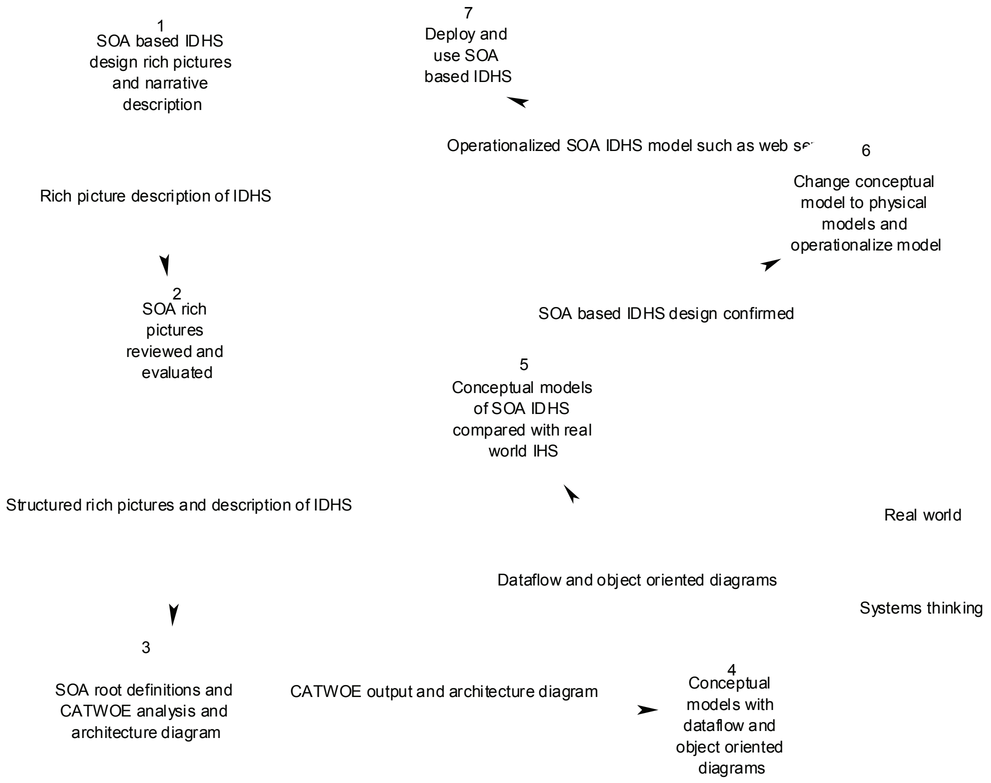
Soft systems methodology (SSM) offers a methodology for a design process in which the various stakeholders involved can evaluate different system models of a problem in a collaborative fashion. These different models are used to structure the debate about problems and solutions. If in the debate some form of accommodation between the interested partners arises, action can be taken to fix the problem (Christis, 2005). Essentially, SSM has been developed for use in ill-structured or messy problem contexts where there is no clear view of what "constitutes the problem" or what action should be taken to overcome the occurring difficulties. In fact, SSM in action should prevent decision makers from rushing into poorly planned solutions based on preconceived notions about assumed problems (Basden and Wood-Harper, 2006; Chujo and Kijima, 2006; Checkland, 1981; Flood and Jackson, 1991). Ultimately, SSM enables the consideration of the views of a diverse set of participants in the SOA development and governance process. The seven-stage SSM methodology for SOA-based IDHS design is outlined in Figure 1 (based on discussion in Brocklesby, 2007; Checkland, 1976, 1981, 1988, 2000; Checkland and Holwell, 1998; Checkland and Scholes, 1990 Jackson, 2000; Luckett and Grossenbacher, 2003; Mobach, 2007; Stowell, 2008; Whitman, 2005).

Stages 1 and 2

In Stage 1, the stakeholders begin to consider interoperability within the proposed IDHS. Rich pictures of an SOA-based framework can be developed to represent the various participants and the shared healthcare services.

Figure 2 represents an example of an overall integrated healthcare delivery framework that the SOA can support (Raghupathi and Kesh, 2007). It highlights the input-service-output components of a typical health system. To the left, the sources of input data are identified. These include in-house legacy hospital systems, databases and other newer information systems. The systems are mostly intra-enterprise and the bulk of the health data is stored in these systems. In the middle, components of the various services are shown. These include governance, patient record management, healthcare delivery and clinical DSS (decision support systems). Governance-related services may include provision of security as well as privacy and compliance procedures for HIPAA. The Patient Record Management services may include patient registration and visit management. Regarding health care delivery, services included are admission, diagnosis, treatment, and those relate to discharge and insurance. The clinical

Figure 1. SSM stages for SOA-based IDHS design



DSSs include a range of physician-related services such as evidence-based services. For example, a physician might prescribe medications upon an evaluation of a patient's symptoms. The services' component of clinical DSSs would include Web Services, which deliver the services via web interfaces. A physician could check laboratory reports for a patient under clinical DSS via a web page, for instance. Gateways to access external health information residing in other systems are enabled by standardized data exchanges.

Lastly, on the right side of Figure 2, the output applications are identified. As a result of service processing of various health data, outputs may include query-response (which patients made visits today?), generation of reports (daily visit summary report) and online analytical processing (drugs prescribed vis-à-vis allergic reactions analysis). These outputs aid providers in making timely health-related decisions. The SOA architecture becomes less challenging to develop once the various components are identified (Raghupathi and Kesh, 2007).

Figure 3 is a graphical framework of the overall SOA framework for the health clinic setting (Raghupathi and Kesh, 2007).

Different services can be configured and offered by service providers who process the service implementations, provide their service descriptions to the registry and provide support. Since services may be offered by different participants—such as hospitals, labs, payers, pharmacies and providers—and communicated via the Web, they provide a distributed computing infrastructure for both intra- and inter-enterprise application integration and collaboration. The virtual connection line can be termed a service bus.

In Stage 2, the different relevant 'services' are confirmed.

Stage 3

In Stage 3 we start to articulate the services in a more operational way, leading to the conceptual models in Stage 4. An overall architecture, derived from the SOA framework-rich pictures painted in

Figure 2. An SOA-based integrated digital health system framework (source: Raghupathi and Kesh, 2007) – Stages 1 & 2

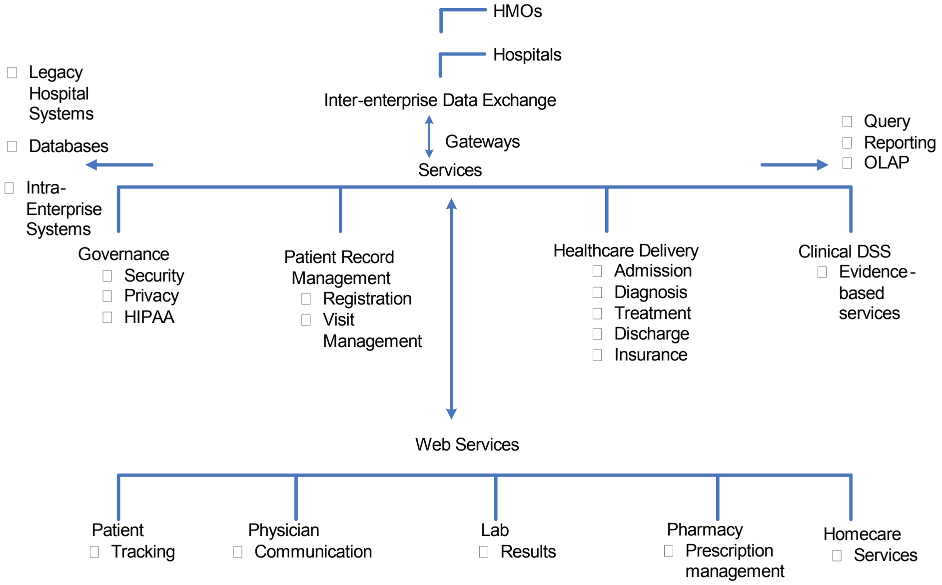
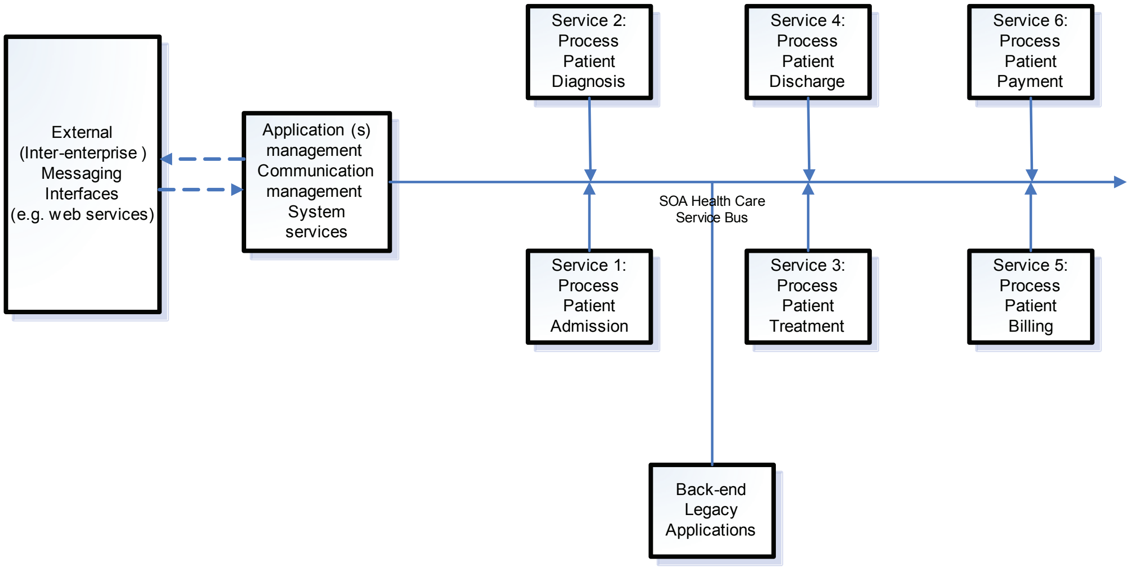
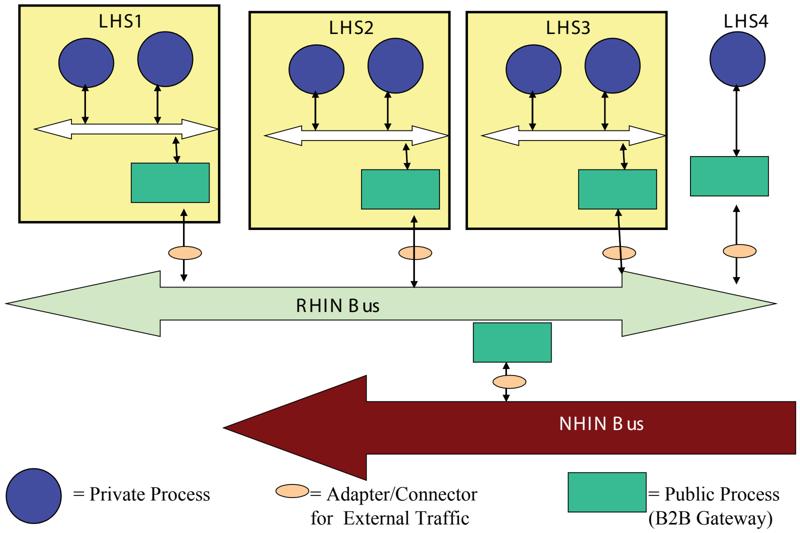


Figure 3. Examples of "services" in the SOA-based IDHS – Stages 1 & 2 (source: Raghupathi and Kesh, 2007)



Stages 1 and 2, is evolved. This diagram shows the various components in a more specific way. Figure 4 shows an overall SOA-based view of how local, regional, national and global healthcare systems could interoperate with to form a large scale IDHS. This architecture would provide a loosely coupled, digital, service-oriented healthcare system where local healthcare systems interact with regional health information networks (RHINs), a national health information network (NHIN), and even a global health information network (GHIN). Basically, an SOA-based service bus exists at local, regional, national and global levels. For example, LHS1 represents a local small physician's office that connects to a hospital, lab, pharmacy, etc through a local service bus. Many of these (e.g. LHS1, LHS2, LHS3, etc) together form an integrated health system such as those of Geisinger, Kaiser Permanente or United Health. These in turn connect into a RHIN, a state-wide or multi-state system, through an RHIN bus. The RHINs could similarly connect into an interoperable NHIN through an NHIN bus. National surveillance systems are examples of how this model can be used. Over the long term, NHINS potentially could link into GHINs, for example, for pandemic monitoring and tracking as well for enabling portability of health data. In addition to flexibility and interoperability, this architecture provides needed privacy and security services through public and private processes and at different levels. Basically, private processes in LHS1 only communicate with other private processes in LHS1, through the service bus. A public process based on the B2B gateway pattern, deals with all external interactions and thus shields the private processes from external processes. The B2B gateways also translate the data between external and internal processes by using adapters and converters. Depending on the application, different types of adapters can be used. For example, if a doctor in LHS1 (Lansing, Michigan) needs to exchange information with a laboratory in LHS2 (Ann Arbor, Michigan), the B2B gateways at the Lansing and Ann Arbor sites will provide the security and privacy checking, and the adapters will provide data translation between the two sites. These adapters also can

Figure 4. Overall SOA-based IDHS SOA architecture – Stage 3



be used to connect legacy applications into the IDHS using screen scrapers.

The root definitions of each relevant service (service descriptions) can also be developed. Typically, within a healthcare delivery environment, a service can be a simple healthcare process capability (such as GET MEDICAL HISTORY DATA or VALIDATE INSURANCE), a more complex transaction (PROCESS INSURANCE POLICY DATA or PRODUCE BILL) or a routine system service (VERIFY PATIENT KEY DATA or VERIFY PRESCRIPTION KEY DATA). Services may be low-level or complex high-level (fine-grained or course-grained) functions, and there are very real tradeoffs in performance, flexibility, maintainability and reuse, based on these definitions. The level of granularity is a statement of a service's functional richness. For example, the more course grained a service is, the richer the function offered by the service. Services are typically course-grained healthcare functions such as EDIT EXISTING PATIENT DATA because this operation may result in the execution of multiple, finer-grained operations, such as REQUEST SERVICE, VERIFY PATIENT KEY DATA, and so on (Raghupathi and Kesh, 2007).

Each root definition may be verified using the techniques outlined by Checkland (1981, 1995) and characterized by the acronym CATWOE (Customers, Actors, Transformation process, Worldview, Owners and Environmental constraints).

- **Customers:** Patients are the beneficiaries of the IDHS activities (services); stakeholders, such as clinics, hospitals, and insurance companies, are also beneficiaries in the sense they achieve interoperability with the SOA.
- **Actors:** Healthcare providers/participants are the agents who execute the various services in the IDHS and thereby carry out the transformation of patient care.
- **Transformation process:** The patient is transformed from a "sick" person to a "well" person. The services contribute to this transformation.
- **Weltanschauung/Worldview:** The overall goal is to deliver quality health service at reduced costs whereby the patient is treated effectively and the health service is delivered in an integrated manner.

- **Ownership of the system:** This is difficult to identify in an SOA-based IDHS. For example, who owns or governs a particular service? It is conceivable that the stakeholder who initiates the service (e.g. a hospital admission clerk) may be the "owner." Or, it could be the insurance claim processor in a health maintenance organization. However, in the IDHS collective ownership and accountability can be envisioned.
- **Environmental constraints:** The designer must consider regulatory issues (e.g. HIPAA) as well as privacy and security issues. A constant survey of the healthcare delivery environment is critical.

The application of CATWOE is iterative and continual. As participants enter and leave the SOA bus and services are added and deleted, ongoing evaluation is necessary for feedback and modifications.

Stage 4

In Stage 4 the designer takes the root definitions (e.g. of the overall architecture, components and services) and translates these into conceptual models using a variety of diagramming and modeling tools. For example, a context diagram using structured systems analysis can highlight the inputs to and outputs from the IDHS. Additionally, a high level dataflow diagram can indicate the "services (processes)," "dataflows" and "data stores (files)." A series of dataflow diagrams represents the various levels in the SOA. These diagrams can be augmented with diagrams in the Unified Modeling Language (UML). Use case and class diagrams can be developed to represent particular services (methods) as well as the data (attributes) of the entire IDHS. These can form the basis of the physical model for implementation. Code can be generated for the methods.

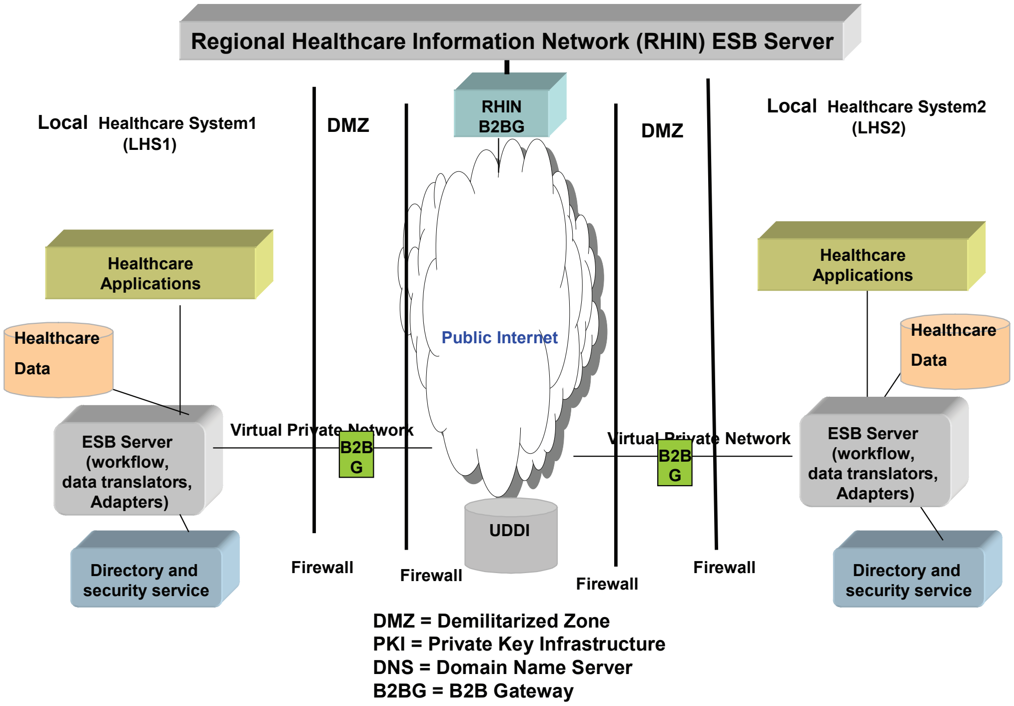
Stage 5

Whether or not a transformation to a service-oriented paradigm takes place, the conceptual models developed in Stage 4 are compared with the rich pictures from Steps 1 and 2. We cross back from the "systems thinking" world to the "real world." The various participants and stakeholders in the IHS may identify differences (e.g. the definition of a service) within the actual healthcare delivery processes.

Stage 6

The various models are vetted in Stage 6 by the stakeholders. Accommodations are sought through a negotiation process so that all stakeholders in the IHS agree on the governance and use of the IDHS. This is done in the context of the prevailing organizational culture, politics, technology acceptance environment and history. The conceptual models are operationalized into more tangible physical models for the purpose of implementation. Figure 5 translates the logical SOA-based architecture into a physical SOA-based architecture that shows how two LHSs actually communicate with each other. At each LHS, an ESB server, such as IBM WebSphere or Microsoft Biztalk Server 2006, is installed. These servers provide workflow, data translation and adapter capabilities. The B2B gateways manage the communications between different systems over the Internet by using the virtual private network capabilities. The B2B gateways themselves are placed in so-called demilitarized zones that are protected through multiple firewalls. In addition, directory and security services are provided for secure communications between the healthcare applications (private processes) at each LHS. An RHIN connects to this network through an RHIN B2B gateway as shown in Figure 5.

Figure 5. SOA architecture – a physical view – stage 6



Stage 7

This stage involves taking "action" based on the outcome of Stage 6. The physical architecture can be implemented as a series of web services. Web services (WS) technologies play an important role in this model. The public applications, supported by the B2B gateways, have WSDLs that are stored in a B2B UDDI directory shown in Figure 6. The B2B traffic between the RHIN and the LHSs operates at the B2B gateway level by using the B2B UDDI directory as a basis for discovery and connections. As more LHSs are added, more B2B gateways are added to this network and more entries are added to the B2B UDDI directory for discovery by the participants when they search the directory. Thus, new LHSs can be easily added to an RHIN.

Of course, there are several issues with implementation. The following discussion illustrates how a patient service, provided by a hospital (hospital1.com), can be defined, discovered, and invoked by using the following implementation steps:

Step 1. Define a patient service (in WSDL) that supports an operation (QueryPatient). It receives a query and processes it. Other operations, such as REGISTER PATIENT and DISCHARGE PATIENT, can be defined. The listing in Figure 6 simplifies WSDL for the patient service with an operation QueryPatient. A WSDL service definition consists of the following elements (all represented in XML):

- **Port:** Defines the service (PatientService) and the operation (QueryPatient) which uses the message types for input/output. The port associates the binding with the URI http://hospital1.com/QueryPatient where the running service can be accessed.
- **Message:** Defines input and output messages for the question that is sent to the directory

Figure 6. WSDL definition for a patient service

```
WSDL Definition for a Patient Service

<definitions name=”PatientService“
        …  initialization instructions ..



<portType name=”QueryPatient”>
    <operation name=”QueryPatient”>
      <input message=”Patient-Name”/>
      <output message=”Answer”/>
    </operation>
 </portType>



 <binding name=”Query_Patient” type=”tns:Purchase”>
    <soap:binding style=”rpc”
      transport=”http://schemas.xmlsoap.org/soap/http”/>
    <operation name=”QueryPatient”>
      <soap:operation soapAction=””/>
      <input>
        <soap:body
          encodingStyle=”http://schemas.xmlsoap.org/soap/encoding/”
          namespace=”urn:examples:healthcareservice”
          use=”encoded”/>
      </input>
      <output>
        <soap:body
          encodingStyle=”http://schemas.xmlsoap.org/soap/encoding/”
          namespace=”urn:examples:purchaseservice”
          use=”encoded”/>
      </output>
    </operation>
 </binding>




</definitions>
```

(by a person) and the information returned (a phone number).

- **Binding:** Tells that the communication is through SOAP (RPC). It also shows some technical details such as the type of encoding used, and so on.
- **Definitions and Types:** (not shown). Deals with data types that are defined using XML

Schema and some simple message types that are defined from the data types.

Step 2. Publish this service and the hospital (hospital1.com) that provides this service in UDDI. In many cases, a WSDL can be read directly and a SOAP message then issued to the service provider. In real life, this situation is comparable to being a recognized customer at the market you frequent. But, if you are looking for bargains, then you may have to "discover" different suppliers. In these situations, the real power of Web Services is displayed. That is, services are defined in UDDI and then discovered by the clients. UDDI provides a directory for all services and defines the following data types (although not all are required):

businessEntity: Business Details (name, contacts, etc.)
businessService: Web services provided by business (online-ordering, etc.)
bindingTemplate: Technical details to invoke Web services
tModel: Technical fingerprints used to access service specifications
publisherAssertion: Show relationship between business Entities

The UDDI statements in Figure 7 define the hospital1.com and the service (HealthService). The service provider can add extra information in the service such as service guarantees, cost, etc.

Step 3. Find (discover) the hospital and the service from the UDDI directory. The UDDI services can be discovered by SOAP messages. These messages use APIs for discovery. To search for a company, "Hospital1.com" defined in the above UDDI, we would create the following query within a SOAP envelope:

```
<find_business generic=”1.0“
    xmlns=”urn:uddi-org:api”>
        <name>Hospital1.com</name>
</find_business>
```

To search for a service, "PatientService" defined in the above UDDI, we would create the following query within a SOAP envelope:

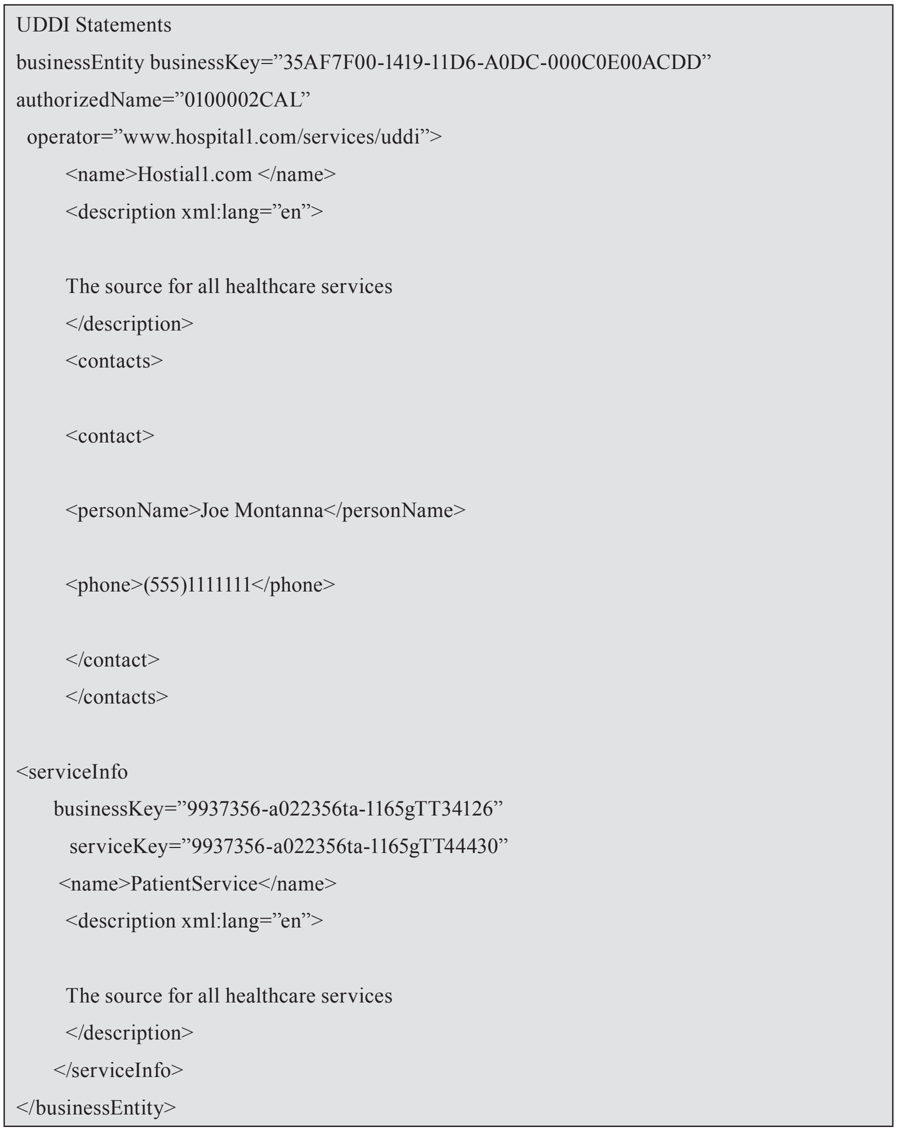
```
<find_service generic=”1.0“
    xmlns=”urn:uddi-org:api”>
        <name> PatientServcie </name>
</find_service>
```

Step 4. Invoke this service by sending and receiving SOAP messages. The SOAP messages can be used to invoke the WSDL service defined above. The SOAP message in Figure 8 activates the patient service and issues a query for a patient "Sam Nun." Figure 9 shows the SOAP message with the response that the patient (Sam Nun) is in the emergency room.

The overall SSM approach can be evaluated in terms of efficacy, efficiency, effectiveness, ethics, and elegance, which, like the components CATWOE, have special meanings (Checkland, 1995):

- **E1 – *Efficacy***. Does the system work? Is the transformation achieved? Are patients treated and records digitized?
- **E2 – *Efficiency***. Will the system work with minimum resources? Is the system worthwhile? To answer this, a comparison of the value (not necessarily monetary) of the system's output and the resources needed to achieve that output is necessary. How many patient records are processed per day? How much money is saved compared to manual processing? How does the IDHS compare to the manual IHS?
- **E3 – *Effectiveness***. Does the system contribute to the enterprise? Does the system achieve its long term goals? Is there a reduction in medical errors? Is there an increase in delivery quality?
- ***E4 – Ethics.*** Is it sound morally? Are privacy and security issues considered in design?
- **E5 – *Elegance***. Is the IDHS aesthetically designed? Is the system functionally robust?

Figure 7. UDDI statements



```
UDDI Statements
businessEntity businessKey="35AF7F00-1419-11D6-A0DC-000C0E00ACDD"
authorizedName="0100002CAL"
  operator="www.hospital1.com/services/uddi">
        <name>Hostial1.com </name>
        <description xml:lang="en">

        The source for all healthcare services
        </description>
        <contacts>

        <contact>

        <personName>Joe Montanna</personName>

        <phone>(555)1111111</phone>

        </contact>
        </contacts>

<serviceInfo
      businessKey="9937356-a022356ta-1165gTT34126"
         serviceKey="9937356-a022356ta-1165gTT44430"
       <name>PatientService</name>
        <description xml:lang="en">

        The source for all healthcare services
        </description>
      </serviceInfo>
</businessEntity>
```

This discussion is based on work reported in Raghupathi and Kesh (2008).

CHALLENGES IN SOA-BASED IDHS DESIGN

Several challenges need to be addressed in SOA-based design. Against the backdrop of a lack of uniform standards (although there are efforts in development), defining a service is very difficult considering the semantic issues. Additionally, moving to a service-based approach would entail major redesign of organizational processes. The issue of SOA governance is a still a work in progress. The SOA development process requires the application of multiple techniques such as business process modeling, conceptual modeling with methods, such as object-oriented methods. In addition, the evaluation and measurement of

SOA functionality is fairly complex and models and methods are not yet available. On the systems side, Checkland (1981) as well as Checkland and Scholes (1990) suggest that SSM may be supplemented by "other systems thinking." For example, strategic assumption surfacing and testing (SAST) (Mason and Mitroff, 1981) might be used to expand the inclusion of the range of alternatives while critical systems thinking (CST) (Jackson, 1991) might be brought in to help handle conflict. In practice, a hybrid approach that combines the SSM for high level meta analysis and modeling with specific socio-technical approaches to operationalize the model.

CONCLUSION

We have discussed the potential of the SOA in the design of interoperable IDHSs, and we have described a soft systems methodology for development of the SOA architecture, illustrated with a prototype implementation. Future research can focus on the operational and validation issues in the implementation of SOA in healthcare as well as on developing solutions to meet the SOA challenges discussed. Additional systems approaches need to be compared and evaluated for future design of RHINS and the NHIN to be efficacious. In the long-term, the challenge will be to design a global health information network (e.g. pandemic surveillance). And as ever, cost-benefit issues will have to be addressed.

REFERENCES

Aarts, J., Peel, V., & Wright, G. (1998). Organizational issues in health informatics: a model approach. *International Journal of Medical Informatics*, *52*, 235-242.

Basden, A., & Wood-Harper, A.T. (2006). A philosophical discussion of the root definition in soft systems thinking: an enrichment of CATWOE. *Systems Research and Behavioral Science*, *23*, 61-87.

Berg, M. (1999). Patient care information system and health care work: a socio-technical approach. *International Journal of Medical Informatics*, *55*, 87-101.

Berg, M., Aarts, J., & van der Lei, J. (2003). ICT in health care: sociotechnical approaches. *Methods of Information in Medicine*, *42*(4), 297.301.

Blobel, B.G.M.E. (2006). Advanced EHR architectures – promises or reality. *Methods of Information in Medicine*, *45*(1), 95-101.

Brocklesby, J. (2007). The theoretical underpinnings of soft systems methodology – comparing the work of Geoffrey Vickers and Humberto Maturana. *Systems Research and Behavioral Science*, *24*, 157-168.

Burrell, G., & Morgan, G. (1979). *Sociological Paradigms and Organizational Analysis*, Hememann, London, UK.

Carter, S. (2007). *The New Language of Business – SOA and Web 2.0*. IBM Press.

Charette, R. (2006). EHRs: electronic health records or exceptional hidden risks? *Communications of the ACM*, *49*(6), p. 120.

Chaudhry, B., Wang, J., Wu, S., Maglione, M., Mojica, W., Roth, E., Morton, S.C., & Shekelle, P.G. (2006). Systematic review: impact of health information technology on quality, efficiency, and costs of medical care. *Annals of Internal Medicine*, *144*, 742-752.

Checkland, P. (1976). Towards a systems-based methodology for real-world problem-solving. In J. Beishon & G. Peters, (Eds.), *Systems Behaviour,* (pp. 51-77). London: Harper and Row.

Checkland, P. (1981). *Systems Thinking, Systems Practice*. Chichester: Wiley.

Checkland, P. (1988). Soft systems methodology: an overview. *Journal of Applied Systems Analysis*, *15*, 27-30.

Checkland, P. (1995). Model validation in soft systems practice. *Systems Research*, *12*(1), 47-54.

Checkland, P. (2000). Soft systems methodology: a thirty year retrospective. *Systems Research and Behavioral Science*, *17*, S11-S58.

Checkland, P., & Holwell, S. (1998). *Information, Systems and Information Systems*. Chichester: Wiley.

Checkland, P., & Scholes, J. (1990). *Soft Systems Methodology in Action*. Chichester: Wiley.

Cherns, A. (1976). The principles of socio-technical design. *Human Relations*, *29*, 783.

Christis, J. (2005). Theory and practice of soft systems methodology: a performance contradiction. *Systems Research and Behavioral Science*, *22*, 11-26.

Chujo, H., & Kijima, K. (2006). Soft systems approach to project-based education and its practice in a Japanese university. *Systems Research and Behavioral Science*, *23*, 89-105.

Deetz, S. (1996). Describing differences in approaches to organization science: rethinking Burrell and Morgan and their legacy. *Organization Science*, *7*(2), 191-207.

Emery, F.E., & Trist, E.L. (1960). Sociotechnical systems. In Churchman, C. W., & Verhulst, M. (eds). Management Science Models and Techniques. In *Proceedings ofthe Sixth International Meeting of The Institute of Management Sciences*, *2*, 83-97. Pergamon Press.

Flood, R.L., & Jackson, M.C. (1991). *Creative Problem Solving*. West Sussex, England: John Wiley & Sons.

Frisse, M.E. (2005). State and community-based efforts to foster interoperability. *Health Affairs*, *24*(95), 1190-1196.

Gold, J.D., & Ball, M.J. (2007). The health record banking imperative: a conceptual model. *IBM Systems Journal*, *46*(1), 43-55.

Health & Human Services. (2004).*The Decade of Health Information Technology: Delivering Consumer-centric and Information-rich Health Care-Framework for Strategic Action*.

Himmelstein, D.U., & Woolhandler, S. (n.d.). Hope and hype: predicting the impact of electronic medical records. *Health Affairs*, *25*(5), 1121-1123.

Institute of Medicine. (2001). *Crossing the Quality Chasm: A New Health System for the 21st Century*. The National Academies Press.

Jackson, M.C. (1991). *Systems Methodology for the Management Sciences*. Plenum, New York.

Jackson, M.C. (2000). *Systems Approaches to Management*. New York: Kluwer Academic/Plenum Publishers.

Jackson, M.C. (2003). *Systems Thinking: Creative Holism for Managers*. Chichester: Wiley.

Katehakis, D.G., Sfakianakis, S.G., Kavlentakis, G., Anthoulakis, D.N., & Tsinakis, M. (2007). Delivering a lifelong integrated electronic health record based on a service oriented architecture. *IEEE Transactions on Information Technology in Biomedicine*, *11*(6), 639-650.

Kroes, P., Franssen, M., Poel, I. van de., & Ottens, M. Treating socio-technical systems as engineering systems: some conceptual problems. *Systems Research and Behavioral Science*, *23*, 803-814.

Kuhn, K.A., & Guise, D.A. (2001). From hospital information systems to health information systems problems, challenges, perspectives. *Methods of Information in Medicine*, *40*(4), 275-287.

Luckett, S., & Grossenbacher, K. (2003). A critical systems intervention to improve the implementation of a district health system in KwaZulu-Natal. *Systems Research and Behavioral Science*, *20*, 147-162.

Marks, E.A., & Bell, M. (2006). *Service-Oriented Architecture (SOA): A Planning and Implementation Guide for Business and Technology.* Hoboken, New Jersey: John Wiley & Sons, Inc.

Mason, R.O., & Mitroff, I.I. (1981). *Challenging Strategic Planning Assumptions*. Chichester: Wiley.

McDonald, C.J. (1997). The barriers to electronic medical record systems and how to overcome them. *Journal of the American Medical Informatics Association*, *4*(3), 213-221.

McMurry, A.J., Gilbert, C.A., Reis, B.Y., Chueh, H.C., Kohane, I.S., & Mandl, K.D. (2007). A self-scaling, distributed information architecture for public health, research, and clinical care. *Journal of the American Medical Informatics Association*, *14*(4), 527-533.

Melvin, V.C. (2008). *Health information technology – HHS is pursuing efforts to advance nationwide implementation, but has not yet completed a national strategy.* General Accounting Office, GAO-08-499T.

Mobach, M.P. (2007). A critical systems perspective on the design of organizational space. *Systems Research and Behavioral Science*, *24*, 69-90.

Nadkarni, P.M., & Miller, R.A. (2001). SOA in medical software: promise and perils. *Journal of the American Medical Informatics Association*, *14*(2), 2001, 244-246.

Overhage, J.M., Evans, L., & Marchibroda, J. (2005). Communities readiness for health information exchange: the national landscape in 2004. *Journal of the American Medical Informatics Association*, *12*(2), 107-112.

Raghupathi, W., & Kesh, S. (2007). Interoperable electronic health records design: towards a service-oriented architecture. *e-Service Journal*, *5*(93), 39-57.

Raghupathi, W., & Kesh, S. (2008). Designing electronic health records versus total digital health systems: a systemic analysis. Accepted for publication in *Systems Research and Behavioral Science.*

Raghupathi, W., & Umar, A. (2007). Exploring an MDA approach to developing information systems in health care. *International Journal of Medical Informatics*, *77*(5), 305-314.

Stowell, F. (2008). Do we mean information systems or systems of information? *International Journal of Information Technologies and the Systems Approach*, *1*(1), 25-36.

Ulrich, W. (1980). The metaphysics of design: a Simon-Churchman "debate". *Interfaces*, *10*(2), 35-40.

Walker, L. (2007). IBM business transformation enabled by service-oriented architecture. *IBM Systems Journal*, *46*(4), 651-667.

Warren, L. (2004). A systemic approach to entrepreneurial learning: an exploration using story telling. *Systems Research and Behavioral Science*, *21*, 3-16.

Whitman, J. (2005). Human systems and global governance. *Systems Research and Behavioral Science*, *22*, 311-317.

Wright, A., Goldberg, H., Hongermeier, T., & Middleton, B. (2007). A description and functional taxonomy of rule-based decision support content at a large integrated delivery network. *Journal of the American Medical Informatics Association*, *14* (4), 489-496.

Yasnoff, W.A., Humphreys, B.L., Overhage, M., Detmer, D.E., Brennan, P.F., Morris, R.W., Middleton, B., Bates, D., & Fanning, J.P.A consensus action agenda for achieving the national health information structure. *Journal of the American Medical Informatics Association*, *11*(4), 332-338.

This work was previously published in the International Journal of Information Technologies and Systems Approach, Vol. 2, Issue 2, edited by D. Paradice and M. Mora, pp. 15-33, copyright 2009 by IGI Publishing (an imprint of IGI Global).

Chapter 2.11

Evaluation Methods to Monitor Success and Failure Factors in Health Information System's Development

Jytte Brender
University of Aalborg and Virtual Center for Health Informatics, Denmark

ABSTRACT

This chapter discusses the extent to which factors known to influence the success and failure of health information systems may be evaluated. More specifically, this is concerned with evaluation of such factors—for screening, diagnostic or preventive purposes—by means of existing evaluation methods designed for users. The author identifies that it is feasible to identify evaluation methods for most success factors and failure criteria. However, there is a need for situational methods engineering as the methods are not dedicated to answering the precise information needs of the project management. Therefore, demands are being placed on the evaluators' methodical and methodological skills, when evaluating health information systems. The author concludes the chapter by pointing at research needs and opportunities.

DOI: 10.4018/978-1-59904-792-8.ch011

INTRODUCTION

"Evaluation is the act of measuring or exploring properties of a health information system (in planning, development, implementation, or operation), the result of which informs a decision to be made concerning that system in a specific context." (Ammenwerth et al., 2004, p. 480)

Many times health informatics professionals have suggested verbally that there are not enough evaluation methods that can be used to evaluate health information systems. A review of the evaluation literature regarding biases in assessment of medical IT-based solutions (Brender, 2006a, pp. 243-323) indicates that the general level of knowledge among evaluators is insufficient, that is, such methods and their assumptions are not appropriately known to their target users. This was also discussed among a group of key evaluation researchers and journal editors gathered in 2003 on the topic "New

Approaches to the Systematic Evaluation of Health Information Systems" (HIS-EVAL), sponsored by the European Science Foundation (ESF) (see Ammenwerth et al., 2004). The outcome of this workshop was a number of recommendations as regards the future of health information systems evaluation, also called the Innsbruck Declaration. Among others, the declaration suggests promotion of reports on methodological and methodical evaluation studies, and that evaluation studies should be grounded on scientific theory and rigorous approaches.

The above implicitly indicates that the literature on evaluation of health information systems is far from robust. Recent publications of textbooks, such as the *Handbook of Evaluation Methods* for *Health Informatics* (Brender, 2006a; a Danish version was published in 2004), have demonstrated that there exists a substantive number of evaluation methods applicable within health informatics. This handbook has the nature of an encyclopedia, since it takes a (critical) meta-view on an extensive list of evaluation methods while focusing on their areas of application, assumptions for application, tacit built-in perspectives as well as their perils and pitfalls, rather than putting emphasis on detailed cookbook prescriptions for application.

Therefore, the purpose of this chapter will be: (1) to verify whether there exist appropriate evaluation methods for the assessment of factors known to influence the success and failure of IT-based solutions, and (2) to identify potential needs as regards further development of evaluation methods, be it innovation or refinement of existing methods. More specifically, this chapter will emphasize the assessment of IT-systems from a user perspective within organizational settings, that is, this chapter is concerned with methods addressing interactions between a technology and its organizational, psychological and social components, as well as its effects. The methods in the handbook have been gathered from a variety of disciplines, ranging from psychology and social science to computer science and health informatics. Some of the methods are not designed as dedicated evaluation methods, but may be valuable as supportive means in an evaluation context. Thus, in such cases situational method engineering will be needed, thereby putting demands on the methodical and methodological skills of the evaluator.

There are two types of evaluation, constructive (or formative) and summative evaluation. Both types of evaluation serves the purpose of providing the (project) management with a decision-making basis in some context, cf. the definition given in the introductory citation. The difference is the overall context within which they each operate. For example, constructive assessment has the purpose of providing the foundation for identifying new or the need for altered directions with regard to subsequent development or implementation tasks. Alternatively, it can illuminate possible issues associated with specific problem situations. Since most IT-projects involve some compromises between an ideal solution and something realizable, controlled by local concerns, considerations and limiting factors, the role of constructive evaluation is to provide guidance to organizations in optimization of the dynamic health information systems development and/or implementation process.

The purpose of summative evaluation is to provide a concluding statement on properties of a health information system in a different kind of decision-making context. Examples of summative evaluation include: the evaluation of objectives fulfillment (i.e., assessing a health information system implementation in terms of its ability to fulfill organizational objectives), or assessing a system when it is delivered and one wants to ascertain that the system functions in accordance with the contractual agreement.

Some evaluation methods are retrospective in nature (like **root causes analysis** and **functionality assessment**). Others (like **balanced scorecard** and **delphi**) may guide the planning or revision of a health information systems development and thereby enable constructive evaluation. Still, other

Table 1. Examples of the hierarchy of success factor from Brender et al. (2006). The dots indicate that the list is continued at that particular place

Functional success factor

1. Careful preparation of the User Requirements Specification to appropriate and balanced take into account and express users' requirements, needs as well as demands
    a) (in general)
    b) Fulfill the needs (whether stated or not) rather than only the requirements of the users
    c) Enable and allow ongoing extension, while carefully controlling the aspect of moving targets
2. Alignment of the role and design of the IT-system
    a) …..
    b) Semantic understanding of the application domain
    c) The socio-technical nature of health information systems is understood
    d) The functionality has to be compatible with the users' way of thinking (cognitive aspects)
    e) …..
3. Coping with the complexity
4. ……

Organizational success factor

1. Collaboration and cooperation
    a) …..
2. ……
3. Work from the workflow
    a) …..
    b) Planning of new procedures must appropriately take existing patterns of collaboration into account
    c) …..
    d) The users show a willingness to change practice
4. …..

evaluation methods are not clearly prospective or retrospective in nature; rather they allow one to assess evolving situations.

BACKGROUND

The analysis of whether there exist appropriate evaluation methods for the assessment of known success and failure factor will be based on the union of factors identified within the literature. A huge number of studies of a single case have concluded on one or a few specific factors influencing the diffusion, penetration, or acceptance of IT-based systems, implying that the literature is a puzzle of findings. Consequently, we will take advantage of existing, significant reviews, based on different approaches.

Recently, Brender et al. (2006) conducted a delphi study where they identified a comprehensive list of success and failure aspects of health information systems development or implementation. The study was conducted as a follow-up initiative on the MIE2004 Special Topic Conference, in Munich, 2004, with the purpose of identifying success and failure characteristics of health informatics applications. Even though the study was conducted in the health informatics domain, its findings may also be valid for a number of other domains as well. In their work a total of 110 success factor and 27 failure criteria were identified and rated quantitatively for a number of different types of health information systems. These factors were organized in a hierarchical structure based on a number of categories, such as functional, behavioral, technical, managerial, cultural, and so forth; see the sample in Table 1. The reader is referred to Brender et al. (2006) for the complete list of factors, or alternatively, almost all of them are included in the below discussion on methods to support the evaluation of such factors.

Within the delphi study, none of the aspects identified were concluded to be insignificant by the expert panel at the final quantitative rating.

Therefore, none of the factors could be excluded from the list. Brender et al. (2006) suggest that the reason for including all of the success/failure factor arises as a consequence of the contextual nature of the factors themselves. If one uses this list of success and failure factor as a starting point only additional factors identified within literature reviews shall be included in the below analysis.

Three major case studies on IT systems' success and failure factor were reported in the 90s: Bikson and Eveland (1989), Crosswell (1991), based on quantitative and qualitative analysis of 55 and 39 cases, respectively. Lastly, Price Waterhouse (1997) conducted an extensive questionnaire survey of 500 cases worldwide. These three studies all indicate that there are a number of strong indicators of success and failure residing within the organizational context, from the beginning of the projects' lifecycle till full-blown operation. As compared to Brender et al.'s work (2006), one additional success indicator was reported by Bikson and Eveland (1989):

- Users' conception of their own status in terms of technological innovation

Croswell's work (1991) focused on obstacles and identified the following additional IT success and/or failure factors:

- Organizational coordination and conflicts
- Database structure and source materials
- Data communication and networking
- Software complexity/maturity

Croswell noted (with surprise) that there were few technical obstacles associated with IT failure. Nevertheless he observes more of this kind of obstacles than the two other reviews. These technical obstacles are included implicitly in the analysis below.

Price Waterhouse (1997) identified a number of success factor in addition to the set outlined in Brender et al.'s delphi study (2006):

- Competing resource priorities
- Insufficient communication
- Long lead-time for IT solutions
- Initiative fatigue
- Poor integration of IT and non-IT aspects of change
- Lack of HR policy re-inforcement

A more recent report by Stavri and Ash (2003) used a review of narrative stories of success/failures from a consensus conference on CPOE involving 13 experts. The study suggests that two additional factors (reported as success factor) are of relevance in our context:

- "When they say 'no way,' we asked 'what can you live with?'" and
- Change (goals, software, plans) based on lessons from pilot.

A recent, but smaller, literature review aimed at developing a better conceptual foundation for health information systems failure (and success), was presented by Heeks (2006). Heek's work identifies a couple of archetypes of IT failure that need to be added to the list of success/failure factor:

- Dominating design inscriptions—be they technological, managerial or medical—that incorporate particular cultural values, the failure arising when the stakeholder groups differ from the designer groups and/or includes different levels of formality and rationality
- Varying organizational conditions and cultures between private and public hospitals
- Differences in cultures between industrialized and developing countries, within and between countries of the latter type

These additional factors were included in the following analysis explicitly as separate factors or implicitly as part of the explanation of one or more given other factors.

In summary, the literature in general points to the presence of soft and organizational factors rather than hard-core technical factors as primary determinants of IT success and failure. Haimes and Schneiter (1996) reference the following definition of a 'system' (p. 483): "a system is all the components, attributes and relationships needed to accomplish an objective." With this definition of a system, the conclusion is not surprising: The soft human and organizational issues associated with a health information systems development and implementation range in complexity from addressing concerns about user interface aspects to the social nature of the employment and organizational context. The soft human and organizational issues also include the qualities and characteristics of the organization, its members as well as mutual interactions among individuals at every level (from a psychological, anthropological and sociological point of view to a legal and liability point of view). These factors all contribute to the shaping of organizations. Therefore, since the implementation of new IT systems inevitably induces changes in the organization as a whole, the mentioned soft human issues are not invariant factors. They will as primary or propagated effects influence the success or failure of IT-based solutions within the healthcare organization.

Delimitation

The primary objective of this study was to verify whether there exist appropriate evaluation methods for the assessment of each of the known success and failure factor. However, naturally, not all success factor and failure criteria need an explicit evaluation method for their assessment. For example, some forms of information need require simple 'yes/no' questions. Other types of success and failure factor, like 'evolution rather than revolution,' constitute (simple) project management aspects of a kind for which calling for a dedicated evaluation method would seem artificial. Furthermore, the study of political factors in general has another nature than those relevant in a pure evaluation context. All of these kinds are omitted from the below analysis, since space does not permit us to go detailed into each and every factor on the list.

There are a number of key themes that arise when one examines the success and/or failure of health information systems. For example, when one examines success/failure factor, one can see that some success factor are prerequisites for others. Therefore, these success factors have second or third order propagation effects upon the organization. For instance, senior management commitment is a prerequisite for strong, clear, and appropriate leadership, effective communication and resource allocation, but not for the ability to generate sustainable solutions. This was not taken into account in this chapter. As well, the issue of whether a given success/failure factor constitutes a root cause or a propagated effect was not addressed. They all represent the pattern of presentation of the success or failure much as a symptom is a part of a disease pattern.

In any case, it is the project management's responsibility to reduce the uncertainties as early as possible within the natural trajectory of a project—that is, to take into account the success/failure factor. This is where we perceive evaluation as a valuable means to timely address known symptoms. Preferably, one should look beyond the symptoms to the root cause. The project management should not merely tinker with problems (i.e., treat symptoms) but radically seek and address the root causes of problems. Such investment in evaluation during project management is necessary as only then will the chances of implementation success be dramatically increased. However, tinkering or not is not the issue of this contribution. In the following, there is merely a point to point correlation of an information need and candidate sources of information needed to ensure that a project succeeds. Some methods can dig deeper than others. Furthermore, evaluation methods can be combined and be used to explicitly address the root causes of identified problems; see for instance **root causes analysis** and **functionality assessment** in Brender (2006a).

CANDIDATE METHODS OF EVALUATING SUCCESS/ FAILURE FACTOR

In the present section of this chapter IT success/failure factor will be matched to evaluation methods. One factor or criterion at a time will be analyzed for its overall meaning and then matched with the individual methods' application area, location in the life cycle, and assumptions for application, perspectives, and so on.

Note that within the sections following, the success/failure factor are indicated in Italics between apostrophes. Likewise, methods (as named in Brender, 2006a) are stated in bold. For ease of referencing the names from Brender (2006a) have been kept; however, since these are usually identical with the original authors' own naming of their methods or intuitively understandable the reader may easily find alternative descriptions in the literature. The structure of this entire section follows the framework suggested in Brender et al. (2006).

Note also, that it is the decision-makers within the organization that ultimately are the responsible (liable) for the final outcome of the information system development and/or implementation process when it concerns operation of and with an IT-based solution. The following shall be perceived by the readers as suggestions for instruments supporting an organization at the development and/or implementation of such systems. However, it is entirely up to the project management whether or not to monitor for given success/failure factor, and whether he or she finds the issues relevant or the suggested methods useful in their specific project context.

Suggestions on Methods Applicable for the Evaluation of Success Factor

Functional Factors

The first functional factor is *'careful preparation of the user requirements specification to appropriate and balanced take into account and express users' requirements, needs as well as demands.'* More specifically, this factor is concerned with fulfillment of needs (whether stated or not) rather than fulfilling users' explicit requirements alone. The method **requirements assessment** supported by the method **framework for assessment of strategies** may address issues like feasibility, verifiability, completeness, and alike. These methods may also address whether the solution described is the right one ('relevance'). However, user needs are to some extent tacit, and consequently, user requirements may be very difficult to fully and reliably assess. Requirements addressing a functionality that is characterized by tacit needs cannot be fully assessed, but input based on a combination of focuses may at least support such an assessment; see for instance, the above mentioned **framework for assessment of strategies** and the methods **analysis of work procedures**, **stakeholder analysis**, and **organizational readiness**, as well as **future workshop**.

Another functional factor is *'enable and allow ongoing extension, while carefully controlling the aspect of moving targets.'* This factor is a consequence of the indeterministic nature of system development projects and is aggravated by the long lead-time for IT solutions. Extensions and modifications of project plans are necessary among others to take into accounts unforeseen tacit requirements as well as to handle project encounters. Such work calls for a strong project vision, a clear project purpose, as well as a defined strategy. A strategy is necessary in order to accommodate for emergent project changes while maintaining project direction. In such cases the use of an evaluation method like the **balanced scorecard** may be helpful in handling strategic and directional aspects, while methods like **BIKVA** and **KUBI**[1] might be better as a means in the initial social process of deciding on the project direction.

The overall factor *'alignment of the role and design of the IT-system'* includes a number of issues of relevance for the IT success and/or failure. A first component factor is *'the functionality has to be compatible with the users' way of thinking.'* For example, in case of users performing repeated activities, users can be trained to operate a system in spite of its cumbersome functionality. However, for systems dedicated to supporting users' decision-making and work procedures (like the electronic healthcare record) the functionality has to comply with user tasks and user methods of operating within the work environment. Otherwise, dissatisfaction and human operational errors will arise. Awareness of the need to change work procedures when implementing a new system is necessary in order to limit the number of changes to user activities to what is feasible within a given organizational context or domain. Since alignment of user role and design of an IT system is clearly related to the cognitive aspects of work, several **usability** approaches may be applicable in this respect, prospectively and retrospectively. Methods such as **cognitive assessment**, **cognitive walkthrough**, **heuristic evaluation,** and **think aloud** may be useful when the study is assisted by cognitive psychologists. More research is needed in this area, since really effective assessment methods for addressing cognitive aspects are sparse at present.

The second component factor is *'the system has to be usable and useful, helping the user in his/her daily routine work.'* The issues here include the defined system's coverage of daily practice and whether it supports the accomplishment of the primary goal of user activities. For a prospective assessment of whether the system is usable and useful the **analysis of work procedures** may be a valuable source of input. For a retrospective assessment of whether a system is usable and useful the **functionality assessment** is valuable to identify deviations and explore causal relations.

The third component factor is *'the role and the design of the system have to comply with the organizational context, including structure, people, information flow and external links.'* Of course, organizations need to adapt to the new technology during their implementation of a new IT-based system, but the number, nature and seriousness of changes is an invariant factor that determines the degree of the system's success or failure. Therefore, prospective studies of organizational change should bear this factor in mind. The means is—as above—systems analysis methods, like different approaches for **Analysis of Work Procedures**.

The fourth component factor is *'the IT-system has to be compatible with the organization's daily practice.'* The issue and the means for addressing this factor are the same as for the previous factor.

The fifth component factor is *'semantic understanding of the application domain is necessary.'* The syntactic aspects (i.e., corresponding to work procedures) are addressed by systems analysis and design approaches. The semantic aspects are concerned with the profession-oriented culture of the domain, like determinant factors in decision-making. For example, in healthcare this may be illustrated by the tendency by healthcare staff to consider and treat all patients as unique cases, as opposed to the opposite and rational perspective that prescribes strict compliance to clinical protocols and guidelines. There is no need for dedicated evaluation methods in this respect, but there is a need for awareness from the designers and managers side, as the perspective of uniqueness implies a huge need for flexibility.

The sixth component factor is *'the socio-technical nature of health information systems needs to be understood.'* Socio-technical aspects of health information systems address people issues. The socio-technical perspective espouses the view that IT systems are more than technical constructs and that a flexible planning that balance social and technical effort is recommended. Consequently, there is a need to develop policies for handling the people issues. However, there are strong cultural differences in this respect, as discussed in Brender (2006a, part III; 2006b). Also this factor does not need an evaluation method, but has to be an integrated part of the systems development approach.

The final two component factors to the mentioned overall functional factor are: *'coverage of daily practice has to be sufficient, compared with the defined role of the IT-system'* and *'addressing a real, high-impact problem area rather than a borderline problem area.'* These two (sub-)factors are addressing the issue of attracting the attention of the users. It is important that the IT-system supports the users in accomplishing the primary goal of their activities to avoid competing activities. And again, a means (systems design and/or evaluation-wise) is systems analysis methods such as **analysis of work procedures**.

The overall factor *'coping with complexity'* comprises three factors, all of which have the nature of systems analysis/design rather than objects for formal evaluation:

- 'The implementation project should apply explicit means for coping with the complexity'
- 'Keep it simple, but not simpler than needed'
- 'Evolutionary or incremental development as an approach to cope with complexity, including the educational aspect.'

The factor 'flexibility towards dynamic changes and changes in the organizational context' is closely related to organizational readiness and may therefore be evaluated prospectively by means of the method **organizational readiness**. On the other hand, too many organizational changes or fluctuations may become a problem in itself. Methods like the **balanced scorecard** and **risk assessment** may be used as a means for organizations that are hyper-innovative and where change is a constant.

The final functional factor is *'added functionality are provided by the IT-system, enabling the user to provide new or better services.'* It is related to the users' motivation for engaging. The sub-theme of this factor, *'the incentive for the user (and stakeholders in general) must be clear and visible,'* in itself indicates the solution, namely to establish a clear and visible motivation. No formal evaluation method is dedicated to assess this issue. If user engagement turns out to be a project issue or one wants to prevent this then it is relevant prospectively to assess whether the incentive for the users is sufficient (or what is further needed) to motivate the user. Here, the methods **focus group interviews** or **delphi**, in combination with **social network analysis** or a **stakeholder analysis** might be useful.

Organizational Factors

The organizational factor *'Collaboration and cooperation'* concerns the delicate issue of social and other types of relations between elements in an organization. Such relations can be horizontal (i.e., across organizational units) and/or vertical (i.e., hierarchical). Evaluation of aspects related to collaboration and cooperation of relevance for the health information system success/failure may all be addressed prospectively by means of methods such as **social network analysis** and **stakeholder analysis**.

The organizational factor *'make implementation a transparent process within the organization'* has a sub-theme *'generally open for debate.'* These two factors address the question of balancing between two issues: transparency versus covertness, and decision-making versus decision-taking. Both are culturally influenced topics, and culture can here be understood in either the national respect and/or in the organizational respect that also includes the organization's prior history. By "decision-making versus decision-taking" is referred to the distinction between a hierarchical, top-managed approach for the development or implementation process (i.e., decision-taking) as opposed to a process that leads to a decision among relevant stakeholders (i.e., decision-making). Decision-making does not preclude the management from concluding on a decision, but implies that stakeholders' issues are openly discussed. So, the issue in reality is whether the decision approach taken is aligned with the needs and interests of the (involved) stakeholders. Methods like **focus group interviews**, alone or in combination with **social network analysis** or a **stakeholder analysis** might be valuable in providing insight into these aspects.

The organizational factor *'work from the workflow'* concerns among others the issue *'planning of new procedures must appropriately take existing patterns of collaboration into account.'* Radical changes to workflow and patterns of collaboration can be disruptive to the delicate social balance in an organization. Consequently, radical change bears the risk of all kinds of negative social reactions. The method **social network analysis** addresses the relations between elements within an organization (such as individuals, professions, departments or other organizations). Therefore, this method may provide useful input into the design and other planning of health information systems development or implementation, and thus it constitutes the candidate evaluation method.

Behavioral Factors

The behavioral factor stating that *'the users are key'* is highly culturally dependent. In some cultures end users refrain from being involved at all due to their perception of the division of roles between the management and the employees, see the discussion in (Brender, 2006b). However, in the Western countries suitable involvement of employees is a significant success factor—that is, involvement of the right type, level, and scale of employees. Another relevant question here is whether the right competences are available and accessible—that is, a question of competing activities. **Stakeholder analysis** and **social network analysis** are valuable methods for assessing behavioral aspects related to the development or implementation process. Both of these approaches may provide input as to what users to involve and/or to involve in what situations.

The behavioral factor *'the personal attitude, engagement and commitment'* concerns end users, managers as well as other stakeholders. It addresses issues such as employee opposition, lack of middle management support, aspects of executive leadership, and managerial commitment. Employee opposition may be explored by means of **focus group interviews** throughout a project. Managerial commitment can be addressed indirectly, for example by conducting a situation analysis, such as using that of the **logical framework approach**. The success factor *'presence of sufficient motivational activities'* relates to all aspects of personal attitude, engagement and commitment.

The behavioral factor *'user conception of their own status as regards technological innovation'* was pointed out by one of the reviews as a motivating factor. User conceptions influence motivation and can be elicited by means of different kinds of individual **interviews** and/or **focus group interviews**. Both types of interviews are general methods and that are well suited towards illuminating individual' opinions, attitudes and perceptions regarding a phenomenon and observations (e.g., health information system implementation).

Cultural Factors

There are many types of cultures, ranging from national, over religious to professional cultures. The deeply rooted, tacit cultural factors in general are not factors that one should evaluate. They just are, and changes in this respect may not be a short term effort. For example, some national cultures perceive answering a question with a "no" as highly impolite. Therefore, imagine the potential bias in a questionnaire study or the effect of yes/no-buttons in a user interface when asking individuals with such cultural backgrounds to answer those yes/no questions. Hence, project management needs to understand how to take cultural factors into account, especially when transferring technologies and/or development methodologies or specific information systems from one culture to another.

More specifically, project management needs to be aware of a couple of factors related to the professional culture need awareness:

- *'Understand medicine and healthcare in general as a separate culture:'* The strong professional culture in healthcare implies that healthcare staff should be involved in the implementation process—if not being in the driver's seat. There may even be varying organizational conditions and cultures that are present between private and public hospitals. For example, Heeks (2006) suggests that accounting and billing procedures are less of an issue in publicly rather than privately funded hospitals. And certainly this difference is pronounced between American IT solutions and the majority from the European countries. Differences of this kind may be identified by means of **analysis of work procedures.** Here, comparisons can be made between a system's business or enterprise model, and/or data models.
- *'Understand the local culture:'* Even within a given domain there may be islands of differing professional cultures. This factor may be addressed in the same way as the previous factor, but requires a finer level of analysis.

The cultural factor *'preparedness and willingness towards cultural change'* refers to the need for cultural changes, however, mainly related to the professional culture, for instance in work procedures. It includes a number of issues, such as:

- 'Awareness of the need for cultural change'
- 'Readiness for a potential new business model'
- 'Readiness for solutions not invented in-house'

Implementation of a (new) IT-based solution inevitably changes the organization. It is therefore important to nurture a new local culture for it to embrace the new technology. One problem may be that there is no perceived need for change by the local culture. Therefore, it is important to evaluate the readiness of an organization along with the factors outlined. **Organizational readiness** as an evaluation method was explicitly designed for prospective assessment in this respect. Unfortunately, the impression is that it is not yet a fully matured evaluation method. Alternatively, both the **field study** (screening and monitoring) and the **equity implementation model** (diagnostic) approaches may be useful as they allow for retrospective assessment of organizational context in terms of cultural success/failure factor.

Management Factors

The overall factor *'management support'* is mentioned in several of the reviews and hence it must be considered a significant success factor. Management support includes a number of sub-factors. However, some of these are yes/no aspects or belong under project management solely, and therefore, they are excluded here.

The first management factor is *'formulation and expression of a clear vision for the enterprise showing the IT-system as part of it.'* In most cases project management need not initiate an evaluation activity to assess the clarity of an organization's IT vision. In cases where an organization wishes to evaluate management factors such as clarity of organizational IT vision, a more formal evaluation approach can be taken. For example, the methods **balanced scorecard** and **framework for assessment of strategies** both require a clear and operational vision and strategy to be able to proceed smoothly in a development or implementation process. These two methods may therefore be valuable indirectly to assess the clarity of the vision specifically with respect to aspects of strategic relevance for implementing information technologies. Such evaluation may be carried out by performing the preparatory steps of either of these methods to see if the vision is sufficiently clear and operational.

There are a number of useful methods for assessing the management success factor *'Setting goals and courses'* (i.e. clarity of objectives), for example:

- **Framework for assessment of strategies** may be used prospectively to analyze the feasibility, timeline, risks, viability, and so forth, of the defined IT goals and courses.
- **KUBI** elicits a set of user or customer/client defined values, norms and objectives, and may provide an alternative set of goals and courses for comparison.
- **Balanced Scorecard** is a strategic project management approach based on goals and courses. These goals are used as a kind of measuring stick at decision making throughout the project. Applying **balanced scorecard** even as a desktop pilot may provide users and project team members with feedback on whether the established set of goals and courses are operational or defined in a useful way.

Regarding the management factor *'understanding the return of investment (whether material and/or immaterial benefits)'*: Beyond economic assessment of material benefits, a **delphi** investigation may reveal and characterize the immaterial benefits, other bottomline benefits, as well as the attitudes towards these both prospectively and retrospectively.

The management factor *'flexible planning'* includes the following themes:

- 'Enabling and allowing change of project plans and time tables'
- 'Realistic time lines'
- 'Understanding that implementation of an IT-based solution is a non-linear (indeterministic) process'
- 'Response to shortcomings is constructive'

These success factors are attitudinal in nature and are concerned with the project management itself and are also dependent upon the actual project management experience with the kind of activities in question. They are not topics that are meant for dedicated evaluation efforts. Should an organization wish to evaluate these attitudinal topics, one could prospectively evaluate these factors by means of methods such as **interview** using an external evaluator. Retrospectively, one could assess these IT success factor using **root causes analysis**, investigating the history, events and initiatives associated with the project to identify patterns of problems and possible subsequent actions.

The management factor *'prospective and proactive control'* includes a number of sub-factors, such as:

- 'Project management in general'
- 'A high degree of delegation and involvement combined with good coordination and communication'
- 'Sufficient communication,'
- 'Organizational coordination and conflicts'
- 'Stringent risk management'
- 'Cost-active control'

- 'Coordination'
- 'Appropriate action in response to unanticipated events'
- 'Sanction bottom-up signals as valuable input for steering'

Although this list is long, all of the items are related to good project management. One would not normally make these success factors the object of a formal and dedicated evaluation study in its normal sense. If a project is proceeding in ways that it should not and the project management is experiencing difficulties in diagnosing the causes, a **root causes analysis** could be carried out. Alternatively, if a **root causes analysis** is too difficult to undertake simpler approaches such as the situation analysis in **logical framework approach** would probably suffice in most cases.

The management factor *'consider IT implementation as a change process'* has four sub-factors related to IT success. These sub-factors can serve as guidelines for project management rather than requiring time taken away from project processes for the purpose of evaluation. These sub-factors include:

- 'Acknowledging that the IT-system represents a chance to support a change in the care delivery process'
- 'Stepwise progression rather than reengineering everything'
- 'Good supervision to enable a smooth and continuous change management'
- 'Poor integration of IT and non-IT aspects of change'

The essentials of the management factor *'change (goals, software, plans) based on lessons from pilot'* is that lessons from a pilot application should deliberately be used and taken action upon. Pilot studies allow the project management to find potential project flaws and to address those flaws prior to full IT implementation, irrespective of the nature or causal relation of the flaws. The **functionality assessment** method is perfectly suited for a retrospective investigation of problems and their causal relations. The principle within this method is that problems in the functionality (irrespective of cause) will reveal themselves in terms of unexpected or changed/changing work procedures—that is, resulting in observable, propagated actions and initiatives within the organization's work procedures (other than those that are planned or expected). Consequently, such emergent work procedures reflect the problems and therefore constitute candidates for subsequent exploration and potential action.

The factor *'coping with the impact of change'* concerns the ability to handle the necessary change processes. The method **organizational readiness** is an obvious candidate approach for prospective evaluation of the organization's ability to cope with the impact of change. The evaluation method **equity implementation model** can help in the retrospective assessment of users' reaction to the impact of implementing a new system, and thus this method may be valuable in understanding user behavior.

The factor *'user involvement'* (in general) is highly culturally dependent. **Stakeholder analysis**, as a user assessment strategy, allows one to determine if user involvement is appropriately being dealt with. **Stakeholder analysis** not only assesses who is involved, but how they are involved and engaged? Are they (i.e., the users) engaged in terms of representatives of stakeholder groups? Are users available? And in what way are users engaged: informed, consulted or actively engaged in the decision-making processes? The **stakeholder analysis** addresses these issues, taking into account the culture and existing organizational practice.

Another aspect of the *'user involvement'* factor is the sub-factor *'time must be freed or funding allocated for users to participate in the process.'* This aspect of IT success is closely connected to another sub-factor, *'competing resource priorities.'* These aspects of user involvement may prospectively be dealt with using a **risk assessment** approach, for instance by means of the concept of 'external factors' from the method **logical framework approach**. Retrospectively, user involvement may be explored in many ways, such as **interview** methods in general, **questionnaires**, or for instance, the situation analysis in **logical framework approach**.

One further management factor is *'when they say "no way," we asked "what can you live with?"'* This factor is concerned with the management approach to dealing with stakeholders' attitude. No formal evaluation method is needed to assess whether a given approach is the right solution for a given case, but the **balanced scorecard** and **KUBI** are two evaluation methods that can stimulate stakeholder-management dialogue in finding the way forward.

The factor *'strategy'* refers to the ability of an organization to formulate the foundation for all significant decisions and action plans (i.e., plans, methods, or series of maneuvers or stratagems for obtaining a specific goal or result). In terms of evaluation approaches organizational strategy can be evaluated using the method **framework for assessment of strategies.** The **framework for assessment of strategies** is a valuable method that can be used to assess an organizational strategy or to choose among alternative organizational strategies for instance with respect to feasibility, time lines and implicitly also sustainability.

A sub-factor where organizational strategy is concerned is *'synergy between initiatives.'* Synergy between IT initiatives may be assessed during the IT development and/or implementation by analysis of flows of information between relevant initiatives, combined with **stakeholder analysis** and/or **social network analysis**.

The last management success factor is *'handling the diversity within stakeholder goals.'* This includes the organization's capacity in the following respects:

- 'Awareness and mediation of diverging goals'
- 'Handling of hidden agendas'
- 'Initiative fatigue.'

Evaluation in the context of an organization's ability to handle diverse stakeholder goals may be accomplished by using evaluation approaches such as **stakeholder analysis** and **organizational readiness analysis**. With respect to the first two of the listed issues, a **stakeholder analysis** may be useful in providing a rich picture of individual stakeholder goals and interests. **Stakeholder analysis** raises awareness and reveals the stakeholders who will benefit from as well as be victims of the new IT solution. *'Initiative fatigue'* implies the loss of organizational capability for change. Here, **organizational readiness** as an evaluation approach can be used to identify the severity of initiative fatigue.

Technical Factors

A number of the technical factors that affect IT success/failure were identified in the delphi study and the literature reviews mentioned in the background section. These technical factors are to a great extent of a nature that renders it obvious for them to be assessed as an integrated part of the **technical verification**. They will not be mentioned individually here. A factor such as *'integrated functionality and communication standards'* includes sub-factors like (1) *'integration with legacy system,'* (2) *'interoperability'* (connected systems logically and functionally co-operating in real-time), and (3) *'interconnectivity.'* From an IT evaluation perspective the previous mentioned technical factors are considered part of the **technical verification**, but may require special skills for their in-depth evaluation. Especially the technical interoperability of interconnected legacy systems may be challenging to assess in practice because of its dependency on timing for all kinds of transactions (requesting, cancelling, modifying, and reporting), to verify that timing is not an issue in practice. Technical verification may also involve determining if the system has semantic interoperability. Evaluating semantic interoperability requires special expertise and includes activities related to ensuring that the meaning of communicated data and information is the same when it appears in two different but interfaced systems. In today's practice, the latter involves aspects of communication and architectural standards, medical vocabularies, and the use of appropriate terminology servers (see for instance Blobel et al., 2006; Engel et al., 2006; Ingenerf, Reiner, & Seik, 2001).

The factor *'usability'* (i.e., the technical implementation of usability aspects) is also a critical IT success factor. A number of methods are dedicated to the evaluation of system usability, either constructive evaluation or summative evaluation: **cognitive assessment**, **cognitive walkthrough**, **heuristic evaluation**, **think aloud**, and **video-recording**.

Another technical factor is *'balance between flexibility and stability.'* IT flexibility enables variation in work procedures. However, flexibility can severely increase the complexity of an IT solution and therefore tends to counteract the stability. And consequently, finding the right balance between flexibility and stability is a dilemma for the project management. A limiting factor may be organizational readiness as regards change. Consequently, the method **organizational readiness** may be valuable here.

The last technical success factor is *'evolution rather than revolution'* in combination with a couple of its sub-topics: *'stepwise progress following functional needs as well as technological achievements and potentials'* and *'flexibility and adaptability, enabling future functional and technical changes.'* These factors are project management issues and will not be further dealt with here.

Strategy Factors

The overall factor *'strategy'* may be subdivided into three topics (see also *'strategy'* in the section on management factors): *'national,' 'regional,'* and *'organizational.'* There is a dedicated approach designed to assess alternative strategies, in particular aspects related to their feasibility and timing aspects: **framework for assessment of strategies**. Furthermore, **interviews** in general can help to elicit individuals' opinions, attitudes and perceptions regarding phenomena and observations, including those related to a strategy. And in particular, the **focus group interview** method is suited, when a model solution is discussed.

Another factor related to strategy is *'Accepted also at lower levels.'* Here, in particular the **focus group interview** method is well suited when addressing whether a given strategy is acceptable by the stakeholders.

Economy

An IT success factor related to economy is *'there has to be a return of investment (whether material or immaterial).'* The return of investment is concerned with the justification of the system prior to any decision to move forward on initiating a given IT project. Organizational arguments in favor or against an IT project have to be balanced against time, resources, and fiscal investments, as well as the inherent risks. If it's difficult to prospectively assess such justification, a **delphi** approach may get arguments on the table regarding the immaterial benefits. Retrospectively, **impact assessment** or a **field study** may be valuable to assess immaterial effects, but are themselves quite laborious, thereby indicating that their own return of investment may be questionable.

Education

The factor '*sufficient training*' in general points at two other factors: '*to make the best out of the* *daily operation*' and '*to provide an understanding of its limitations and future potentials*.' How much education employees need to use a system effectively depends on the actual system and its future organizational context. Unfortunately, the level of education and training users will need is not something one can fully assess prior to operating a system, but one can learn from the experiences of reference sites and other organizations. Moreover, one may get a good hint (prospectively) by means of one or more of the methods designed for **usability** assessment. In daily operation (retrospectively) one can follow up on deviations from desired operation in terms of user errors in the operation of a system. Here, for instance the **functionality assessment** method may be valuable. However, **functionality assessment** may be too stringent to use in all such cases.

User Acceptance

'User acceptance' is a factor, for which a number of dedicated tools and studies have been published in the health informatics literature. The approach applied is mainly **questionnaires**; see also **user acceptance and satisfaction**. However, also the **equity implementation model** and **focus group interviews** approaches may be valuable in this respect, depending on what precisely one wants to know. Of these, the latter may be applied prospectively, the others only retrospectively.

Suggestions on Methods Applicable for Evaluation of the Failure Criteria

Functional Criteria

The first functional failure factor is *'limitations in the way the user can express him or herself.'* Such limitations may be caused by either usability problems or by functional barriers. The usability may prospectively—or retrospectively—and constructively be dealt with by means of one or more of the **usability** evaluation approaches (human factors engineering). This can even be done as part of the selection among bids, see examples under **bids assessment** in Brender (2006a). If the problems are not (solely) of an ergonomic or cognitive nature, but are caused by an awkward functionality the organization may retrospectively analyze the IT system using the **functionality assessment** method.

The functional failure factor *'moving target'* is risky. It is risky but also inevitable because of the long lead-time for IT solutions, because it means that the project conditions, plans and directions may get out of control. For example, the technologies of healthcare organizations change rapidly as a function of the technological evolution and knowledge gain. Or the moving target may arise as a consequence of indecisiveness or of increased insight into the opportunities created by the new IT technology. If the moving target issue is considered a problem in a project one may use the **balanced scorecard** to assess each individual suggestion for change.

Organizational Criteria

The overall organizational failure factor *'not understanding the organizational context'* includes at least the below three topics.

The first of the three sub-factors is: *'not understanding or foreseeing the extent to which the new IT-system affects the organization, its structure and/or work procedures.'* This type of lacking insight is a bad foundation for the design or purchase of an IT-based solution and can be risky for the organization. The organization's commitment to forecasting the extent to which the work procedures will change is considered an obvious concern during planning activities. A **future workshop** may provide some input for the decision making in this respect. However, judging whether the organization is capable of making the necessary changes to the organizational structure and/or work procedures also requires assessment of **organizational readiness**.

The second sub-factor is *'too many changes of work procedures.'* Project management may overestimate the organization's capability for change. **Organizational readiness** as an evaluation method may help proactively but probably only partly to support assessment of organizational ability to accept and implement planned change. Presently, true organizational capability for change—that is, the number and severity of changes that an organization can cope with is still guesswork. Bearing such knowledge in mind the identification of a limited organizational readiness at evaluation is important prior to the preparation and assessment of the user requirements, as well as at bids assessment. Retrospectively, the method **equity implementation model** may be effective in understanding users' reaction to information systems by focusing on the impact that such a system brings about.

The third failure sub-factor related to organizational aspects is: *'Analysts dominate the development at the expense of those understanding the organizational context.'* Such cases may arise when stakeholder groups differ significantly from the designer groups and/or include different levels of formality and/or rationality. A **stakeholder analysi**s would reveal those stakeholder characteristics and the relationship dynamics that influence IT implementation success. A stakeholder analysis normally has the purpose of identifying participants for the completion of a given task, problem solving activity or project, and thereby stakeholder analysis as a preventive action may lead to the best balance of the two parties in a project.

Behavioral Criteria

The behavioral failure factor *'overloading the user'* is concerned with planning and designing the functionality of a health information system. More specifically, designs that forces the user to remember too much (data or sub-tasks) in order for him or her to complete an activity may lead to an overload of the mental capacity of a user. Therefore, this factor is tightly connected to aspects dealt with by methods of **usability**. And consequently, differing types of usability studies that could be employed—for preventive and/or curative purposes—are: **cognitive assessment**, **cognitive walkthrough**, **heuristic evaluation**, **think aloud**, and **video-recording**.

The factor *'underestimating user acceptance'* is a complex issue. User acceptance is not only affected by usability but also by psychological aspects beyond the functionality of the IT system. For example, aspects may be grounded in the implementation process itself. Therefore, **user acceptance and satisfaction** evaluation approaches are important where there is a need to measure the level of user satisfaction retrospectively. Alternatively, the **equity implementation model** may provide a deeper understanding of the reasons behind potential IT system problems.

The last failure factor related to behavior is the factor *'resistance because of fear or loss of control of own job situation.'* Indications of resistance may be explored prospectively by means of **focus group interview** as well as **interview** methods in general, as these methods are particularly suited for elucidation of individuals' opinions, attitudes and perceptions regarding phenomena and observations.

Cultural Criteria

Two cultural failure factors are addressed here. The first is *'assuming that what works at one place also works somewhere else.'* Many managers tend to make the mistake of assuming that what works one place also works in their organization. Such mistakes are often made during the technology transfer between industrialized and developing countries (or vice versa), but they also occur at transfer of technologies between countries of the former type. Differences in legislation or legislative processes, in professional culture, in specialized equipment, and even in the profession-oriented terminology may hinder the transferability of an IT-based solution. This is well-known for knowledge-based systems, where even more invariant factors are present, such as the epidemiology; see (Nolan et al., 1991). Consequently, there is a need to study the transferability of a health information system to explore the system's applicability at new sites. Such transferability evaluation may involve almost any existing evaluation method. Presumably **analysis of work procedures** is the best general approach for preventive (prospective) purposes, while **functionality assessment** may fulfill the information need for curative, retrospective purposes.

The other failure factor addressed here is *'users have too high expectations.'* This failure factor may indeed be prevented by proactive evaluation of the expectations followed by communicative actions that focus at aligning or harmonizing expectations. Here, **interviews**, in particular **focus group interviews**, are suited as these methods may elicit individuals' opinions, attitudes and perceptions.

Technical Criteria

There are a number of technical failure factors, of which the first to be addressed is *'limitations in the way users can express themselves.'* This factor is parallel to the functional success factor with the same name, see above. Project management need to be cognizant of the technical limitations of a system and discuss this with the user organization, including how a system affects users' expressions of themselves. However, the functional consequences of the technical barriers in the perspective of this factor compares to a needle in a haystack, if you do not know what to look for then the solution space is too big and too undetermined to even think of initiating an evaluation study.

Another technical failure factor is *'the technology is so restricted that it impacts design and implementation choices.'* According to the author's personal experience restrictiveness is usually correlated with the capabilities of analysts, designers, and implementers rather than the technology itself. Complexity as well as software immaturity may also influence technological restrictiveness. However, rather than being a topic specifically for evaluation technical restrictiveness is an issue for the project management to prevent and/or take action upon at an early point in the development process.

The factor *'response rate and other performance measures'* has two component aspects: a general one regarding the traditional technical performance (response times, throughput times, reliability, etc.) and a functional regarding *'the time needed to complete the users' tasks.'* The technical performance is normally evaluated as part of a **technical verification** provided that technical performance is specified as part of the contract. Technical verification normally takes place in an experimental set-up of a system within an organization, and it may require deep functional insight to define and establish the right evaluation set-up with realistic workloads and patterns of work activities. The second factor mentioned above (*'time needed to complete user tasks')* compares to a kind of organizational response and throughput times, sometimes denoted service delivery times. An example is the time from a flight lands till the customers get their luggage, or the time from receipt of an order in an electronic healthcare system to the submission of the end result to the requester of the information. Service delivery times may be dealt with in a fashion similar to the technical counterparts. Evaluation of such service delivery times for user tasks requires before-and-after time-motion studies (time measurement for paradigm use scenarios and tasks: **prospective time series**). Some of the measures may be provided by the IT-system involved. Unfortunately, these measures may be more difficult to realistically evaluate in an experimental set-up in systems that are deeply interwoven or integrated with and dependent on other technologies and/or medical instruments.

This is especially the case for some kinds of information systems (e.g., the production support part of laboratory information systems).

Another two technical failure factors are: *'vendor did not support the functionality quoted'* and *'insufficient verification of conformity with requirements specification.'* These factors are closely related. One has a small chance of realizing the former if the latter factor is present, and this may result in unpleasant surprises when the system is placed into daily operation. Even a trifle in the functionality that is not supported may have a great impact on organizational practices or resource consumption. The means for preventing this is to tenaciously and meticulously verify the delivery of the agreed functionality by means of **technical verification** using the contract (or other formalized agreement) as the frame of reference. The author recommends that the user evaluation in this respect takes the user organization's daily reality in terms of tasks and work procedures as the starting point and design test scenarios that mimic the daily work in all its details. Therefore, not only should prescribed organizational rules be tested, but the entire variation in organizational activities as well as exceptions to activities that arise in daily organizational work should be tested. This is the only way to prevent surprises during daily operation, but such an approach assumes that the contract (the requirements specification) is an adequate frame of reference.

Educational Criteria

An educational failure factor identified is the *'visible discrepancy between successive versions of the IT-system.'* Obviously, visible discrepancy between successive system versions implies a need to provide users with continuous learning and support. No evaluation method that is dedicated to assess this criterion has been identified. If the discrepancies between versions of an information system are too large for the organization to deal with prior to operation the organization should recognize that there will be some temporary inefficiency that will arise in work procedures and that will be accompanied by operational errors involving the system. Problems associated with version changes and education may originate from a lack of communication, understanding or foreseeing the extent to which the version changes affect the organization, its structure and/or work procedures. Such lack of communication, understanding or foreseeing of the need for education may slow down proactive educational activities. As well, organizations must also recognize that such issues may arise from users' inability to cope with change (see this separately).

DISCUSSION

The first objective of this chapter was to verify the existence of appropriate evaluation methods for the assessment of known factors that influence the success and failure of health information systems. The chapter is based on a comprehensive set of IT success/failure factor synthesized from a number of literature reviews as well as a delphi study conducted by Brender et al. (2006). This approach leads the author to suggest that the list of success and failure factor itself is fairly complete. Therefore, the union of factors is a reasonably good instrument for analyzing whether adequate evaluation methods exist for monitoring or preventing given success and failure factor for health information systems. The author suggests it is feasible to identify suitable approaches for evaluating most of the IT success and failure factors.

There was one surprise that arose from the analysis: The author had expected risk management approaches with monitoring of risk factors to be high scoring as an approach particularly valuable for optimization with respect to the identified success and failure factor. It was not. This certainly does not rule out risk management as an integral part of best practice for systems development or implementation. It just shows that more is needed.

The top eleven methods referred to in the above are (in order of decreasing significance. However, some of the methods—like the bottom five methods—are ranked with the same significance):

- Stakeholder analysis
- Focus group interview
- Interview
- Social network analysis
- Analysis of work procedures
- Organizational readiness
- Framework for assessment of strategies
- Usability
- Equity implementation model
- Functionality assessment
- Balanced Scorecard

Almost all of these evaluation methods focus on the soft human aspects, such as who is affected by IT related decision-making, patterns of decision making, and management of change. The outcome of the present study simply reflects the fact that most of the factors identified in this work are related to the soft human factors outlined previously. Therefore, at least in the Western countries where most of the incorporated reviews originate, the organizational issue, as well as project management of information systems related issues are central: policy, commitment, and approaches.

FUTURE RESEARCH DIRECTIONS

The second objective of this chapter was to identify the potential needs as regards further development of evaluation methods. The main problem in many cases is that evaluation methods are not designed in a dedicated fashion to the assessment of those specific success factor and failure criteria. An example of this is **analysis of work procedures** approach, which has been adopted from the domain of systems analysis. Therefore, methods engineering is necessary.

Many places above a reference to a method is stated as "might be valuable"—or similar. This means that the method in question may not be dedicated to answer that specific information need. All of these evaluation approaches are obviously candidates for methods engineering and further evaluation research. Furthermore, evaluation methods need to be made more accessible to the common, organizational evaluator. Until then, practical application of such candidate evaluation methods requires methodological and methodical skills, imagination and flexibility in order to adapt the methods to a specific case, its conditions and its particular information need.

One method is explicitly mentioned as possibly needing more maturation as an evaluation method: **organizational readiness**. Organizational readiness is a very complex phenomenon, and relevant in connection with numerous success/failure factor. Organizational readiness ranges from the hospitality (openness) to solutions not invented in-house, to the capacity of organizations to invent efficacious IT-based responses to changes within the healthcare environment, to triggering the invention of such IT-based solutions, and to building the capacity to develop sustainable solutions.

Furthermore, several of the methods referred to in this chapter are designed to provide exhaustive and highly accurate information, bordering on scientific stringency. This implies that large investments of calendar time and/or resources are needed to undertake such evaluation studies—which may be out of the question in a practical evaluation setting. Therefore, in the practical context of a specific project, the challenge may be to modify or simplify a specific evaluation method to the practical needs of the organization, again, the situational methods engineering is required.

As Rigby emphasizes: "Adequately funded evaluation, based on proven sound techniques, is the means of moving forward to a credible discipline …" (Rigby, 2006, p. 119). Implicitly, he says in his conclusion that there is a step ahead of us before the evaluation methods are sufficiently dedicated and matured for their application purpose. This conclusion is in agreement with the statement in the review by (Berghout & Remenyi, 2005, p. 88) that "… there has been only marginal improvement in the maturity in this field over the past eleven years." Implementation of IT-based solutions (and therefore also the implied evaluation needs) are somewhat indeterministic. However, the present study indicates that we do have a foundation of approaches valuable for most evaluation purposes. From this foundation of evaluation approaches we may adapt or develop and mature evaluation methods dedicated to the specific information needs. Still, major research efforts are needed.

Finally, according to Brender (2006b) there are a number of evaluation research challenges ahead of us: Research needs to focus on constructive evaluation of cognitive and work process-oriented aspects of IT-based solutions to cope with the full complexity. This full complexity includes the dynamics, the variation, and the evolution of the target domain—here health care. The analysis in the present contribution could not go into sufficient detail to confirm or reject this hypothesis.

CONCLUSION

Evaluation is perceived as a means to optimize the likelihood of success while minimizing the likelihood of failures of health information systems development and/or implementation. A list of success and failure factor identified within the literature was examined to identify candidate evaluation methods. It turned out being feasible to identify suitable approaches for most of the factors. However, there is a need to undertake situational methods engineering in many situations as the evaluation methods referred to in this chapter often are not dedicated to answering the precise information needs of an organization. This therefore, also points at the research needs and opportunities.

REFERENCES

Ammenwerth, E., Brender, J., Nykänen, P., Prokosch, H.-U., Rigby, M., & Talmon, J. (2004). Visions and strategies to improve evaluation of health information systems—Reflections and lessons based on the HIS-EVAL workshop in Innsbruck. *International Journal of Medical Informatics*, *73*(6), 479–491. doi:10.1016/j.ijmedinf.2004.04.004

Berghout, E., & Remenyi, D. (2005). The eleven years of the european conference on IT evaluation: Retrospectives and perspectives for possible future research. *The Electronic Journal of Information Systems, 8*(2), 81-98. Available online at www.ejise.com

Bikson, T. K., & Eveland, J. D. (1989). Technology Transfer as a Framework for Understanding Social Impacts of Computerization. In M. J. Smith & G. Salvendy (Eds.), *Work with computers: Organizational, management, stress and health aspects. Vol. 1.* (pp. 28-37). Amsterdam: Elsevier.

Blobel, B. G., Engel, K., & Pharow, P. (2006). Semantic Interoperability—HL7 Version 3 compared to advanced architecture standards. *Methods of Information in Medicine*, *45*(4), 343–353.

Brender, J. (2006a). *Handbook of evaluation methods for health informatics*. New York: Academic Press.

Brender, J. (2006b). Evaluation of health information applications—Challenges ahead of us. *Methods of Information in Medicine*, *45*, 62–66.

Brender, J., Ammenwerth, E., Nykänen, P., & Talmon, J. (2006). Factors influencing success and failure of Health Informatics Systems, a pilot delphi study. *Methods of Information in Medicine*, *45*, 125–136.

Crosswell, P. L. (1991). Obstacles to GIS implementation and guidelines to increase the opportunities for success. *URISA Journal*, *3*(1), 43–56.

Engel, K., Blobel, B., & Pharow, P. (2006). Standards for enabling health informatics interoperability. In A. Hasman, R. Haux, J. van der Lei, E. De Clercq, & F.H. Roger France (Eds.), *Ubiquity: technologies for better health in aging societies, Procedings of MIE2006. Studies in Health Technology and Informatics 124*, 145-150.

Haimes, Y. Y., & Schneiter, C. (1996). Covey's seven habits and the systems approach: A comparative approach. *IEEE Transactions on Systems, Man, and Cybernetics*, *26*(4), 483–487. doi:10.1109/3468.508826

Heeks, R. (2006). Health information systems: Failure, success and improvisation. *International Journal of Medical Informatics*, *75*, 125–137. doi:10.1016/j.ijmedinf.2005.07.024

Ingenerf, J., Reiner, J., & Seik, B. (2001). Standardized terminological services enabling semantic interoperability between distributed and heterogenous systems. *International Journal of Medical Informatics*, *64*, 223–240. doi:10.1016/S1386-5056(01)00211-8

Nolan, J., McNair, P., & Brender, J. (1991). Factors influencing transferability of knowledge-based Systems. *International Journal of Bio-Medical Computing*, *27*, 7–26. doi:10.1016/0020-7101(91)90018-A

Price Waterhouse. (1997). *Without change there is no progress—Coping with chaos, a global survey*. London: Price Waterhouse.

Rigby, M. (2006). Evaluation—the Cinderella science of ICT in health. *IMIA Yearbook of Medical Informatics*, *2006*, 114–120.

Stravri, P. Z., & Ash, J. (2003). Does failure breed success: narrative analysis of stories about computerized provider order entry. *International Journal of Medical Informatics*, *72*, 9–15. doi:10.1016/j.ijmedinf.2003.08.001

ADDITIONAL READINGS

Ammenwerth, E., Iller, C., & Mahler, C. (2006). IT-adoption and the interaction of task, technology and individuals: A fit framework and a case study. *BMC Medical Informatics and Decision Making* *6*(3). Retrieved July, 25, 2007 from http://www.biomedcentral.com/1472-6947/6/3

Coolican, H. (1999). *Introduction to research methods and statistics in psychology* (2nd ed.). London: Hodder & Stoughton.

Davidson, E. J. (2005). *Evaluation methodology basics: The nuts and bolts of sound evaluation.* Thousand Oaks: Sage Publications Inc.

DeLone, W. H., & McLean, E. R. (2003). The DeLeone and McLean model of information systems success: A ten-year update. *Journal of Management Information Systems*, *19*(4), 9–30.

Fink, A. (2005). *Evaluation fundamentals: Insights into the outcomes, effectiveness, and quality of health programs* (2nd ed.). Thousand Oaks: Sage Publications Inc.

Friedman, C. P., & Wyatt, J. C. (2006). *Evaluation methods in biomedical informatics* (2nd ed.). Springer.

Kaplan, B., & Shaw, N. (2004). Future directions in evaluation research: People, organizational, and social issues. *Methods of Information in Medicine*, *43*, 215–231.

Kushniruk, A. W., & Patel, V. L. (2004). Cognitive and usability engineering methods for the evaluation of clinical information systems. *Journal of Biomedical Informatics*, *37*(1), 56–76. doi:10.1016/j.jbi.2004.01.003

Murphy, E., Dingwall, R., Greatbatch, D., Parker, S., & Watson, P. (1998). Qualitative research methods in health technology assessment: A review of the literature. *Health Technology Assessment 2(16)*. Retrieved July 25, 2007, from http://www.ncchta.org

Neville, D., Gates, K., MacDonald, D., Barron, M., Tucker, S., Cotton, S., et al. (2004). *Towards an evaluation framework for electronic health records initiatives: A proposal for an evaluation framework.(* pp. 82). Retrieved July 25, 2007, from http://www.nlchi.nf.ca/research_evaluations.asp

Patton, M. Q. (2002). *Qualitative research & evaluation methods* (3rd ed.). Thousand Oaks: Sage Publications Inc.

Schalock, R. L. (2002). *Outcome-based evaluation* (2nd ed.). New York: Kluwer Academic/Plenum Publishers.

(See also the extensive lists of annotated references and World Wide Web sites on evaluation methods and case studies in (Brender 2006a)).

Southon, G. (1999). IT, Change and evaluation: An overview of the role of evaluation in health services. *International Journal of Medical Informatics*, *56*, 125–133. doi:10.1016/S1386-5056(99)00043-X

Talmon, J. L. (2006). Evaluation and implementation: A call for action. *IMIA Yearbook of Medical Informatics*, *2006*, 11–15.

van der Meijden, M. J., Tange, H. J., Troost, J., & Hasman, A. (2003). Determinants of success of Inpatient Clinical Information Systems: A literature review. *Journal of the American Medical Informatics Association*, *10*(3), 235–243. doi:10.1197/jamia.M1094

ENDNOTE

[1] The full name of the two methods are (in English translation): BIKVA "User involvement in Quality Development," and KUBI "Quality Development through User Involvement."

This work was previously published in Human, Social, and Organizational Aspects of Health Information Systems, edited by A. Kushniruk; E. Borycki, pp. 180-201, copyright 2008 by Information Science Reference (an imprint of IGI Global).

Chapter 2.12

Developing Information Communication Technologies for the Human Services:

Mental Health and Employment

Jennifer Martin
RMIT University, Australia

Elspeth McKay
RMIT University, Australia

ABSTRACT

This chapter introduces a design process for developing useful information communication technologies for the human services. Key to the success of the design process is an in-depth knowledge and understanding of user needs and requirements. The stages involved in the design process are presented in this chapter and include: user and task analysis, persona and scenario development and the establishment of measurable usability goals. A case study illustrates the application of this design process to develop a Web enabled electronic work requirement awareness program (e-WRAP) for people recovering from mental illness seeking employment. The challenge for social workers is to use these new technologies to improve service provision and enhance quality of life without compromising ethical standards of practice; particularly in relation to client confidentiality, privacy and self-determination.

'After the idea, there is plenty of time to learn the technology'. -- James Dyson (1947-), English inventor and businessman, Against the Odds, 1997 in Oxford Dictionary of Quotations (2004, p.294:20).

INTRODUCTION

Information communication technologies today are in abundance. People of all ages, particularly young people communicate through the Internet to access the social networking sites MySpace and Facebook; the online video site YouTube; microblogging sites Twitter and Plurk and the virtual world of Second

DOI: 10.4018/978-1-60566-735-5.ch010

Life. In addition to these are Internet sites such as Wikkipedia, MSN and Google. Most organizations today have a web presence for marketing, attracting users and conducting business. Increasingly organizations in the human services are adopting web technologies to reach user groups to communicate their messages and to increase organizational efficiencies. However the profusion of information on the Internet makes it difficult at times for users to actually locate the information they are seeking. This may be due to diversion sites that can cause considerable frustration, confusion and time delays or an overload of information, with many Internet sources unverified. Access to the Internet can be costly requiring constant updates and virus protection with some media requiring the latest versions of sophisticated software to access them. Available software and the Internet service provider will also affect access and speed.

These new technologies create both challenges and opportunities as designers try to reach their intended user groups using the most appropriate means and messages, delivered in a timely manner. Central to the success of designing useful and usable information communication technologies for the human services is in-depth knowledge and understanding of the target audience, referred to hereafter as "users". The stages involved in the design process are presented including: user and task analysis, persona and scenario development and the establishment of measurable usability goals. This is followed by a case study of mental health and employment illustrating the application of this design process to develop a web enabled Electronic Work Requirement Awareness Program (e-WRAP) designed for people recovering from mental illness seeking employment.

USER ANALYSIS

The main features of user groups are identified by conducting a user analysis. This involves thinking and forming assumptions about what users would like. The next crucial step is to test these assumptions against the "reality" of the users in an endeavor to understand their needs, expectations, knowledge base, experience and preferences. Information is also gained on technologies and software that users have available to them, for example via broadband or dial up, as well as the physical environment where the Internet is accessed. By involving users in the pre-design stage they become active and important partners in the design process. Research techniques that complement each other for conducting a user analysis comprise: contextual interviews, individual interviews, surveys and focus groups (United States Department of Health & Human Services, 2008). The more techniques used the greater the depth of knowledge gained about the needs of users and the less likelihood of design errors. A common mistake to avoid is choosing "flashy" technology over accessibility.

Contextual Interviews

Contextual interviews are similar to participant observation, and involve observing and listening to users while they are engaged with the technologies. These interviews provide information on the physical and social environment as well as the technologies available including means of access, familiarity and level of comfort and support. For instance a person's use will vary according to whether they are on broadband or a modem. Dial up access to the Internet may mean that the users want to use the web quickly so that a telephone line is not tied up for extended periods. Access will vary according to the Internet service provider with many limiting or denying access during peak periods. Insights are gained on whether or not users have anyone who can assist them with the technology and the nature of this support. Contextual interviews are usually informal with the interviewer mindful of not imposing any changes on the environment that is being observed. This is achieved by watching and listening to users and interviewing them by means of questions, probes and reflective statements to gain an understanding of what they are doing, thinking and feeling. The interviewer does not ask users to perform specific tasks or respond to case scenarios.

Individual Interviews

Individual interviews are different to contextual interviews in that they involve collecting information directly from the user and do not include contextual observations. The ultimate goal is to gain deeper understanding and insight into users' ICT needs. Individual interviews allow for a deep understanding of users' attitudes, beliefs, experiences, desires and fears. Individual interviews provide an opportunity to have a detailed one on one discussion where the user has the full attention of the interviewer. This information is usually gained during a 30 minutes to one hour interview that may be conducted in person, on the telephone or by computer aided means such as instant messaging. Information collected during the individual interviews will complement that already gained in the contextual interviews by providing further information as well as confirming or denying observations already made.

Participants are selected on the basis of their embodiment of the main features of the intended user group. An interview protocol, with interview questions designed in neutral language, provides focus and structure with the interviewer mindful of applying this flexibly. The interview style and approach can be adjusted to the personality and communication style of the interviewee, making them feel comfortable and engaged in the interview process.

Interview skills in listening, questioning and follow up probes are useful, particularly those aimed at clarification where the individual interview and contextual interview information differs. For instance, how does the level of comfort with ICT observed in the contextual interview correspond with the user's individual interview responses? This is also an opportunity to gain feedback on particular ICT applications and content by asking users to rank or rate these. The granting of permission to tape record and transcribe interviews or to have note takers will ensure that as accurate a record as possible of interview responses is obtained.

Individual interviews can assist in refining the questions to be included in online surveys or they can be conducted following online surveys to provide more detailed information about particular users.

Online Surveys

Online surveys are structured interviews with users recording and submitting their responses online. These surveys generally generate a greater number of responses than individual interviews but often they do not have the same depth of information. Individual interviews can inform the survey questions. Online surveys are readily accessible on the Internet and very user friendly. Data collection is relatively easy and efficient as users record their own responses rating and ranking ICT applications and content.

Information can be collected in online surveys during an initial planning phase to learn more about who users are and what they would like. Alternatively they can be conducted after ICT applications have been designed to seek feedback from users as to whether or not these meet their needs and if they have suggestions for improvement. This latter approach is particularly suited to use of new or innovative ICT that users have limited knowledge or experience of. A further possibility is for the survey to remain active for instant feedback at all stages throughout the design, implementation and evaluation process. This allows for ongoing incremental improvements and suggestions while they are fresh in the mind of users. A series of online surveys may be conducted at significant stages of design.

The design team needs to be clear on the purpose of surveying users. Survey distribution may be a pre-existing website for the organization or another site where users go. If multiple postings are made it is important to consider the possibility of multiple responses from the one user and whether or not this poses a problem. It may give a false idea of numbers of users who have responded, yet a frequent user may a have a lot of good ideas. Issues of how the data will be recorded, stored and managed need to be considered carefully with ethical approval obtained where necessary.

Group e-mails through listservs are useful for making direct requests to users to participate in online surveys. A letter of request sent directly to the user, with an embedded hyperlink opening directly to the survey, provides for an easy and immediate response. The more complicated the task the less likelihood of users participating, particularly if it is voluntary. When designing an online survey it is best to keep it short, with 10 or less questions preferred. Questions might include demographic information about users, prior experiences of ICT and what they would like.

Ease of completion is a central consideration with the survey preferably taking 10 minutes or less to complete. Open questions provide rich qualitative data about users' needs and experiences as well as the terminology they use. Closed questions provide aggregate numbers and can be useful when collecting demographic information and for asking users for rankings or ratings of ICT applications, the data analysis being quicker and easier than responses to open ended questions. Time and resources available for compiling and analyzing data will influence the number and type of questions asked. More detailed information can be gained in a further online survey, individual interview or focus group.

Focus Groups

Focus groups are a commonly used research technique, particularly amongst social work researchers, educators and practitioners. Information is discussed and shared within the focus group about attitudes, needs, concerns and interests with regard to the design and application of the technologies in relation to the specific context of the user group. This provides a deeper understanding of how users engage with the technology and the problems they face. Information is gained about the culture of the group and shared or diverse viewpoints that can trigger more in-depth discussions. It is also an opportunity to gain information on users' responses to ideas and prototypes.

Focus groups usually comprise of between eight and 12 users, or potential users, for the duration of approximately two hours. During this time a moderated discussion occurs on a range of pre-determined topics or themes. Desired learning outcomes of the focus group are identified and used to structure the discussion by writing a script for the moderator to follow with topics to cover and questions to ask. This script is to be applied flexibly so that the discussion flows smoothly and all participants have an opportunity to contribute to the discussions. This may mean that the moderator changes the order of questions or topics covered but ultimately has covered everything during the time allocated for the focus group. This requires a skilled moderator who is able to keep the discussion focused, deciding when further discussion of a topic is needed and when to move on.

Tape recordings of group sessions and one or more note takers are critical for an accurate recording of the focus group discussions. As the focus of the moderator is managing the discussions and intervening when necessary it is not appropriate for this person to also be a note taker, unless this role is shared with a co-facilitator. In co-facilitation the moderators may take it in turns to chair the group and take notes. Reliance on recordings alone can be problematic, particularly in instances when more than one person is talking at the same time due to background noise and difficulty identifying the speaker. A task analysis provides detailed information on how users achieve their goals and the steps involved.

TASK ANALYSIS

Task analysis is useful in identifying the processes and tasks associated with project design to achieve the desired outcomes (Pruitt & Grundin 2003, p.12). As with user analysis this is influenced by psychological, social and cultural factors, as well as the user's physical environment. Prior knowledge and experience will also influence how tasks are approached. The question of what tasks users need to complete using ICT is considered as well as different levels or types of uses. For example, a tertiary student may be paying a university account, conducting library searches or accessing lecture notes and course materials. The specific steps that students follow in undertaking these tasks are examined. This activity may or may not involve use of ICT. The student may go to the library to conduct their research, rely solely on electronic sources or a mixture of both. A task analysis provides information on how this activity is being conducted and the number of steps involved. How users currently perform tasks is examined with consideration of how efficient this. If ICT can assist in producing more efficient outcomes this needs to be considered according to how well these match with users' ways of thinking and working as well as contextual factors.

A task analysis provides information on the tasks and activities that the ICT must support and the scope and nature of these. It will inform decisions on the choices of different technologies for different activities that match users' goals, tasks and the steps involved. These steps will be refined to support users achieving their goals in the most efficient and effective manner. Once the user and task analyses have been completed the persona is designed.

PERSONA

The persona is a hypothetical construct that embodies the main features of the population that the project is being designed for. The persona assists in understanding user information needs informing design and accessibility and ultimately suitability. However, it must not become a replacement for active user involvement. User profiles have been used for some time in marketing with the persona introduced in project design by Alan Cooper in the late 1990s. Cooper's (1999) early work focused on goal directed design by creating fictional personas used as a basis for creating activity scenarios. In later years more detailed personas were developed by using interviews and ethnography to gain a clearer picture and understanding of intended user groups across a much wider range of disciplines (Bloomquist, & Arvola, 2002). Lang (2007) stresses the importance of locating the persona within the relevant discipline and the disjuncture that can often unwittingly occur in beliefs and actual practices across disciplines. Where interdisciplinary differences exist these can be managed and resolved by basing decision making on what is best suited to the needs of the persona (McKay & Martin, 2007). Research conducted by Ronkko (2005) in Sweden cautions against tokenistic and inappropriate use of personas to justify design decisions without proper user consultation as well as problems that can occur when power is used inappropriately within the design team.

For personas to be used effectively a strong commitment is required by all members of the project team. The use of abstract representations to guide design have been used extensively, however often designers do not have a shared view of their intended user group and can fall in to the trap of designing for themselves. Cooper (2004) argues that designing for a persona is better than designing for the designer, or for a vaguely defined user group. Hourihan (2002) warns against the project team designing for themselves and losing sight of the intended user group. She comments, 'We thought we were the primary persona. Like a recovering substance abuser, it's a constant challenge for me to refrain – I can always imagine that I'm the user' (p.3). Use of the persona can create a safeguard against this by developing empathy between the designer and the user. It can also prevent "design creep" by providing a constant reference point for all design decisions. "Constant" is not to be confused with "static" as with all human computer interaction it is the dynamic nature of this interaction that is central to its relevance and currency.

Personas superseded the so-called "elastic users" by replacing them with a real identity that becomes an integral part of the project design process. The persona provides a conduit for transmitting a wide range of information about design and use. Whilst Cooper (2004) was not particularly concerned with the persona being representative of the user group, Grundin & Pruitt (2002) argue that representation of the user group is crucial and that this is the main advantage of using a persona. A persona provides a lens that includes the socio-political context and addresses issues around quality of life and difference. By focusing attention on a particular user group, personas assist in identifying different kinds of users as well as those who are not being designed for.

Designing the right persona or set of personas is particular to the main features of the user group and is time and culture specific. Decisions are often made to create maximum effect with others brought up to speed later, or perhaps left behind. Increasingly in the human services decisions are geared to particular user populations with this seen in targeted media campaigns, particularly for young people such as the "safe sex" campaign using text messages on Valentines Day and World Vision's Teenage Affluenza video on YouTube (Ryan 2008).

Personas were used to assist in the development of Microsoft Windows and MSN Explorer. Both of these products were designed to cater for varied and complex user groups across all generations and cultures. When designing Windows two target audiences were identified by using personas and customer segments. The Window's persona team comprised 22 people including technical writers, graphic designers, usability engineers, product planners and market researchers who developed six personas. A panel of 5,000 users who matched the persona profiles was established and consulted as part of the design team on a regular basis (Pruitt & Grundin, 2003). Like Microsoft, many other organizations including Ford Motor Company, develop and use personas reporting numerous benefits from doing so such as better understanding of users needs, shorter and improved design periods and a superior end product. Similarly, personas aid in educational design for the human services workforce (Martin, McKay, Hawkins & Murthy 2007).

The persona comes to life as a "real person" for whom the project is being designed. Decisions are now being made about a person with a name and identity, albeit hypothetical. Detailed written documentation that succinctly describes the main features of the persona is essential. The level of detail suggested by Freydenson (2002) for a persona includes; 'at least a first and last name, age, goals, background story, a telling quote, e-mail address, job title and a photograph', (p.1). Other features might include: gender, educational background, family, class, health, ability/disability, race, ethnicity and culture, sexuality and spirituality. Cooper (2004) comments, 'All things being equal I will use people of different races, genders, nationalities and colors' (p.3). The persona will change and develop with the project and at times more than one persona may be required, particularly in instances of extreme diversity amongst potential user groups. Freydenson (2002) recommends the development of primary and secondary personas. These personas extend beyond the user to include others such as managers and funding bodies. The main focus is on the primary persona, whilst also being mindful of the needs of secondary personas. Ultimately the primary persona must be satisfied with the system that is delivered, with a common vision and commitment to the persona essential for successful design and implementation. Effective communication is important, particularly with those who may be absent from meetings where the persona is discussed. Creative strategies are required to keep the persona relevant and the focus of activity. It is useful to have something to signify this. This may simply be an empty chair at meetings that represents the presence of the persona in discussions and decision-making.

SCENARIOS

Scenarios are short stories, or narratives, that provide greater detail about users and their particular needs. Depending upon the size and scope of the project, between 10 and 20 of the most common scenarios that depict users and the tasks they need to perform will be written. This keeps the focus on users rather than organizational structures, creating a greater understanding of the content to include in the design and how to best structure this. Scenarios can be created during user analysis. These scenarios can be given to users to follow in usability tests to see if they match their requirements. Three main types are goal based, full scale task and elaborated scenarios (United States Department of Health & Human Services, 2008).

Goal based scenarios include only the activity the user is required to do. An example is a social worker registering a client's name and address on an electronic database. Simple goal based scenarios inform the architecture of the site and content.

Full scale task scenarios support goal based scenarios by including all of the steps involved in achieving a particular goal. This is a technique familiar to workers in the human services using behavior modification programs. Task scenarios can be developed by watching and recording the steps taken by users when performing a task or they can be developed independently by the project team. Most benefits are gained from an approach that is customized to the user group's style of engagement, with the project team adding improvements and efficiencies that sit comfortably with them.

Elaborated scenarios provide greater detail, allowing for deeper understanding of users' level of comfort and skill in using ICT as well as their motivations and possible fears. This more in-depth understanding assists in developing the required content at an appropriate level. For example an elaborated scenario of the goal based scenario might be this social worker not only required to enter basic registration data but to move from a paper based system of client file notes to an electronic one. An elaborated scenario might be:

A social work practitioner with over twenty years experience who uses a computer in her work to access e-mail and write reports. She has been told that the new system will allow for file notes to be sent electronically between agencies. She is not comfortable with the idea of writing personal information about clients on a web site and is particularly concerned about issues of privacy and confidentiality. As a result she has decided that when the new system is introduced she will limit what she puts in her file notes.

An elaborated scenario would include these fears and concerns with strategies developed to address these and avert the possibility of users limiting or modifying the level or type of engagement due to a distrust of the new technologies and how they will be used.

The persona and scenarios are tested, evaluated and further developed by feedback from usability testing with actual, rather than fictitious members of the user group.

USABILITY TESTING

Continuous feedback is obtained by conducting usability tests frequently, particularly early on in the design process. This means problems can be identified early on and are therefore less costly to fix, as well as providing valuable feedback on whether or not the design is achieving its intended outcomes. When conducting usability testing it is important to remember that it is the ICT and its application that is being tested, not the users. Data is collected through observations and user ratings. Five point scales can be used to assess levels of user satisfaction. These tests are generally conducted over a one hour period, with the size of a usability testing group usually between eight to 16 users. This number may vary according to the main characteristics of the user group, with four to six people appropriate for user groups that are fairly homogenous. Smaller groups with varied membership may be used to test particular aspects of a design at different stages of the design process. The staff who have developed the ICT and activities observe and listen carefully, taking notes on user experiences as they follow scenarios to implement the ICT given to them by the project team. This information is used to reflect upon how to improve the design.

It is preferred that usability testing be conducted throughout the design period on a series of proofs and prototypes rather than on a final product only. This requires adequate planning for the allocation of sufficient time and resources. For each round of testing it is important to identify what the specific goals are and to focus on these. For instance, the focus in an early round might be on testing for levels of user comfort, and in a later round on levels of satisfaction. The aim of the test is to determine how well each goal is being met. Typically a usability test is assessing both user performance and preference by collecting data on: usability problems, user performance, task completion, speed, and levels of satisfaction.

Successful, accurate completion of a task in a timely manner is generally considered a more important measurable usability goal than user satisfaction. Results on performance are more reliable than user preference as the latter may be based on levels of comfort, keeping in mind that learning new tasks will generate stress. Low user ratings indicate that the ICT applications need to be improved. However, high ratings do not necessarily mean that problems do not exist. This could be due to the influence of extraneous factors such as users blaming themselves for difficulties encountered, unwanted personal attention and the particular tendency amongst human services workers to be kind to members the project team.

Ultimately the measure of usability is that the application of the ICT allows users to do their tasks in the same amount of time or less, with similar or improved levels of success and satisfaction. No doubt there will be varied needs and experiences amongst members of the user group with the design tailored to meet as many user needs as possible to successfully complete the required task. Ideally the ICT will improve upon other ways users have achieved their goals or they are not likely to embrace them unless they are compelled to do so. If this is the case, ongoing conflict management strategies will need to be employed while further user and task analysis is conducted (Martin & McKay 2007).

The following case study demonstrates the application of the project design stages of user and task analysis, persona and scenario development, and usability testing for the development of a web based resource to assist people recovering from mental illness gain employment.

CASE STUDY: DESIGN OF ELECTRONIC WORK REQUIREMENT AWARENESS PROGRAM (E-WRAP).

Background

Web based resources available for finding work are primarily listings of positions that can be searched according to type of position, location and pay rate. Templates and examples of resumes are available as well as tips for interview. These sites are targeted at the general population and do not address issues of self-esteem, motivation, concentration, discrimination, stigma and perceptual difficulties associated with recovery from severe mental illness and long term unemployment. The World Wide Web Consortium (W3C) standards for web-design and accessibility do not include design features tailored to meet the needs of people recovering from mental illness (W3C, 2005). Instead, these standards concentrate on the machine-dimension of human computer interaction. As such, they focus on web-access protocol development and browser privacy issues. Despite the Web Access Initiative (WAI) there are no web enabled work searching systems designed for people recovering from mental illness (WAI, 2002). e-WRAP was developed to provide a tailor made web based resource to assist people recovering from mental illness gain employment. Project team members were users, carers, practitioners and academics with expertise in the areas of mental health, psychology, social work and information communication technology. The team's first task was user analysis.

User Analysis

Contextual interviews were conducted with people who were recovering from mental illness by observing and discussing the approaches and strategies they used when looking for work. Useful information was gained on work searching strategies and the varied paper and web resources available. Of particular note was the range of web resources accessed designed for the general population and the lack of sites designed specifically for people recovering from mental illness. Valuable information was also gained on type of Internet access and levels of comfort with accessing and navigating these sites, concentration and frustration when using them, as well as the suitability of the content and design features.

Individual interviews were conducted with users as well as experts in the fields of information communication technology, mental health and vocational rehabilitation and employment. These experts were chosen due to their knowledge and experience with the user group. The individual interviews supplemented the contextual interviews with further information provided on web-based employment services designed to provide open, flexible and distributed access for people who may experience difficulty in returning to work after a long absence. An immediate challenge for the project team was to provide evidence of the need for a more specialized web-mediated work searching system designed specifically for people recovering from mental illness if the project was to proceed.

The project team held many focus group meetings with users and experts. An outcome of these meetings was the need to focus on easily accessible information related to employment as well as support and education concerning mental health and well being. This was in order to enhance the self-confidence of people (all age groups) recovering from mental illness who may have been out of work for many years, or have never experienced paid employment. There was general consensus that the design needed to ensure that navigation was kept simple and that a person could take regular breaks and easily return to the site. It was suggested that in order to return to the Login Screen, the user should only need to press a Close button to finish a session. Re-entry should be made possible again by repeating a simple Login procedure. It was suggested that touch screen technology be used to facilitate easy access to information. This meant that the system should function without a keyboard and mouse. The outcome of much discussion with a user focus group, was that the Home Page should welcome the user through an audio greeting that could be toggled to a textual description as an alternative. Key job seeking options were identified during the focus groups.

Figure 1. **e-WRAP prototype log in screen** *(reproduced in McKay & Martin 2007)*

Electronic Work-finding Requirements Awareness Programme

Welcome to eWRAP - this system provides helpful hints that are useful when looking for work

Task Analysis

A task analysis enabled identification of the processes and tasks associated with the goal of gaining and maintaining suitable employment, as well as promoting and supporting positive mental health and well being. The design was informed by knowledge of the difficulties and frustrations navigating a range of print and electronic work search systems and the absence of any facility designed especially for people recovering from mental illness wanting to re-enter the workforce. Brainstorming assisted in identifying the five key tasks of looking, applying, commencing and keeping work as well as surviving and maintaining motivation and positive self-esteem if unsuccessful. These were developed as the main search menu for site entry and navigation as shown in Figure 1.

Task analysis was used to identify all of the steps involved in each of these activities, informing the development of a persona and scenarios.

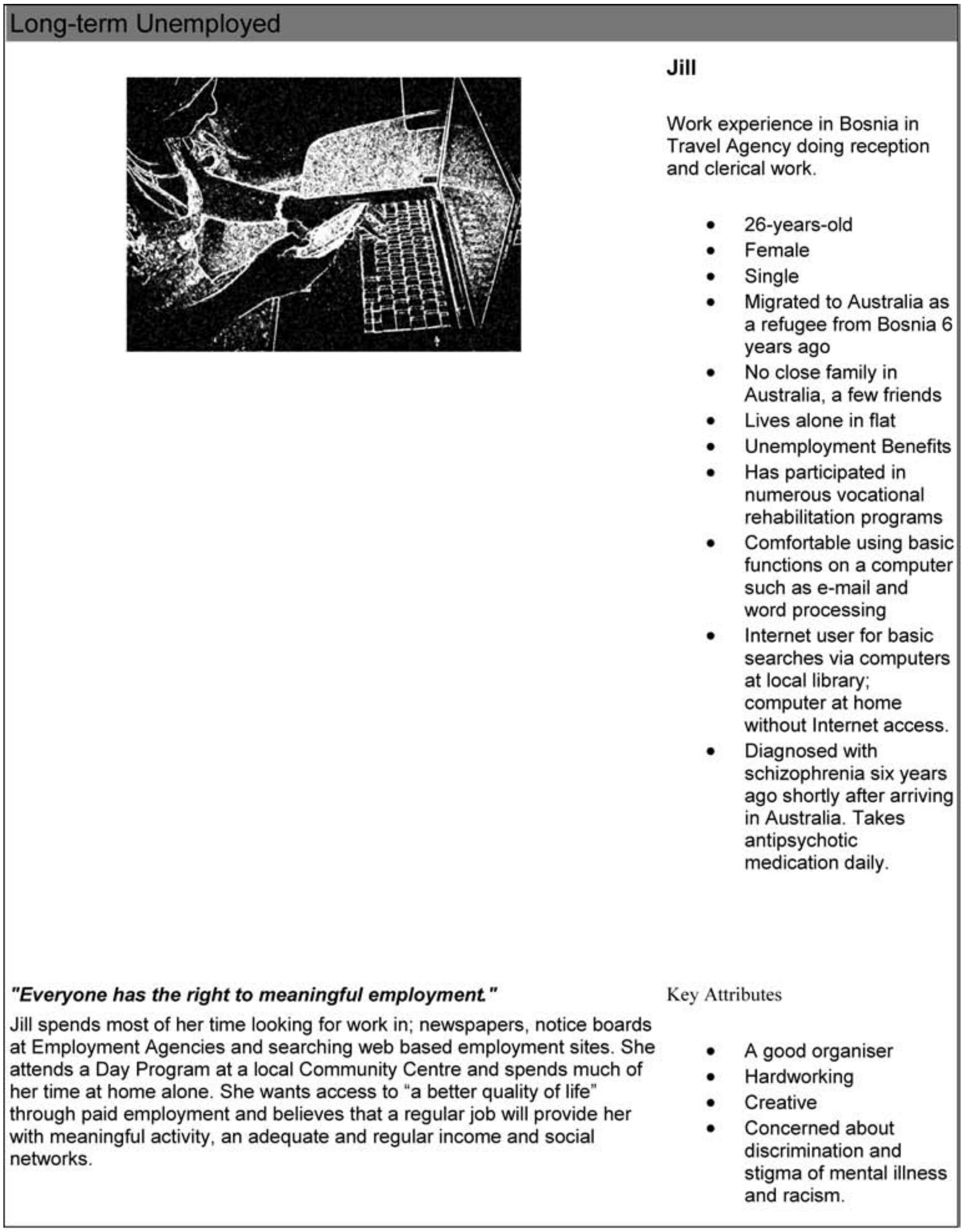
Persona

The personal and disciplinary background of members of the project team member led to divergent interests and priorities. A persona proved useful in providing a focus for the project team to develop a more in-depth and shared understanding of what a potential user might look like. A brainstorming process was used to develop the main features of the persona. A name that could be used for both sexes was originally preferred so as to avoid gender bias in the design. However, it soon became apparent that the persona needed a gender to enable effective communication between team members and to create empathy. Inadvertently team members were referring to the persona as female so this was formalized by naming the persona Jill.

Jill was now the main reference point for all further discussions about the project design and implementation. She came to life with not only by name but also in terms of age, gender family, educational background, health and mental health, employment history, housing, socio-economic status and race ethnicity and culture. This was done in a manner that was respectful in the realization that Jill could not possible represent the diversity of people recovering from mental illness who might be looking at returning to work. Figure 2 provides an example of a brief description of a larger persona developed for Jill.

By including in the "Jill persona" several features of disadvantage, that are not uncommon to people recovering from mental illness seeking employment, the project team was able to cater for a wider range of contingency factors in the scenarios developed.

Figure 2. Persona of Jill



Long-term Unemployed

Jill

Work experience in Bosnia in Travel Agency doing reception and clerical work.

- 26-years-old
- Female
- Single
- Migrated to Australia as a refugee from Bosnia 6 years ago
- No close family in Australia, a few friends
- Lives alone in flat
- Unemployment Benefits
- Has participated in numerous vocational rehabilitation programs
- Comfortable using basic functions on a computer such as e-mail and word processing
- Internet user for basic searches via computers at local library; computer at home without Internet access.
- Diagnosed with schizophrenia six years ago shortly after arriving in Australia. Takes antipsychotic medication daily.

"Everyone has the right to meaningful employment."

Jill spends most of her time looking for work in; newspapers, notice boards at Employment Agencies and searching web based employment sites. She attends a Day Program at a local Community Centre and spends much of her time at home alone. She wants access to "a better quality of life" through paid employment and believes that a regular job will provide her with meaningful activity, an adequate and regular income and social networks.

Key Attributes

- A good organiser
- Hardworking
- Creative
- Concerned about discrimination and stigma of mental illness and racism.

Scenarios

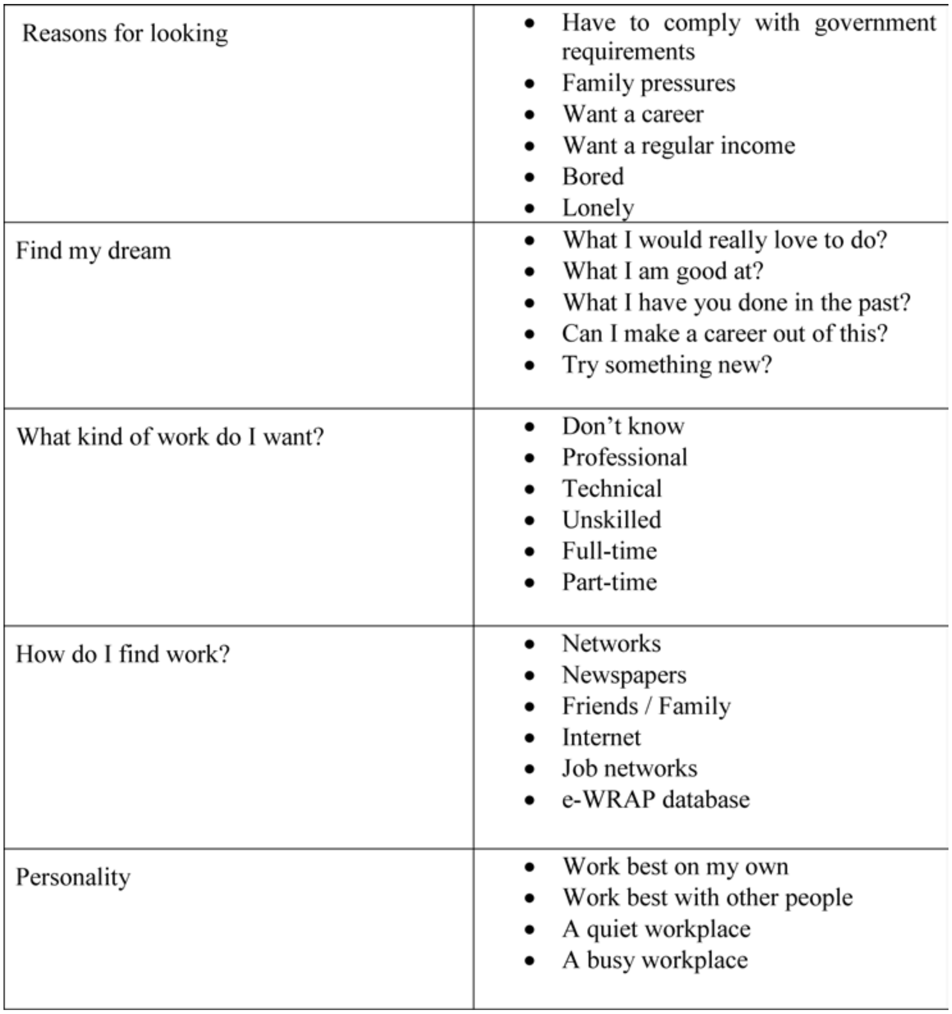
A mapping process assisted in the development of scenarios by identifying Jill's needs, interests and concerns when looking for work and use of ICT. Full scale task scenarios were used to assist Jill achieve particular tasks. For instance, Jill did not have suitable clothes to wear to interviews leading to an additional design feature of information on clothing banks. Elaborated scenarios were written for the five key tasks of "looking, applying, starting, keeping and surviving", identified in the task analysis. A key question was, "What kind of work does Jill want?" with the addition of the search icon "Find My Dream Job" under "Looking For Work." Questions invariably started with "What if?" What if Jill did not want to return to work but simply needed to comply with government requirements to keep government benefits?" "What if Jill wants to pursue a career or perhaps she wants a change of career?" Questions were asked around voluntary work vis-à-vis paid employment and the possibility that Jill might need to pursue further education to gain qualifications in the area she wanted to work in. "Was an adequate income a main priority for Jill?" "What was her level of English – written and spoken?" "How had Jill adjusted with issues of resettlement in Australia and possible trauma?" Care was taken to consider at all of the possible scenarios that Jill may encounter.

When unwell Jill struggled with motivation, had reduced levels of concentration and an increase in paranoid thoughts and auditory hallucinations contributing to lowered self esteem. Technical aspects were designed so as to be responsive to Jill's mental health and issues of motivation and level of perceptual comfort using e-WRAP. This led to the inclusion of design features that meant Jill could log in and out without losing any data stored as well as addressing issues of privacy. These features were consistent with recommendations made by participants in the focus groups during user analysis. The stigma and discrimination Jill experienced both when seeking employment and in general, as well as already lowered self-esteem, led to the inclusion of design features on dealing with knock backs, general health and well-being, self-care and building self-esteem. Low-cost leisure activities were built into the design in recognition of the loneliness and boredom that Jill experienced, also taking into account the difficulty of managing on a low income. What initially began as an employment focused project broadened into quality of life. Figure 3 shows the menu hierarchy designed for "Looking for Work".

Touch screen technology was used to design a computer system that was easy to use and tailored to the needs of people recovering from mental illness considering employment. Main features of e-WRAP were design features that were responsive to the difficulties people using the system may experience in relation to motivation, cognition and perception. Pictures, photos, graphics, video streaming and quizzes were used to add variety and make the design interesting, relevant and fun to use. The graphics and images were designed mindful of Jill's mental state.

The instructional designer worked tirelessly to be responsive to the needs identified for Jill to design appropriate screen chattels. For instance, a simple press of each key option was designed to deliver a sub-level menu. The screen chattels were always on display and included: an orientation button (top of screen), audio/text toggle button, page navigation mechanisms: back button (previous screen), a home page button, and the full menu of key job seeking options displayed along the bottom edge of the screen. This framework presented an intuitive/inquisitive approach to information where the user has complete control over where they may wish to go next. In keeping with the 5-star principles of instruction (Merrill 2003) the prototype offered video on demand (Okamoto, Matsui, Inoue & Cristea 2000). These vignettes showed users everyday activities concerning health and safety issues, preparing for an interview, typical job environments, and

Figure 3. Looking for work



Reasons for looking	• Have to comply with government requirements • Family pressures • Want a career • Want a regular income • Bored • Lonely
Find my dream	• What I would really love to do? • What I am good at? • What I have you done in the past? • Can I make a career out of this? • Try something new?
What kind of work do I want?	• Don't know • Professional • Technical • Unskilled • Full-time • Part-time
How do I find work?	• Networks • Newspapers • Friends / Family • Internet • Job networks • e-WRAP database
Personality	• Work best on my own • Work best with other people • A quiet workplace • A busy workplace

benefits of socializing at work. Four categories of work were offered; professional, community, health and education, and trades and services. Video On Demand buttons were located beneath each category. The focal point of the prototype was the interactive job selection module with a comprehensive employment knowledge system including job vacancy listings and specific position descriptions (McKay & Martin, 2007).

Usability Testing

A pilot study of e-WRAP was executed over a four month period. Arrangements were made with users to test system components as they were finished progressively. Specific goals were set at each stage of testing to assess; usability problems, user performance in terms of navigation, successful completion of tasks, speed and levels of satisfaction. Preliminary qualitative feedback, including that of several people who were not regular users of computers, was very positive. They found the system easy to use and a helpful resource and were able to relate to the characters in the various Video On Demand vignettes. The prototype was launched at a Mental Health Conference run by the psychiatric disability support sector. This conference attracts a large number of consumers and carers as well as service providers in vocational rehabilitation. A display was set up in the foyer with people able to use e-WRAP at their leisure. Members of the project team were able to observe how people used the navigation system as well as seeking informal and formal feedback. Participants who identified themselves as users, carers, workers, students or academics were asked to complete a short questionnaire on the usefulness and functionality of e-WRAP. Both quantitative and qualitative data was collected on degree of comfort, ease of use, areas for improvement with specific feedback sought on use of video on demand, employer data bases and types of jobs. Respondents were asked what they liked the most about e-WRAP and what they liked the least. Five point rating scales were used to assess levels of satisfaction. Users were asked where they would prefer e-WRAP to be located to ascertain where people would like to access this resource and ultimately whether or not they would use e-WRAP themselves or recommend it to family or friends recovering from mental illness seeking employment.

Observations at the trials and Conference, combined with informal and formal feedback, indicated that users were able to complete tasks with ease and success as well as having high levels of satisfaction. The project team was mindful of the importance of the successful completion of tasks in a timely manner as more significant than reported user satisfaction. Participants acknowledged that whilst there are numerous work search systems available none of these are tailored specifically to the needs of people recovering from mental illness and that e-WRAP is a much needed and welcome resource to assist people recovering from mental illness to achieve their vocational goals. All respondents commented favorably about e-WRAP and supported the idea of developing a live version that included data bases of employers as well as links to all of the other databases indicated as links on the proto-type.

CONCLUSION

As illustrated in the case scenario of e-WRAP, developing useful and usable Information Communication Technologies for the human services requires in-depth knowledge and understanding of the intended user group. Techniques for user analysis include contextual interviews, individual interviews, online surveys and focus groups. Contextual interviews provide essential information on the intended user group through careful listening and observations of users while they are engaged with the technologies. Individual interviews, online surveys and focus groups allow for more in-depth understanding of users attitudes, beliefs, fears and concerns and the degree to which these are shared amongst members of the user group. Task analysis assists in identifying the processes and tasks associated with project design to achieve the desired outcomes focusing on how users achieve their goals and the steps involved in doing so. Personas aid the design of suitable ICTs by providing a constant reference point for all design decisions on a hypothetical user that embodies the main features of the intended user population. Scenarios based on personas provide greater detail about users' goals and associated tasks, needs and levels of comfort with ICTs. Usability testing throughout all stages of the design process assists in assessing both user performance and preference as data is collected on navigation, successful completion of tasks, speed and levels of satisfaction. This design process facilitates in the development and application of information communication technologies that are relevant for the human services. Social workers are encouraged to embrace new technologies to improve service provision and enhance quality of life without compromising ethical standards of practice pertaining to client confidentiality, privacy and client self-determination.

REFERENCES

W3C. (2005). *Leading the Web to its full potential.* Retrieved August 19, 2005, from http://www.w3.org

Bloomquist, A., & Arvola, M. (2002). Personas in action: Ethnography in an interaction design team. *Nordic CHI, 12*(23).

Cooper, A. (1999). *The inmates are running the asylum*. UK: Macmillam.

Cooper, A. (2004). *The inmates are running the asylum: Why high tech products drive us crazy and how to restore the sanity* (2nd ed.). UK: Pearson Higher Education.

Freydenson, E. (2002). *Bringing your personas to life in real life*. Retrieved September 9, 2005, from http://boxesandarrows.com/archives/002343.php

Grudin, J., & Pruitt, J. (2002). *Personas, participatory design and product development*. USA: PDC.

Hourihan, M. (2002). *Taking the "you" out of user: My experiencing using personas*. Retrieved September 9, 2005, from http://boxesandarrows.com/archives/002330php

Lang, J. (2007). Crafting a teaching persona. *The Chronicle of Higher Education*, *53*(23), 2.

Martin, J., McKay, E., Hawkins, L., & Murthy, V. (2007). Design-personae: Matching students' learning profiles in Web-based education. In E. McKay (Ed.), *Enhancing learning through human computer interaction.* Hershey, PA: Idea Group Inc.

McKay, E., & Martin, J. (2007). Multidisciplinary collaboration to unravel expert knowledge. In M. Keppell (Ed.), *Instructional design: Case studies in communities of practice.* New York: Information Science Publishing.

Merrill, M. D. (2003). Does your instruction rate 5 stars? In *Proceedings of the eLearning Conference on Design and Development: Instructional Design - Applying first principles of instruction*. Melbourne: Australasian Publications On-Line. Retrieved December 6, 2004, from,http://www.informit.com.au/library/

Okamoto, T., Matsui, T., Inoue, H., & Cristea, A. (2000). A distance-education self- learning support system based on a VOD server. In Kinshuk, C. Jesshope, & T. Okamoto (Eds.), *Proceedings of the International Workshop on Advanced Learning Technologies (IWALT 2000): Advanced Learning Technology: Design and Development Issues* (pp. 71-72). Palmerston North, New Zealand: IEEE Computer Society.

Pruitt, J., & Grudin, J. (2003). *Personas: Practice and theory*. Retrieved January 1, 2008, from http://www.research.microsoft.com/users/jgrudin/publications/personas/Pruitt-Grudin

Ronkko, K. (2005). An empirical study demonstrating how different design constraints, project organization and contexts limited the utility of personas. In *Proceedings of the 38th Conference on System Sciences*, Hawaii.

Ryan, J. (2008). New ways of communicating: How new media is being used to communicate health messages. *Vic Health Letter*, *33*, 16–17.

United States Department of Health & Human Services. (2008). *Your guide to developing useful and usable websites*. Retrieved September 26, 2008, from http://www.usability.gov

WAI. (2002). *Web Access Initiative (WAI): Five primary areas of work.* Retrieved January 3, 2006, from http://www.w3.org/WAI

This work was previously published in Information Communication Technologies for Human Services Education and Delivery: Concepts and Cases, edited by J. Martin; L. Hawkins, pp. 152-166, copyright 2010 by Information Science Reference (an imprint of IGI Global).

Chapter 2.13

Enhancing ‘Fit’ of Health Information Systems Design Through Practice Support

Craig E. Kuziemsky
University of Ottawa, Canada

ABSTRACT

The design and implementation of healthcare information systems (HIS) is problematic as many HIS projects do not achieve the desired outcomes. There exist a number of theories to enhance our ability to successfully develop HIS. Examples of such theories include ‘fit’ and the sociotechnical approach. However, there are few empirical studies that illustrate how to understand and operationalize such theories at the empirical level needed for HIS design. This chapter introduces a practice support framework that bridges the gap between the theoretical and empirical aspects of HIS design by identifying specific process and information practice supports that need to be considered to actively produce fit of an HIS within a healthcare setting. The chapter also provides an empirical case study of how practice support was used to develop a computer based tool in the domain area of palliative care severe pain management.

DOI: 10.4018/978-1-59904-792-8.ch003

INTRODUCTION

The design and implementation of healthcare information systems (HIS) is problematic as many HIS projects do not achieve the desired outcomes. It has been reported that up to 30-50 percent of implemented HIS fail (Anderson, Aydin, & Jay, 1994) and in fact we may not know the true rate of failure of HIS due to the disincentives to publish about failures (Pratt, Reddy, & McDonald, 2004). Part of the problem is that a HIS needs to reconcile the complexity of both a healthcare domain area and an information system. Introducing a technical artifact such as a HIS will impact workflow, communication and other clinical tasks. Having some understanding about user requirements to achieve those clinical tasks will enhance our ability to design and implement HIS that meet user needs.

The concept of ‘fit’ refers to the need to establish fit between HIS and the organizational context where it is being implemented. ‘Fit’ was first introduced by Southon, Sauer and Dampney (1997) and further described by Kaplan (2001). Aarts, Dooreward, and Berg (2004) suggest that fit is not a passive process but rather needs to be actively produced between the HIS and organization where the HIS is being implemented. Although the citations on 'Fit' have acknowledged its importance to HIS design there are few empirical studies that illustrate how to understand and operationalize fit at the detailed level needed for HIS design. Fit requires methodological rigor through qualitative research methods for understanding how HIS implementation impacts healthcare settings and for actively constructing fit between a HIS and a healthcare setting. However, the range of analysis that is possible in qualitative studies can be an obstacle as it can be difficult to determine how to study a healthcare setting to establish fit.

This chapter extends existing research on 'fit' by introducing a framework called practice support. Practice support refers to the need to understand all perspectives of how a HIS will impact healthcare providers when implemented in a healthcare setting. The chapter will describe existing theories and models related to fit of HIS and outline some of the limitations in the theories and models. It will then introduce the practice support framework and methodology, and provide a case study illustrating how the practice support framework was used to construct fit of a computer-based tool for palliative care severe pain management.

BACKGROUND

Theories and Models Related to 'Fit' of HIS

There exist a number of theories and models to explain the fit of HIS with healthcare providers and settings.

Berg describes the sociotechnical approach, which refers to increasing our understanding of how information systems or other communication techniques are developed, introduced and become a part of social practices (Berg, 1999). Sociotechnical approaches emphasize the interrelation between information systems and the social environment where they are used (Berg, Aaarts, & van der Lei, 2003). HIS design from a sociotechnical perspective is about finding the synergy between the particularities of healthcare and information and communication technologies (Berg, 2003). The sociotechnical approach is also about designing interactions between users and technology such as interfaces and information retrieval not from the view of the technology but rather from the view of the agents that work with the technology and the work practices where the technology is embedded (Coeira, 2003). However Berg, Aarts, and van der Lei (2003) subsequently point out that there is no actual sociotechnical per se, but rather it has many roots including methods such as participatory design and fields such as computer supported collaborative work.

The concept of 'fit,' which refers to the need to establish fit between the HIS and the organizational context where it is being implemented, has been discussed by Southon, Sauer, and Dampney (1997) and Kaplan (2001). Kaplan (2001) summarizes studies about fit that identify a number of dimensions as being part of fit including clinical workflow (Kaplan, 1995; Safran, Jones, Rind et al., 1998; Sicotte, Lehoux, & Denis, 1998), healthcare providers level of expertise (Sicotte et al., 1998), organizational setting and cultures (Kaplan, 1988; Massaro, 1993), communication patterns (Aydin, 1994) and cognitive processes (Patel, Allen, Arocha, & Shortliffe, 1998). An important consideration is that Aarts et al. (2004) suggest that establishing fit is not a passive process but rather fit needs to be actively produced between the technology and the practice where the technology is being implemented.

As the HIS discipline has evolved so has the appreciation for conducting studies within an interpretative framework. Interpretative studies have shown to be valuable for "producing an understanding of the context of the information system, and the process whereby the information system influences and is influenced by the context" (Walsham 1993, pp. 4-5). Interpretive research does not predefine dependent and independent variables, but focuses on the full complexity of human sense making as the situation emerges (Kaplan & Maxwell, 1994).

Although quantitative methods have historically been the predominant methods used to capture data for HIS design and evaluation the limitations of relying solely on quantitative methods has been shown. Qualitative research methods are valuable for studying how HIS intersect with healthcare providers and for providing answers to the how and why questions about HIS usage that quantitative methods cannot provide (Ash & Berg, 2003). Kaplan and Duchon (1998) conducted a joint qualitative-quantitative evaluation of a laboratory information system and advocate using mixed methods because qualitative-based interviews, observations, and open-ended questions revealed a number of significant human and contextual findings about the system that were not identified through a quantitative based survey.

Models also exist from the behavioral science and management information systems (MIS) disciplines and such models have been applied to HIS research. Examples of such models include the technology acceptance model (TAM) from the behavioral sciences and DeLone and McLean's information system (IS) success model from the MIS discipline. TAM purports that user behavior with technology is dependant on intention to use technology, which is derived from the attitude towards usage, perceived ease of use and perceived usefulness of the technology (Kukafka et al., 2003). In healthcare, Chismar and Wiley-Patton (2002) used TAM to study internet and information technology usage in pediatric care. DeLone and McLean's IS success model, which was originally published in 1992 and revised in 2003, contains six concepts used to measure IS success (DeLone & McLean, 1992, 2003). The six concepts are system quality, information quality, service quality, user satisfaction, intention to use and net benefits. DeLone and McLean's IS model has been applied in healthcare for telehealth evaluation (Hebert, 2001).

How to Operationalize 'Fit'?

The previous section advocated the need for fit and sociotechnical based approaches for understanding the social, behavioral and human contexts of HIS usage but there is a gap between such approaches and the means of operationalizing them. Empirical details are needed about the elements that comprise fit in order to inform HIS design. As stated in the previous section there is no actual sociotechnical approach but rather it is a combination of methods, frameworks and theories to support an understanding of the social and technical aspects of HIS implementation. Further, fit was defined as a concept that needs to be actively produced in each unique healthcare setting as opposed to a cookbook approach that applies to multiple settings.

The need to embrace qualitative methods and interpretative approaches is critical to studying and understanding the context of how HIS are developed and used in specific clinical settings. However, a challenge lies in how to apply qualitative methods to understand and establish fit. Qualitative research methods, particularly interpretative studies, provide a wide range of opportunities to study and analyze healthcare settings. Combine that with the complexity and unstable nature of healthcare and it can be difficult to determine what factors to consider for establishing fit. The literature in the previous section identified a number of studies that provided multiple dimensions of fit and those dimensions are certainly not exhaustive of the dimensions of fit. It would enhance our ability to establish fit if there was a methodological approach to studying fit coupled with a framework for understanding fit of an HIS within a healthcare setting.

Models such as TAM and DeLone and McLean's IS success model have value for understanding HIS usage but there are two shortcomings to such models. First, much of the application of these models has been to evaluate HIS usage with less research being conducted to identify critical factors for HIS design. Outcome based studies often do not provide sufficient detail about the processes that lead to the outcomes. It would be more useful to open up the black box outcome concepts into specific variables that can be used to inform subsequent HIS design revisions. DeLone and McLean's IS success model uses information quality as one outcome measure but how do we define information quality with respect to HIS design? Second, models such as TAM and DeLone and McLean's IS success model are from the general IS domain and thus they are intended for use in multiple settings. Therefore there is the need to operationalize the models for use in healthcare settings. Concepts such as perceived usefulness from TAM or intent to use a system from DeLone and McLean's model are both very broad and need to be articulated in the context of healthcare delivery.

CASE STUDY

A case study will be used as the basis for the remainder of the chapter. The case study will introduce the domain of palliative care severe pain management (SPM) and the desire for a computer based SPM tool. It will then describe the research methods and data sources used in the study. The practice support concept and framework will be presented as a means of understanding 'fit' of a healthcare setting. An empirical example will then be illustrated of how practice support was used to design a computer based SPM tool.

Palliative care is care provided to patients with terminal illness when curative therapy is not an option. Palliative care has only been established as a formal discipline of medicine since the 1960s and is still an emerging field. However as our population ages and people live longer with chronic illnesses the need for palliative services will increase. A central aspect of palliative care is relief of symptoms, particularly pain. Severe pain is pain scored as 8, 9, or 10 on a 10 point numeric rating scale. When a patient reports severe pain they are saying they have the worst pain imaginable and thus prompt interventions are required. However, pain is a complex entity that has physical, psychosocial and spiritual dimensions and an episode of severe pain needs to be understood in the context of all of those dimensions. Further, using an inappropriate intervention for pain can cause undesirable side effects, which can actually make the pain worse.

To enhance our understanding of severe pain management (SPM) a group of palliative care providers developed a paper based severe pain tool called clinically applied pain information tool (CAPIT). CAPIT contains 11 categories that outline why a patient may report severe pain and each category contains a listing of signs, symptoms, interpretations and strategies for relief (Downing, 2006). CAPIT also contains a set of fundamental considerations to understand the unique aspects of pain for each individual including impact of disease trajectory and ethical and cultural elements of pain. The palliative care providers who developed the paper based CAPIT also wanted a computer-based SPM tool as they recognized that the paper based CAPIT was limited in functionality. The need for a comprehensive understanding of the SPM domain suitable for design of the computer based SPM tool was the motivation for this study.

A METHOD FOR UNDERSTANDING 'FIT'

Understanding fit requires a methodological approach to understanding the processes that take place in a healthcare setting, the users who conduct the processes and the information required to support those processes. A grounded theory-participatory design (GT-PD) hybrid approach was conceived for understanding the processes that take place in a healthcare setting and the information required to support those processes (Kuziemsky, 2007). The hybrid approach was chosen to provide a means of capturing user requirements through PD and then analyzing and developing theory from the user requirements through GT. The goal of PD is not only to design a product but rather to ensure the usability and utility of the product by engaging end users in design (Shrader, Williams, Lachance-Whitcomb et al., 2001).The extensive user involvement of PD allowed interaction between the palliative care providers to get different perspectives on how severe pain is managed and what support is needed in different situations to assist with SPM.

The data obtained through PD was coded using principles of GT in order to establish concepts and categories that became the practice support requirements. GT is a means of developing theory through coding of empirical data. The hallmark of GT is three coding cycles: open, axial and selective coding (Straus & Corbin, 1998). Open coding establishes concepts and categories from the data which are connected in axial coding based on similarities. Selective coding involves final refinement of the multiple concepts and categories that emerge from axial coding. The resulting analysis is both rich and concise as it emerges from multiple coding cycles.

The GT-PD approach draws out the strength of both methods. PD provides the means of user engagement to obtain a rich perspective on clinical practice and how HIS need to be designed to support such practice. GT develops concepts and categories from the data to develop empirically based understanding about the data. The GT-PD approach emphasizes the methodological approach of capturing and understanding both the content and context of the data that is being used.

Data Sources for Understanding Fit

Three data sources were used with the GT-PD approach to understand fit: practice experience, patient charts and research literature. Each is described below.

- **Practice experience:** Consists of two sources. First is 150 hours of meetings with 12 palliative care providers (three physicians, three nurses and three counselors) to discuss and model how severe pain gets managed. The second source is clinical observations where a researcher spent 40 hours doing qualitative observation and documentation of pain management on the clinical ward of a 17-bed inpatient hospice.
- **Patient charts:** A chart audit was done of 88 retrospective patient cases with at least one severe pain episode. Data collected included medical data (such as current and past disease), severe pain episode (such as onset, duration, location, quality) and interventions (both pharmacological and non-pharmacological).
- **Research literature:** A literature search was done on severe pain in palliative care as well as general pain management. 30 relevant pieces of literature brought in current evidence on severe pain management such as randomized controlled trials on medication, conceptual models on pain management and educational resources on assessment, diagnosis and management of different types of pain. The screening and identification of relevant literature was done by the palliative care providers.

The three data sources were used to provide different perspectives of fit from the view of different palliative care providers (physicians, nurses, and counselors) and also to allow cross validation of the data. It was possible to compare what providers described in meetings with what was observed in day to day practice on the clinical ward. Research literature was used to identify opportunities for incorporating literature into practice settings as a means of knowledge translation of research findings. Patient charts provided information on how patient cases are charted and communicated across different providers, and the vocabulary that is used in charting. Patient charts also provided a baseline for how data is currently charted and communicated around patient cases, which allows comparison with the level of data collection desired through practice experience meetings.

Practice Support

The practice support concept is based on the principle that a HIS is often designed to support a specific clinical task (i.e., decision support or physician order entry). However, in the context of clinical practice it stands to reason the task does not occur in isolation but rather it will interact with other processes both before and after its completion. A clinical decision support system (CDSS) can help establish a diagnosis but it will require patient data to be collected both before and after the diagnosis has been made. Further, once a CDSS helps establish a diagnosis there will usually be clinical tasks such as treatment and follow up care that need to be provided. Practice support also considers issues related to different contexts of HIS use such as levels of clinical expertise, needs of different types of healthcare providers (i.e., physician or nurse) and location of care delivery (i.e., acute care centre or community based care).

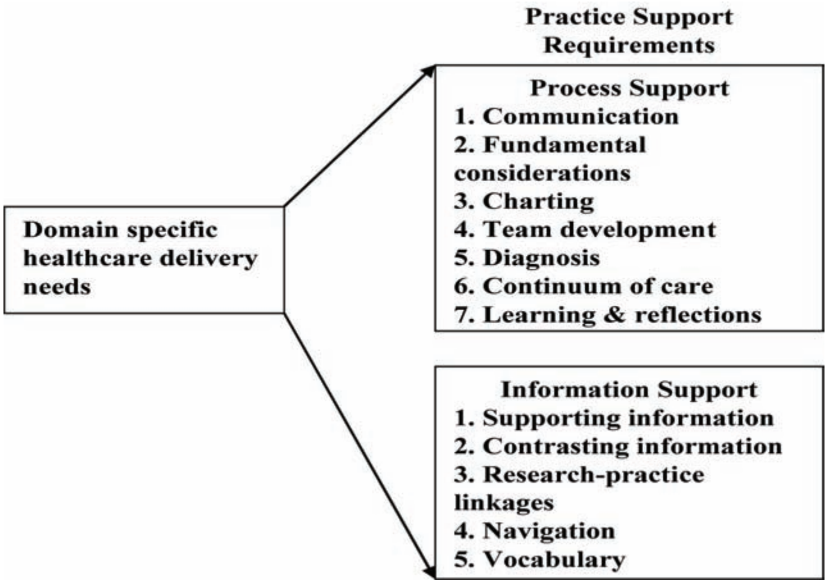
The practice support framework is the summation of the results of applying the GT-PD approach to the three data sources to actively construct fit of the computer-based SPM tool. The data acquired through PD were used to develop concepts and codes through GT. As the coding became more refined and relationships were established between the codes a set of core codes were identified that became the practice support framework for HIS design. The practice support framework is not meant to be another model that explains the fit of healthcare providers and HIS usage, but rather it is meant to operationalize the use of theories such as fit and the sociotechnical approach by providing empirical approaches to those theories. Practice support also provides the means to operationalize some of the models described in the review section. The information quality concept in the DeLone and McLean IS success model is operationalized through the practice support framework by providing specific details on the different types of information support needed for HIS design.

HIS Practice Support Framework

Figure 1 shows the HIS practice support framework. The practice support framework has two sections to it, the domain specific healthcare delivery needs shown on the left side of figure 1 and the practice support requirements shown on the right side of Figure 1. The practice support requirements were categorized into two types: process and information support. The rationale for the two categories is that in order to provide practice support for healthcare providers we not only need to define the processes that are done, the information needed and the relationships between the processes and information. Identifying a process done as part of clinical practice (i.e., a diagnosis) without the necessary information to support that process (i.e., supporting and contrasting information to support different types of diagnoses) will not provide the necessary practice support for a given clinical task.

The process and information supports from the practice support framework are described in the following two sections.

Figure 1. Practice support framework for HIS design



Process Supports

Seven process supports were identified. The seven process supports are listed out in the following.

1. **Communication:** Effective communication needs to be promoted between all healthcare providers such as between physicians and nurses or between multiple nurses during shift change. Communication is also needed to support the ongoing care of a patient given that different providers may take part in patient care and care may take place in multiple settings.
2. **Fundamental considerations:** Cultural, social and ethical factors need be considered with respect to the patients receiving care as well as the healthcare providers and setting where a HIS is being used. Edwards and Roelofs (2006) showed that the domain of healthcare organizations, which included communication and monitoring and reporting mechanisms, varied across cultures and countries.
3. **Charting:** HIS need to ensure that all requisite data is charted about a patient case to facilitate other processes. Diagnoses, communication, team development and continuum of care all depend on requisite data being available.
4. **Team development:** As more patient care is provided from an interdisciplinary team perspective HIS will need to promote team development and team practices.
5. **Diagnosis:** Different types of diagnostic processes are used in healthcare and the different processes require different support. The identification of reasoning strategies used by clinicians may be critical to the optimal design of CDSS (Arocha, Wang, & Patel, 2005).
6. **Learning and reflections:** The level of expertise between users of an HIS will vary. Because of the ability of an HIS to store and retrieve information it can be used as a teaching tool for students and new staff to learn about processes such as diagnosis or team development. HIS can also support reflective practice, which is how *individual*

professionals address uncertain and non-routine, yet repetitive, problems in practice. Reflective practice has been described as a vehicle for learning by intertwining practice and theory (Schon, 1983).

7. **Continuum of care:** Healthcare delivery is not a one time occurrence and continuous communication and monitoring of patient cases are needed to support ongoing patient care. Once a patient has a diagnosis confirmed by a CDSS they may receive treatment or require diagnostic tests that will require follow-up.

The key aspect for each of the processes for practice support is to understand how the functionality of an HIS can implement the processes. Reflective practice is encouraged as a means of helping healthcare providers improve their practice. However, because reflective practice is removed from routine day to day clinical tasks such as charting and provision of medications, it is not something healthcare providers routinely think of doing. Using HIS to provide the means of doing reflective practice one computer screen away from the charting screen is a way of incorporating and encouraging reflective practice as part of routine practice.

Information Support

The second part of the practice support framework provides specific details on the types of information that can be structured in an HIS to support different elements of practice. The information support is broken down into five specific categories.

1. **Supporting information:** Supporting information provides a 'show me how' or 'help me do this' functionality. Waitman and Miller (2004) emphasize that healthcare providers often take a 'show me' stance with respect to CDSS and therefore want both a recommended intervention and detailed steps involved in its implementation.
2. **Contrasting information:** Contrasting information is used to provide information to support diagnostic processes where more than one option exists. A patient may have signs or symptoms present in two or more disease conditions and contrasting information provides a 'show me why' functionality for differentiating the diagnostic options.
3. **Navigation:** As HIS get more complex and make available more information so must our ability to provide guidance for using such information. Part of the fit of information is navigation that provides the right information at the right time as well as ensuring that screens and interfaces have a flow that fits with the practice setting where the HIS is being used.
4. **Common vocabulary:** Part of interdisciplinary care is promoting common vocabulary between different health care providers. Healthcare providers all have their own vocabularies and if HIS are to facilitate interdisciplinary practices then the vocabulary must be acceptable to all providers.
5. **Research/practice linkages:** Because HIS have the ability to store and retrieve information they can be used to promote research-practice linkages as a means of knowledge translation.

APPLICATION OF THE PRACTICE SUPPORT FRAMEWORK TO PALLIATIVE SPM

A specific example of how the practice support framework was used to operationalize fit will be illustrated using the case example of the computer based SPM tool. The sections below illustrate how fit was established for each of the process and information supports from the practice support framework.

Charting and Communication Processes

While collecting the design requirements for the computer-based SPM tool the charting and communication processes were identified as crucial processes for nursing practice. The paper-based CAPIT is a comprehensive knowledge base of palliative SPM and acts as a reference about different etiologies of severe pain. However the paper based CAPIT is not specific to any patient. At the first practice experience meeting with nurses they very adamantly questioned how a computer-based SPM tool would help them if they had a patient in severe pain? Nurses felt the lack of specificity of the paper based CAPIT to a patient case takes away from its utility as nurses do a large amount of the patient charting. Nurses would be more likely to use the computer tool if it could be made specific for a patient by enabling a patient case to be charted. Nurses did not want to use a computer tool to view details about severe pain and then have to go to another application (either paper or computer-based) to chart the patient case. The computer-based SPM tool would provide practice support if they could view the information from the computer based tool and then develop and chart the patient's case directly in the computer based SPM tool.

Further emphasis of the importance of fit between the charting and communication processes was described as nurses stated that it is not uncommon for a patient to have more than one type of severe pain and each type will have its own clinical details such as signs and symptoms. However, the nurses also said that all requisite information about a patient case does not always get effectively communicated across different palliative care providers, which can adversely affect patient care. The charting component of HIS design should not be just an afterthought as charting provides the data that feeds the communication processes around patient care. It is critical to understand the intricate details of patient cases to ensure appropriate charting is supported and to use reminders to ensure charting is actually completed.

Continuum of Care Process

Another process that was identified by physicians and nurses was continuum of care, which is the ability to support ongoing care for a patient. It was pointed out that palliative SPM is not a one time event and often takes place over hours, days, and even weeks. Further, many of the management strategies such as supporting counseling, screening for clinical depression or reduction of neuropathic pain can take days to complete and it is important that such strategies are followed up to monitor their effectiveness. The initial design of the computer tool was a 'one shot' process where a patient case was developed and not revisable unless all the data was reentered. However that 'one shot' functionality would not fit with the context of palliative practice given the ongoing nature of care. Once the computer tool is used to help assess, diagnosis, and recommend a management strategy for a patient's pain there will be follow up care that needs to be monitored. The ability to add progress notes to a previously developed case was devised as a solution to enable continuum of care to be supported.

Team Development Process

Another key process of SPM is team practices. Much of palliative care is done in the context of an interdisciplinary team consisting of two or more types of palliative care providers. Part of the team development process is ensuring that the vocabulary for information used in the computer based SPM tool is appropriate for the different types of healthcare providers (physicians, nurses, and counselors) that will be using the tool. Team development is more complex in instances where an interdisciplinary team is not co-located such as a remote area where there is only a family physician or homecare nurse. In such situations it is important that healthcare providers do not ignore the need to think from an interdisciplinary perspective. Therefore, practice support information resources should be made available to help a palliative care provider consider a team perspective when no team is available. One means of doing that is to have links to websites that offer both information resources about team functionality and in some cases real time interactions such as messaging with other healthcare providers to act as a virtual team. In essence the computer tool becomes the team when no team is available.

Diagnostic Process

In the practice support framework it was described that the fit of the diagnostic processes are important for acceptance of an HIS. The GT-PD approach was helpful for obtaining depth of detail about the diagnostic reasoning support needed in palliative SPM. One of the concepts in the paper based CAPIT is an 'interpretation.' When palliative care providers were queried as to what an interpretation consists of it was articulated that it is two types of diagnostic reasoning, a differential diagnosis and a provisional diagnosis. A provisional diagnosis is when a palliative care provider is relatively sure of the category of severe pain the patient is experiencing but they need some additional information to confirm the diagnosis. A differential diagnosis is when a sign or symptom is present in multiple categories of severe pain and the care provider needs help determining the correct category. Therefore provisional diagnostic reasoning needs to go top down, from an etiology to an explanation of signs and symptoms whereas differential diagnostic reasoning needs to go bottom up, from signs and symptoms to an etiology of severe pain. Those two types of diagnostic reasoning also dictate how information support needs to be structured. Supporting information provides depth for drilling down about a concept (during a provisional diagnosis) whereas contrasting information provides breadth to support decision making across different options (during a differential diagnosis).

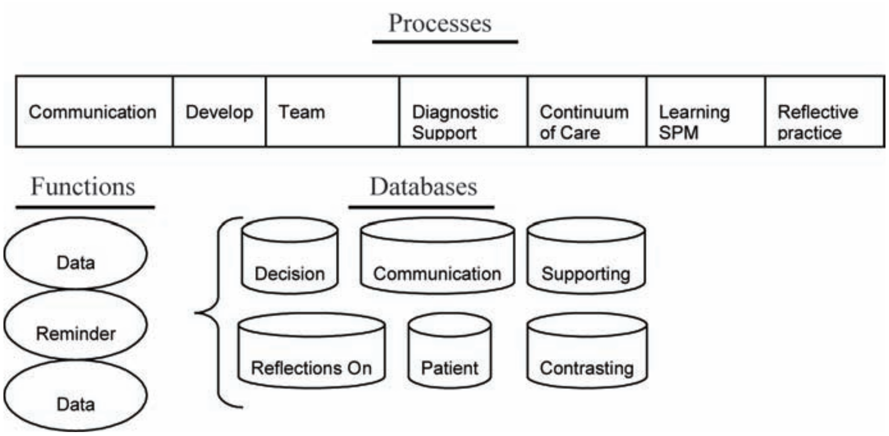
Learning and Reflection Process

Although the computer based SPM tool was designed to support specific aspects of palliative care (assessment, diagnosis, and management) during the GT-PD sessions palliative care providers described how some of the knowledge needed for SPM comes from general pain management and palliative care knowledge that is not contained in the paper based CAPIT. If a student or junior clinician is using the computer tool they may not have the background knowledge about pain or palliative care and thus would need access to educational resources. Supporting information about pain and palliative care needs to be made available.

Fundamental Consideration Process

One issue with designing a HIS is that it may be looked at as mitigating the human factor of patient care. To emphasize the importance of the human factor one practice support process is fundamental considerations. Fundamental considerations draw attention to factors such as the social and cultural issues of HIS usage. When the concept of the computer-based SPM tool was first discussed there was concern, particularly from the counseling staff, that the computer tool may slot a patient into a physical etiology of pain while ignoring the psychosocial dimensions of care. Palliative care is a branch of medicine that emphasizes all dimensions of care including physical, psychosocial, and spiritual dimensions and for a computer tool to be accepted in palliative practice it needs to represent all those dimensions. A number of specific fundamental considerations were derived that need to be considered as part of palliative care delivery. Those fundamental considerations include disease trajectory (i.e., how sick the patient

Figure 2. Architectural diagram of computer-based SPM tool



is), cultural and ethnical aspects of care such as how pain perception and subsequent treatments may differ across cultures and ethnicities, and the context and meaning of both the illness and the severe pain based on the individual uniqueness of each patient. Alerts and checklists were devised as part of the computer tool to ensure the fundamental considerations are incorporated and charted as part of a patient's case.

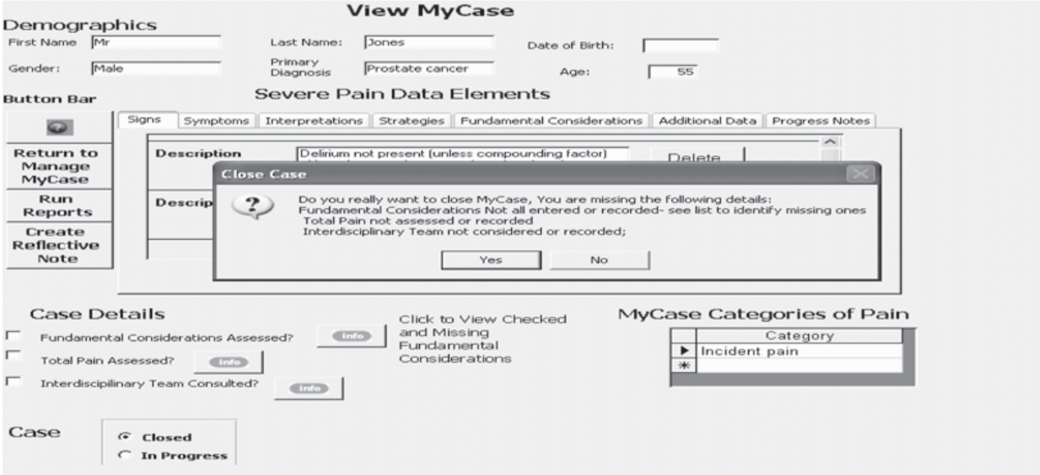
Systems Design and Implementation of Computer-Based SPM Tool

Following the capture of all the requirements of fit for the computer-based SPM tool an architectural diagram was developed for the tool. The architectural diagram is based on the practice support requirements for SPM that were detailed in the previous section. Figure 2 shows the architectural diagram consisting of three sections: processes, functions and databases.

The information practice support requirements were used to design the database tables. The functionality of the computer-based SPM tool is achieved through the data query, data entry and reminder functions. For example there are database tables to store supporting and contrasting information, which can retrieved through a data query. There are also database tables to store patient cases, which can be developed via data entry functions or retrieved and viewed through a data query function. During data entry there are reminders to ensure that requisite data is collected about a patient case and to ensure the fundamental considerations such as cultural elements of care are assessed and charted.

Figure 3 shows the physical implementation of the computer-based SPM tool. The processes and functions from the architectural diagram became the screens of the computer-based SPM tool to allow the entry and query of information. Figure 3 shows the data entry functionality that illustrates many of the practice support requirements that were described in the previous section. Figure 3 shows how specific patient cases can be entered including progress notes for continuum of care and checkboxes for completion of assessments on interdisciplinary teams and the fundamental considerations. There are 'info' buttons next to the interdisciplinary team and fundamental consideration checkboxes in case the palliative care provider needs supporting information about those concepts. Figure 3 also shows a reminder box pointing out that some requisite data has not been charted, which was identified by palliative care providers as a requirement needed to support the communication process.

Figure 3. Screen shot of computer-based SPM tool



First Name: Mr
Last Name: Jones
Date of Birth:
Gender: Male
Primary Diagnosis: Prostate cancer
Age: 55

Description: Delirium not present (unless compounding factor)

Do you really want to close MyCase, You are missing the following details:
Fundamental Considerations Not all entered or recorded- see list to identify missing ones
Total Pain not assessed or recorded
Interdisciplinary Team not considered or recorded;

☐ Fundamental Considerations Assessed?
☐ Total Pain Assessed?
☐ Interdisciplinary Team Consulted?

	Category
▶	Incident pain
*	

Case
● Closed
○ In Progress

The other practice support requirements such as provisional and differential diagnostic support, the ability to engage in learning and reflective practice about palliative SPM and real time interdisciplinary team support are available through other screens of the computer-based SPM tool.

DISCUSSION

This chapter has presented a practice support framework and a methodological approach for establishing fit of a HIS. The practice support framework identified seven process supports and five information supports that should be considered as part of establishing fit of an HIS in a healthcare setting. The chapter also provided a case study illustrating how the practice support framework was used to operationalize fit in order to design a computer-based SPM tool.

The practice support framework is meant to extend existing theories and models by providing the means to operationalize them. Theories such as the sociotechnical approach or fit, and models such as the technology acceptance model are valuable for understanding fit of an HIS, but because clinical practice takes place at an empirical level we need the means of understanding the fit of a HIS in its practical usage. The practice support framework bridges the gap between theoretical and empirical by identifying specific process and information supports that need to be considered to actively produce fit of an HIS within a healthcare setting.

The practice support framework and other research on human and social issues described in this textbook have implications for students and systems designers of HIS. Education implications include illustrating the scope of practice support that is needed in an HIS as well as the need to educate healthcare providers to engage critically in the design of HIS. In the past, the design and implementation of HIS have often been portrayed as two different processes where design takes place in a laboratory and implementation takes place in a healthcare setting. Separating design and implementation leads to issues of weakened communication, lack of reflection and inability to track the continuum of care. Many of the practice support requirements in the case study were not part of the paper based CAPIT and were only identified after extensive engagement and in some cases criticism by the palliative care providers. It was the nurses' criticism of the lack of case specificity in the paper-based CAPIT that led to that function being designed for the computer-based

SPM tool. Similarly it was the counselors fear that the computer-based SPM tool would dehumanize palliative practice that led to the development of specific fundamental considerations and reminders to ensure they are assessed and documented. If the paper-based CAPIT had been implemented as a computer-based SPM tool without the practice support enhancements such as enhanced charting and reminders it would have failed because of human and work practice issues.

System design implications include providing methodological guidance and a framework for engaging in qualitative and interpretative based HIS research. Although systems design is often taught using traditional approaches such as the system development lifecycle (SDLC) studies have shown that such approaches are problematic. Brender (1999) describes a paradox in systems development in that traditional approaches, such as the SDLC, do not consider that requirements change during the design process. The practice support framework and accompanying GT-PD approach provide a different perspective on HIS design through a qualitative based method for understanding the richness of detail of what practice support is needed for an HIS. Greater use of qualitative methods and interpretive research would help us understand the social, human, and work practice issues associated with designing and implementing HIS.

FUTURE RESEARCH DIRECTIONS

Despite the existing theories and models about 'Fit' and the findings presented in this chapter there is still much future research needed to help us understand and implement fit in different healthcare settings. Although this chapter described the importance of qualitative and interpretive research methods such methods are still underutilized in healthcare settings. Chiasson, Reddy, Kaplan, and Davidson (2007) point out that medical informatics as a field uses research methods that are primarily quantitative and experimental. This chapter emphasized that the sociotechnical approach has roots in different research methods and approaches including participatory design and computer supported collaborative work (Berg et al., 2003). Continued research is needed to explore methodological approaches to understand and implement perspectives of fit and the sociotechnical approach. Despite its utility for involving users in HIS design and for helping system designers to understand the users perspective there are few studies that empirically illustrate how to use methods such as participatory design in practice settings. Research is also needed to explore using hybrid methodologies such as the GT-PD approach presented in this chapter. Methods for qualitative analysis such as grounded theory or content analysis are a useful means of making sense of data to enable a comprehensive understanding of how technology and clinical practice intersect. Perhaps most importantly, further research is needed at developing the means of implementing concepts of fit, the sociotechnical approach and other user centered models into the HIS design phase. Relying on models to evaluate failure after the fact does not make full use of their potential. Fit and the sociotechnical approach need to do more than just describe how HIS are used. They must inform the design of the functionality of HIS including interfaces and data entry, retrieval, and decision support functionality.

CONCLUSION

Practice support encourages HIS designers, users and educators to think about the range of processes and information that form healthcare practice. Practice support includes traditional HIS functions such as decisions support and information management and it also encourages us to think about those functions in light of different practice settings, social norms and cultures of system use.

REFERENCES

Aarts, J., Doorewaard, H., & Berg, M. (2004). Understanding implementation: The case of a computerized physician order entry system in a large Dutch university medical center. *Journal of the American Medical Informatics Association*, *11*, 207–216. doi:10.1197/jamia.M1372

Anderson, J.G., Aydin, C.E., & Jay, S.J. (1994). *Evaluating health care information systems: methods and applications*. Thousand Oaks, CA: Sage Publications.

Arocha, J. F., Wang, D., & Patel, V. L. (2005). Identifying reasoning strategies in medical decision making: A methodological guide. *Journal of Biomedical Informatics*, *38*, 154–171. doi:10.1016/j.jbi.2005.02.001

Ash, J., & Berg, M. (2003). Report of conference track 4: Sociotechnical issues of HIS. *International Journal of Medical Informatics*, *69*, 305–306. doi:10.1016/S1386-5056(02)00180-6

Aydin, C. (1994). Computerized order entry in a large medical center: evaluating interactions between departments. In J.G. Anderson, C.E. Aydin, & S.J. Jay (Eds.), *Evaluating health care information systems: Approaches and applications* (pp. 260-275). Thousand Oaks, CA: Sage.

Berg, M. (1999). Patient care information systems and health care work: A sociotechnical approach. *International Journal of Medical Informatics*, *55*, 87–101. doi:10.1016/S1386-5056(99)00011-8

Berg, M. (2003). The search for synergy: Interrelating medical work and patient care information systems. *Methods of Information in Medicine*, *42*(4), 337–344.

Berg, M., Aarts, J., & Van der Lei, J. (2003). ICT in healthcare: Sociotechnical approaches. *Methods of Information in Medicine*, *42*(4), 297–301.

Brender, J. (1999). Methodology for constructive assessment of IT-based systems in an organisational context. *International Journal of Medical Informatics*, *56*, 67–86. doi:10.1016/S1386-5056(99)00042-8

Chiasson, M., Reddy, M., Kaplan, B., & Davidson, E. (2007). Expanding multi-disciplinary approaches to healthcare information technologies: What does information systems offer medical informatics? *International Journal of Medical Informatics*, *76*(Supplement 1), S89–S97. doi:10.1016/j.ijmedinf.2006.05.010

Chismar, W. G., & Wiley-Paton, S. (2002) Test of the technology acceptance model for the Internet in pediatrics. *Proc. AMIA Symp,* 155-159.

Coiera, E. (2003). Interaction design theory. *International Journal of Medical Informatics*, *69*(2-3), 205–222. doi:10.1016/S1386-5056(02)00106-5

DeLone, W. H., & McLean, E. R. (1992). Information systems success: The quest for the dependent variable . *Information Systems Research*, *3*(1), 60–95. doi:10.1287/isre.3.1.60

DeLone, W. H., & McLean, E. R. (2003). The DeLone and McLean model of information systems success: A ten year update. *Journal of Management Information Systems*, *19*(4), 9–30.

Downing, G. M. (Ed.). (2006). *Medical care of the dying* (4th ed.). Victoria Hospice Society Learning Centre for Palliative Care.

Edwards, N., & Roelofs, S. (2006). Developing management systems with cross-cultural fit: assessing international differences in operational systems. *The International Journal of Health Planning and Management*, *21*, 55–73. doi:10.1002/hpm.825

Hebert, M. (2001). Telehealth success: Evaluation framework development. *Medinfo*, *10*, 1145–1149.

Kaplan, B. (1988). Development and acceptance of medical information systems: An historical overview. *Journal of Health and Human Resources Administration*, *11*(1), 9–29.

Kaplan, B. (1995). Information technology and three studies of clinical work. *ACM SIGBIO Newsl*, *15*(2), 2–5. doi:10.1145/216200.216204

Kaplan, B. (2001). Evaluating informatics applications: Some alternative approaches: theory, social interactionism, and call for methodological pluralism. *International Journal of Medical Informatics*, *64*, 39–56. doi:10.1016/S1386-5056(01)00184-8

Kaplan, B., & Duchon, D. (1998). Combining qualitative and quantitative approaches in information systems research: A case study. *Management Information Systems*, *12*(4), 571–586.

Kaplan, B., & Maxwell, J. A. (1994). Qualitative Research Methods for Evaluating Computer Information Systems. In J.G. Anderson, C.E. Aydin, & S.J. Jay (Eds.), *Evaluating health care information systems: Methods and applications* (pp. 45-68). Thousand Oaks, CA: Sage.

Kukafka, R., Johnson, S. B., Linfante, A., & Allegrante, J. P. (2003). Grounding a new information technology implementation framework in behavioral science: A systematic analysis of the literature on IT use. *Journal of Biomedical Informatics*, *36*, 218–227. doi:10.1016/j.jbi.2003.09.002

Kuziemsky, C.E. (2007). A grounded theory-participatory design approach for capturing user requirements for health information systems design. *Proceedings of Information Technology and Communications in Health (ITCH) 2007*.

Massaro, T. A. (1993). Introducing physician order entry at a major academic medical center: 1. Impact on organizational culture and behavior. *Academic Medicine*, *68*(1), 20–25.

Patel, V. L., Allen, V. G., Arocha, J. F., & Shortliffe, E. H. (1998). Representing clinical guidelines in GLIF: individual and collaborative expertise. *Journal of the American Medical Informatics Association*, *5*(5), 467–483.

Pratt, W., Reddy, M. C., McDonald, D. W., Tarczy-Hornoch, P., & Gennari, J. W. (2004). Incorporating ideas from computer support collaborative work. *Journal of Biomedical Informatics*, *37*, 128–137. doi:10.1016/j.jbi.2004.04.001

Safran, C., Jones, P. C., Rind, D., Bush, B., Cytryn, K. N., & Patel, V. L. (1998). Electronic communication and collaboration in a health care practice. *Artificial Intelligence in Medicine*, *12*(2), 137–151. doi:10.1016/S0933-3657(97)00047-X

Schon, D. (1983). *The reflective practioner: How professionals think in action*. New York: Basic Books.

Shrader, G., Williams, K., Lachance-Whitcombe, J., Finn, L.-E., & Gomez, L. (2001). Participatory design of science curricula: The case for research for practice. Paper presented at the annual meeting of the American Educational Research Association, Seattle, WA.

Sicotte, C., Denis, J. L., & Lehoux, P. (1998). The computer based patient record: A strategic issue in process innovation. *Journal of Medical Systems*, *22*(6), 431–443. doi:10.1023/A:1020674527409

Southan, F. C. G., Sauer, C., & Dampney, C. M. G. (1997). Information technology in complex health services: Organizational impediments to successful technology transfer and diffusion. *Journal of the American Medical Informatics Association*, *4*, 112–124.

Strauss, A., & Corbin, J. (1994). Grounded Theory Methodology: An Overview. In N.K. Denzin & Y.S. Lincoln (Eds.), *Handbook of qualitative research* (pp. 273-285). Thousand Oaks: Sage.

Waitman, L. R., & Miller, R. A. (2004). Pragmatics of implementing guidelines on the front lines. *Journal of the American Medical Informatics Association*, *11*(5), 436–438. doi:10.1197/jamia.M1621

Walsham, G. (1993). *Interpreting information systems in organizations*. Chichester: Wiley.

ADDITIONAL READINGS

Ash, J. S., Berg, M., & Coiera, E. (2004). Some unintended consequences of information technology in health care: The nature of patient care information system-related errors. *Journal of the American Medical Informatics Association*, *11*(2), 104–112. doi:10.1197/jamia.M1471

Ash, J. S., Sittig, D. F., Seshadri, V., Dykstra, R. H., Carpenter, J. D., & Stavri, P. Z. (2005). Adding insight: A qualitative cross-site study of physician order entry. *International Journal of Medical Informatics*, *74*(7-8), 623–628. doi:10.1016/j.ijmedinf.2005.05.005

Balka, E., Kahnamoui, N., & Nutland, K. (2007). Who is in charge of patient safety? Work practice, work processes and utopian views of automatic drug dispensing systems. *International Journal of Medical Informatics*, *76*(Supplement 1), S48–S57. doi:10.1016/j.ijmedinf.2006.05.038

Campbell, E. M., Sittig, D. F., Ash, J. S., Guappone, K. P., & Dykstra, R. H. (2006). Types of unintended consequences related to computerized provider order entry. *Journal of the American Medical Informatics Association*, *13*, 547–556. doi:10.1197/jamia.M2042

Chiasson, M. W., & Davidson, E. (2004). Pushing the contextual envelope: Developing and diffusing IS theory for health information systems research. *Information and Organization*, *14*, 155–188. doi:10.1016/j.infoandorg.2004.02.001

Coeira, E. (2007). Putting the technical back into socio-technical systems research. *International Journal of Medical Informatics*, *76S*, S98–S103. doi:10.1016/j.ijmedinf.2006.05.026

Davidson, E. (2006). A technological frames perspective on information technology and organizational change. *The Journal of Applied Behavioral Science*, *42*(1), 23–39. doi:10.1177/0021886305285126

Effken, J. A. (2002). Different lenses, improved outcomes: a new approach to the analysis and design of healthcare information systems. *International Journal of Medical Informatics*, *65*, 59–74. doi:10.1016/S1386-5056(02)00003-5

Goulding, C. (1998). Grounded theory: The missing methodology on the interpretivist agenda. *Qualitative Market Research: An International Journal*, *1*(1), 50–57. doi:10.1108/13522759810197587

Harteloh, P. P. M. (2003). Quality systems in health care: A sociotechnical approach. *Health Policy (Amsterdam)*, *64*(3), 391–398. doi:10.1016/S0168-8510(02)00183-5

Hartswood, M. J., Procter, R. N., Rouchy, P., Rouncefield, M., Slack, R., & Voss, A. (2003). Working IT out in medical practice: IT systems design and development as co-realisation. *Methods of Information in Medicine*, *42*, 392–397.

Heeks, R. (2006). Health information systems: Failure, success and improvisation. *International Journal of Medical Informatics*, *75*, 125–137. doi:10.1016/j.ijmedinf.2005.07.024

Johnson, C. M., Johnson, T. R., & Zhang, J. (2005). A user-centered framework for redesigning health care interfaces. *Journal of Biomedical Informatics*, *38*, 75–87. doi:10.1016/j.jbi.2004.11.005

Klein, H. K., & Myers, M. D. (1999). A set of principles for conducting and evaluating interpretive field studies in information systems. *MIS Quarterly*, *23*(1), 67–93. doi:10.2307/249410

Kuziemsky, C. E., Downing, G. M., Black, F. M., & Lau, F. (2007). A grounded theory guided approach to palliative care systems design. *International Journal of Medical Informatics*, *76S*, S141–S148. doi:10.1016/j.ijmedinf.2006.05.034

Lamb, R., & Kling, R. (2003). Reconceptualizing users as social actors in information systems research. *MIS Quarterly*, *27*(2), 197–235.

Lenz, R., & Kuhn, K. A. (2004). Towards a continuous evolution and adaptation of information systems in healthcare. *International Journal of Medical Informatics*, *73*(1), 75–89. doi:10.1016/j.ijmedinf.2003.09.003

Lorenzi, N. M., & Riley, R. T. (2003). Organizational issues = change. *International Journal of Medical Informatics*, *69*, 197–203. doi:10.1016/S1386-5056(02)00105-3

Luna-Reyes, L. F., Zhang, J., Gil-Garcia, J. R., & Cresswell, A. M. (2005). Information systems development as emergent socio-technical change: A practice approach. *European Journal of Information Systems*, *14*(1), 93–105. doi:10.1057/palgrave.ejis.3000524

McDonald, C. J., Overhage, J. M., Mamlin, B. W., Dexter, P. D., & Tierney, W. M. (2004). Physicians, information technology, and health care systems: A journey, not a destination. *Journal of the American Medical Informatics Association*, *11*(2), 121–124. doi:10.1197/jamia.M1488

Mingers, J. (2001). Combining IS research methods: Towards a pluralist methodology. *Information Systems Research*, *12*(3), 240–259. doi:10.1287/isre.12.3.240.9709

Nykanen, P., & Karimaa, E. (2006). Success and failure factors in the regional health information system design process. *Methods of Information in Medicine*, *45*, 85–89.

Reddy, M., Pratt, W. P., Dourish, P., & Shabot, M. M. (2003). Sociotechnical requirements analysis for clinical systems. *Methods of Information in Medicine*, *42*, 437–444.

Rose, A. F., Schnipper, J., Park, E., Poon, E. G., Li, Q., & Middleton, B. (2005). Using qualitative studies to improve the usability of an EMR. *Journal of Biomedical Informatics*, *38*, 51–60. doi:10.1016/j.jbi.2004.11.006

Samaras, G. M., & Horst, R. L. (2005). A systems engineering perspective on the human-centered design of health information systems. *Journal of Biomedical Informatics*, *38*, 61–74. doi:10.1016/j.jbi.2004.11.013

Sjoberg, C., & Timpka, T. (1998). Participatory design of information systems in health care. *Journal of the American Medical Informatics Association*, *5*(2), 177–183.

Stockdale, R., & Standing, C. (2006). An interpretive approach to evaluating information systems: A content, context, process framework. *European Journal of Operational Research*, *173*, 1090–1102. doi:10.1016/j.ejor.2005.07.006

Zhang, J. J. (2005). Human-centered computing in health information systems Part 1: Analysis and design. *Journal of Biomedical Informatics*, *38*(1), 1–3. doi:10.1016/j.jbi.2004.12.002

Zhang, J. J. (2005). Human-centered computing in health information systems Part 2: Evaluation. *Journal of Biomedical Informatics*, *38*(3), 173–175. doi:10.1016/j.jbi.2004.12.005

This work was previously published in Human, Social, and Organizational Aspects of Health Information Systems, edited by A. Kushniruk; E. Borycki, pp. 50-66, copyright 2008 by Information Science Reference (an imprint of IGI Global).

Chapter 2.14

A Framework for Capturing Patient Consent in Pervasive Healthcare Applications

Giovanni Russello
Imperial College London, UK

Changyu Dong
Imperial College London, UK

Naranker Dualy
Imperial College London, UK

ABSTRACT

In this chapter, the authors describe a new framework for pervasive healthcare applications where the patient's consent has a pivotal role. In their framework, patients are able to control the disclosure of their medical data. The patient's consent is implicitly captured by the context in which his or her medical data is being accessed. Context is expressed in terms of workflows. The execution of a task in a workflow carries information that the system uses for providing access rights accordingly to the patient's consent. Ultimately, the patient is in charge of withdrawing consent if necessary. Moreover, the use of workflow enables the enforcement of the need-to-kwon principle. This means that a subject is authorised to access sensitive data only when required by the actual situation.

DOI: 10.4018/978-1-60566-332-6.ch012

INTRODUCTION

Healthcare Applications are characterised by the integration of software systems in healthcare environments. Healthcare applications seamlessly assist patients and carers in performing their tasks and provide them ubiquitous access to required information. As such, healthcare application can be considered as *pervasive computing systems* (Weiser, 1991). Real-world medical environments present several research challenges that need to be addressed for developing robust healthcare applications. As a showcase for our approach, in this chapter we focus on technology-assisted living, where the domains to be administered are units of personal living. Here, someone may be living alone, perhaps in sheltered housing, perhaps post-operative, perhaps with one or more disabilities, perhaps elderly and infirm. In this scenario, the healthcare applications are composed of several services to monitor the patient conditions, and to assist the patient or the carer in performing the appropriate treatments.

Monitoring the physical condition of a patient is carried out by means of body sensors. Several types of sensors are commercially available to measure blood pressure, blood sugar, pulse rate, etc. Another form of monitoring can be achieved using infra-red cameras that avoid the invasiveness of video surveillance. Combining infra-red cameras with motion detection, such as in the Irisys technology (2007), makes it possible to detect the number of people or animals such as guide dogs that are present, and to make a note of any visitors, in order to find out whether carers are visiting according to schedule. This information, together with the data gathered from sensors could be used to detect critical conditions for the patient and raise an alarm to summon help.

Healthcare applications provide to the carers and relatives visiting the patient's home easy access to patient's medical data. The virtualisation of the patients' medical records allows electronic storage, transmission, display and analysis of healthcare information that can improve and streamline healthcare delivery. However, it also poses new challenges to individual privacy. Healthcare information contains sensitive personal information; i.e. it may include the details of a person's history of diseases and treatments, history of drug use, genetic testing, sexual orientation and practices etc. Improper disclosure of this data can influence decisions about an individual's access to credit, education and employment. Therefore, it is crucial that healthcare information systems should offer adequate protections to address these concerns.

The European standards on confidentiality and privacy in healthcare (2007) states that *patient information is confidential and should not be disclosed without adequate justification. The justification for disclosure should normally be consent*. However, most security models for clinical information systems are merely variations of Role-Based Access Control (RBAC) which make access decisions based on the role of the user rather than patient consent. There are some exceptions, for example the BMA policy model (Anderson, 1996a; 1996b) and Cassandra (Becker & Sewell, 2004a; 2004b). The BMA policy model is the first security model which requires the patient's consent for accessing healthcare information. Cassandra is a trust management system designed for securing electronic health records which captures consents as special roles in the system. Nevertheless, they have some common problems. First, how to capture patient consent properly. Patient consent can be *explicit*, e.g. in written form, but more often is *implicit*, e.g. the context in which the access is being executed could carry enough information for implicitly obtain consent. In general, when the use and disclosure of patient information is for the patient's own healthcare purposes, and provide the patient or his legal representative has been informed of what information sharing is necessary for such purposes, implicit consent is sufficient. But in the BMA model and Cassandra, the consent must be explicit. This requirement adds unnecessary workload to healthcare professionals. Second, how to ensure that the consent is obtained on a well informed basis. A valid consent requires that the patient has been informed as to what information is intended to be used or disclosed, and for which purposes. Consent that has been obtained does not imply information has been given. However, none of the current models handle this.

In this chapter, we make us of a home-based healthcare scenario to address two main problems of current access control mechanisms. The first problem is the integration of patient consent with access control. Most access control models are designed for non-healthcare systems and do not have the concept of patient consent at all. However, patient consent occupies a pivotal role in legitimising the use and disclosure of healthcare information. Patients have a right to control access to and disclosure of their own healthcare information by giving, withholding or withdrawing consent. Therefore patient consent should serve as the ultimate foundation of access control decisions in healthcare systems. The second problem is related to the **need-to-know** principle. According to this principle, even when one has the necessary approvals, i.e. if the patient consents, access should not be given unless one has a specific need to know. An access decision should be justified by not only who is requiring access and what is being accessed, but also why the information needs to be accessed. Capturing and enforcing the access is also useful for mitigating exposure of healthcare systems to insider attacks (Anderson 1996a). For example, browsing a patient's medical record by a doctor should be allowed when the doctor is diagnosing the patient, but should not be allowed if the doctor is off-duty. Access control models such as RBAC cannot capture the access needs precisely. For example, in RBAC, the permission assignment is decided by "job functions" assigned to the role. The set of permissions is assigned to the role statically to enable the subjects playing this role to perform all the job functions. The subject has all the permissions all the time even when they are not performing certain job functions.

We believe that to better protect patient privacy, access control should not just be based on rules of who should or should not access what. Enforcing a correct procedure is also important. That is why we introduce a workflow based control framework. The framework is designed for healthcare systems and can enforce consent-based access control as well as the need-to-know principle and various other constraints. In addition, it releases end users (e.g. the medical professionals) from security related configurations so that they can concentrate on their medical duties.

This chapter is organised as follows. Section 2 discusses other approaches related to our work. In Section 3, we describe the benefits of workflow systems in healthcare environments. Section 4 describes in details the components in our framework for capturing patient consent. For validating our ideas in Section 5 we introduce a case study where a medical procedure is implemented using our framework. We conclude in Section 6.

BACKGROUND

The BMA policy model was developed in late 1990s in response to the National Health Service (NHS) project of building a nationwide medical database. The access privileges for each medical record are defined in the form of access control lists (ACLs) and managed by a responsible clinician who is the only one can change the ACLs. The main goal of the BMA model is to enforce the principle of patient consent, and to prevent too many people getting access to too large databases of identifiable records. A prototype implementation has been built in a General Practice environment (Hassey & Wells, 1997). Apart from the weakness we discussed in the introduction, other criticisms include the ACLs are not flexible and expressive enough, and the model is more clinician-centred rather than patient-centred.

Cassandra is a role-based trust management language and system for expressing authorisation policy. Cassandra supports credential-based authorisation between administrative domains, and rules can refer to remote policies for credential retrieval and trust negotiation. Cassandra focuses on healthcare systems. Cassandra has been used to develop a policy for the UK national electronic health record (EHR) system, based on the requirements of the NHS' National Programme for Information Technology (NPfIT). The notion of consent is captures in Cassandra as a special role. The consent is given to a subject, that is assigned to a special role, only if the subject requests the consent from the patient. This requirement adds extra workload for the healthcare professionals.

As we shown in this paper, in most situations the consent can be implicitly derived from the context.

Also relevant to our discussion is the RBAC model proposed in (Sandhu, 1996}. RBAC is motivated by the observation that in the real-world most access control decisions are based on the subject's job functions in an organisation. This observation is valid for organisations that own the data that is being accessed. For healthcare organizations however, the medical data that is being accessed is ``owned'' by patients. Ideally, medical data should only be disclosed when consent is obtained from patients. But the notion of consent is not captured by the original RBAC model. Thereby, extensions to this model are required for its applicability in healthcare systems (such as Cassandra).

The idea of using the workflow concept for deriving access rights was first conceived by Atluri and Huang in (Atluri, 1996), where they introduce the Workflow Authorisation Model (WAM). In WAM, authorisation constraints for data and resources are synchronized with the execution of workflows. Our framework described here is a refinement of the WAM model where the patient consent plays a crucial role in the access control decisions.

WHY WORKFLOW?

One of the significant benefits of using workflow is that it provides better process control. Users must follow predefined procedures, ensuring that the work is performed in the planned way and meets business and regulatory requirements. Workflows can also provide feedback to carers. For instance, if an action defined in a medical procedure is not performed within a certain amount of time then an alarm could be raised. The use of workflows enables the logging of the actions being executed by subjects. These logs can be used for assessing and improving the performance of carers. Moreover, logs should be made available to patients, or they representatives, in case they want to audit the medical procedures to which they were subjected and track responsibilities of subjects in case of negative experiences during their treatment.

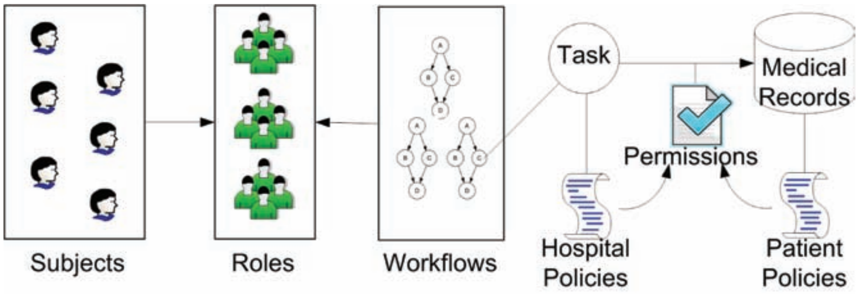
Obtaining patient consent can be easily captured as a mandatory step in a medical workflow before any use or disclosure of patient healthcare information. By executing the workflow, the control requirements for patient consent can be enforced.

A workflow also provides a way of limiting access permissions to the context in which an action is being performed enforcing the need-to-know principle. The intuition behind this is that subjects need to access specific parts of the patient's medical record only when they are executing a specific task in a workflow. Therefore by associating permissions with tasks and tracking the execution of tasks, we can ensure that the subjects can access medical records only when they have a need.

Another reason why we consider workflow is that many efforts has been made in developing and experimenting with automated or semi-automated medical workflow systems which support evidence-based medical procedures, therapies and hospital administrations (Ardissono, 2006; Poulymenoulou, 2002; Quaglini, 2001).

In our work, we assume that governmental organisations such as the National Health Service in the United Kingdom are responsible for designing and providing to hospitals standard medical procedures. Workflow systems help with this through secure auditing mechanisms that can track and record accesses, and support analysis of anomalies, failure etc.

Figure 1. Overview of our consent-based framework



CONSENT-BASED FRAMEWORK

Our workflow based framework consists of the following components: subject, role, workflow, task, policy, permission and medical records (see Figure 1).

Each **workflow** is defined according to a medical protocol or administrative process. It consists of multiple **tasks**. Each task is associated with a set of **policies**. The policies define the **constraints** for executing the task. Policies can be defined by both the hospital and the patient.

A **subject** is an entity who needs to access a medical record, e.g. a doctor, a nurse. Each subject has a set of attributes. The attributes can be used for authorisation decisions.

A **role** is a named collection of subjects. Unlike in RBAC, which assign permissions directly to roles, in our framework roles are associated with a set of workflows.

Permissions define the access right the subject has on the medical records when they are executing this task. The permissions define what actions can be operated on which part of a medical record by the subject who is executing the task. Permissions are derived from the enforcement of the policies defined on the task.

A **medical record** is the container of a patient's healthcare information. Most current electronic medical record standards define hierarchical substructures which help organising the information and make it possible for us to define fine-grained permissions on these substructures.

In our model, a permission to access a patient's medical record is granted by combining and enforcing two separate sets of policies. The first set contains medical policies that are defined by the carers' medical institutions that treat the patient (i.e., hospitals, sheltered houses for elderly people, GP and dentist studios). Policies in this set can be used for defining constraints related to time and location (i.e., a carer can perform a task only in a specific location during working hours) or to address separation-of-duty (i.e., a doctor prescribing a medication should not be also the pharmacist that sells that medication). The second set of policies contains policies specified by the patients for protecting the privacy of the information stored in their medical records.

When a subject executes a task that requires access to the medical record of a patient, the relevant policies are chosen from each set and enforced accordingly. The overall access control mechanism can be thought of as a two-step process and is represented in Figure 2. In step (1), the Policy Enforcement Point (PEP) enforces authorisation policies defined in the subject's institution (in this case a hospital). If authorisation is granted then the access is evaluated against the set of policies defined by the patient that are enforced by the PEP in step (2). If permission is also granted here, then in step (3) it is possible to get access to the actual data in the medical record.

The implementation of our framework is realised by integrating two main systems that are described in the following.

YAWL Workflow System

We use the YAWL system for the specification and enactment of workflows (Van der Aalst, 2004). YAWL provides a very powerful workflow language together with a workflow execution engine, and an editor for creating workflow specifications. YAWL can be customized to export to external components certain events that occur in the lifecycle of workflow instances. On receiving a task-enabled event, a component may decide to "check-out" the task from the engine. On doing so, the engine marks the task as *executing* and effectively passes operational control for the task to the component. When the component has finished executing the task, it will check it back in to the engine, at which point the engine will mark the task as *completed*, and proceed with the workflow execution.

It should be realised that our framework is independent of the specific workflow language/engine used as long as the workflow system provides means for interacting with our framework.

Ponder Policy Language

The other component in our framework is the policy-based system based on the Ponder policy language and interpreter developed at Imperial College London (The Ponder2 Project, 2008). The language supports the specification of policies for governing the choices in the behaviour of a system (Sloman, 2002). Ponder supports the specification of authorisation policies and event-condition-action (ECA) policies. The policy interpreter organises the entities and resources on which policies operate in hierarchical domains of **Managed Objects**. A managed object has a management interface that the object has to implement in order to be managed by the interpreter. Domains allow the classification and grouping of managed objects in a hierarchy. Furthermore, domain paths can be used to address managed objects in policy specifications. Domains can be used to group resources (e.g., data repositories, printers, X-ray machines, etc.), devices (e.g., sensors), and people (i.e., nurses, doctors, GPs, etc). An assisted living scenario is highly dynamic, as entities, including medical professionals, carers and sensor equipment, may frequently enter and leave a particular care domain. This dynamism means that the system must autonomously manage these entities, by identifying them, assigning the requisite privileges and triggering various events and/or workflow tasks. Another aspect of entity management, particularly important in the healthcare domain, concerns the performance of an entity. Actively monitoring and evaluating the behaviour of an entity allows for a higher quality of service, by allowing active intervention whilst functioning as a deterrent against misbehaviour.

Figure 2. Steps executed for granting a permission

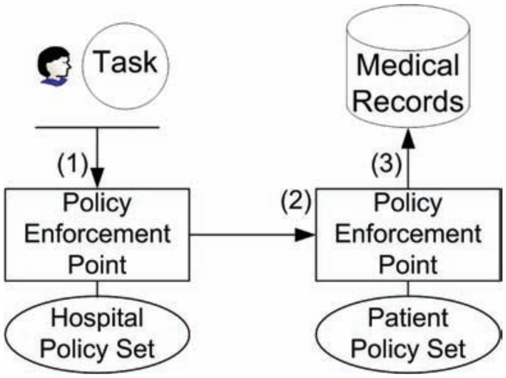
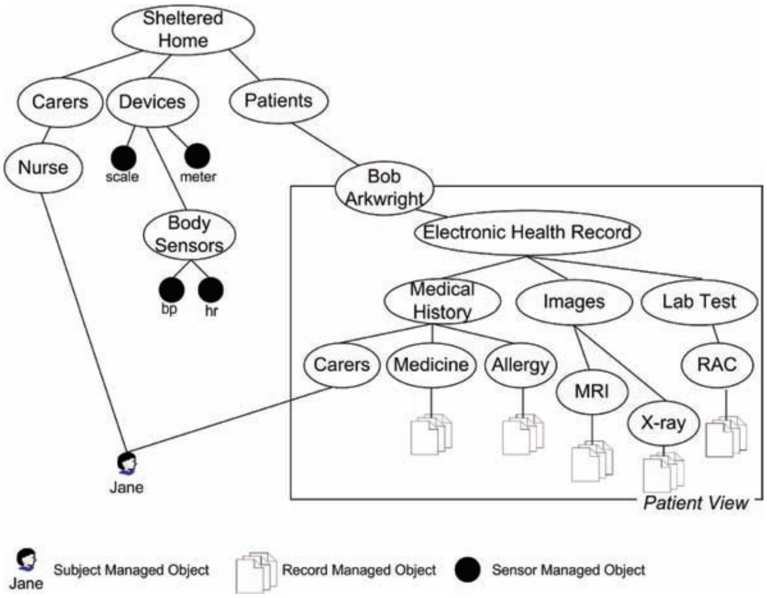


Figure 3 shows how Ponder's domain structure may be used for organising the entities and medical data for a sheltered home scenario for a patient Bob Arkwright being visited by a nurse Jane. Carers are represented by means of **Subject Managed Objects** (SMO) that could be assigned to the respective domain according to the subject's role. An SMO can be thought of as an electronic credential that identifies a specific individual working for a medical institution. The Electronic Health Record (EHR) of a patient, that

Figure 3. Representation of a sheltered home domain using ponder

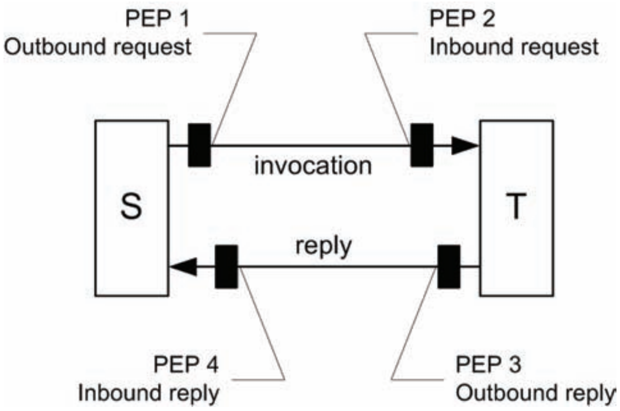


is the digital representation of a patient medical record, is also represented as a domain structure. The leaves in this domain structure are **Record Managed Objects** (RMO). RMOs represent specific instances of medical documents, such as the record of allergies, the list of current and past medications, an MRI picture, and so on. It should be noted that, although Figure 3 shows Bob's EHR within the structure of the sheltered house, the actual storage of the EHR itself could be done in a remote location. As a matter of facts, the EHR structure can be seen as a collection of distributed resources. For instance, RMOs could be stored within the organisations that created them, i.e. the X-ray images in Bob's EHR could be stored in another hospital where Bob attended when he broke is leg. Domains in Ponder transparently support external links to point to domains and managed objects contained in domain structures residing in remote location.

The sensors and devices that are deployed in the environment are represented by means of **Sensor Managed Objects** (SeMO). In this way, the devices can interact with other managed objects sending events and reacting to changes in the environment.

The EHR represents the patient's *private view* of her digitalised medical information shown as a square around Bob's EHR in Figure 3. As such, in our framework patients are enabled to specify access control policies that govern the access to such resources. In Ponder, authorisation policies are used for controlling the rights that entities have on the resources managed in a domain structure. In our case, entities are medical personnel and resources are the patient's medical data, represented as SMOs and RMOs, respectively. Sensors can be seen as resources but also can invoke actions of other managed objects. For instance, if a sensor detects an anomaly it can send an alarm to the nurse in charge. Authorisation policies are defined on (subject,target,action)-triples. The language also supports negative authorisation policies, that when applied negate the execution of the defined action. To be able to specify authorization policies, patients need to refer to the subjects executing the accesses. For this reason, the domain **Carers** in the patient's EHR is used for containing refer-

Figure 4. The fine-grained access control model supported in Ponder



ences to SMOs, as shown in Figure 3. This domain contains a collection of references to SMOs of medical personnel known to the patient. Actually, this domain represents an important part of the medical history of the patient because it provides an overview of the medical personnel that have provided care to a patient.

Fine-grained Access Control in Ponder

An important feature of the authorisation model in Ponder is the fine-grained access control mechanism. Authorisation policies can be independently specified for controlling the subject-side and the target-side of an action. A full description of the model can be found in (Russello, 2007). Here, for brevity reasons, we just recall the details of the model that are relevant for our discussion.

As shown in Figure 4 the access control mechanism provides 4 different PEPes to enforce policies. Policies can be specific for the subject and the target side of a request. The policies enforced at PEP 1 control the subject when it sends out a request. We name such policies *Subject authorisation (SA)* policies. The PEP 2 is used for enforcing authorisation policies for control on the target side. We name these policies *Target authorisation (TA)* policies. The policies enforced at PEP 4 and PEP 3 are the dual of SA and TA policies. These policies, called respectively *Subject-return authorisation (SRA)* and *Target-return authorisation (TRA)*, are used for controlling the return part of an action. SRA policies can be used for protecting the integrity of a subject (i.e. checking that the reply does not contain malicious data). TRA policies can be used for filtering the data that is returned to a subject.

Using SA and TA policies (enforced at PEP 1 and PEP 2), it becomes possible to employ this mechanism for implementing our consent-based model. In particular, hospital policies are specified and enforced as SA policies. On the other hand, patients can use TA policies for controlling the access to the private view of their medical data. A patient uses the references contained in the Carers domain for specifying which SMO a TA policy is to be applied.

In case of authorisation conflicts, that could happen when authorisation policies of different signs apply to the same triple, the interpreter is also able to autonomously resolve those conflicts. For more details on the rules that are applied for resolving conflicts, we refer the interested reader to (Russello, 2007).

Ponder ECA policies are used to dynamically adapt the system to changes of either context or behaviour of applications. Events are trigged by such changes and are propagated using an event bus. ECA polices capture events and execute actions for adapting the system. For example, ECA policies can change the domain structure adding/removing domains and managed objects, can invoke action on managed objects, can enable/disable other policies and can trigger other ECA policies by sending more events.

IMPLEMENTATION OF A HOME CARE SCENARIO FOR EDEMA

In this section, we present the implementation of a simple healthcare application for the Edema treatment based on situated workflows and implement using our framework.

Edema refers to swelling caused by excess fluid in body tissues. Monitoring involves a carer taking various measurements and performing tests. This example allows us to show several aspects of our approach in more detail:

1. Authentication of the carer when entering the home healthcare domain.
2. Assignment of careplan for Edema treatment to the carer.
3. Carrying out treatment procedures according to patient's consent.
4. Departure of the carer from the home environment.

Carers are provided with portable devices, such as PDA, that helps them in performing their task. The PDA has a domain structure instantiated where an SMO representing nurse Jane is already instantiated. The domain structure for the sheltered home is instantiated on the home PC.

Entering the Home Domain and Assignment of Careplan

Figure 5 shows the steps executed in the framework when a carer enters the patient's home. On entering the patient household, the PDA carried by the nurse and the home PC discover each other (1). The discovery of the home domain will raise an event on the nurse device that triggers an ECA policy (2). This policy forces the nurse SMO on the PAD to present the electronic credential to the Authentication Service of the home domain (3). The Authentication Service verifies the credentials and activates the nurse SMO that is contained in the domain structure of the sheltered home (4). The local nurse SMO will act as a proxy for the nurse SMO instantiated on the PDA and a mutual reference is exchanged between the two SMOs. In this way, the nurse can follow the Edema treatment procedures for this particular patient using her device. The nurse SMO also instantiates the workflow for the Edema Treatment that the nurse Jane is required to follow (6). This is done by means of the **WMS-MO** (7), a managed object that is interfaced with the YAWL engine instantiated in the home domain.

Treatment Procedures

The specification of the workflow for the Edema treatment is shown in Figure 6. The workflow is specified using the YAWL editor (shown in Figure 6) and then saved as an XML file. When an instance of the workflow needs to be instantiated, the workflow engine loads up the XML specification and enacts the first task.

The Edema treatment consists of the following tasks. First the carer checks the previous measurements. Following, the petting test is executed. Afterwards, a new set of measurements is collected for blood pressure, weight, and body measurements. In the end, the set of measurements is saved in the electronic medical record. These measurements are performed using devices and body sensors, such as scale, meters and the blood pressure sensor (BPS) already present in the home.

In our framework, the execution of a medical workflow is associated with the **Implicit Consent with Explicit Deny (ICED)** policy. The main idea

Figure 5. Authentication phase when the nurse's device is detected in the sheltered home domain

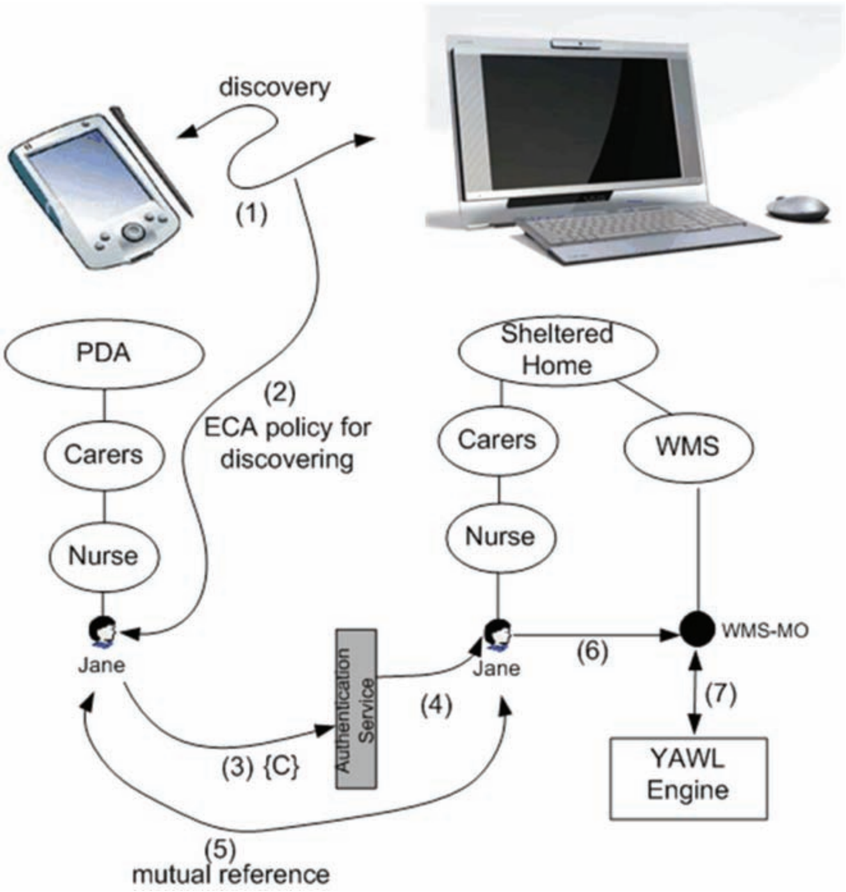
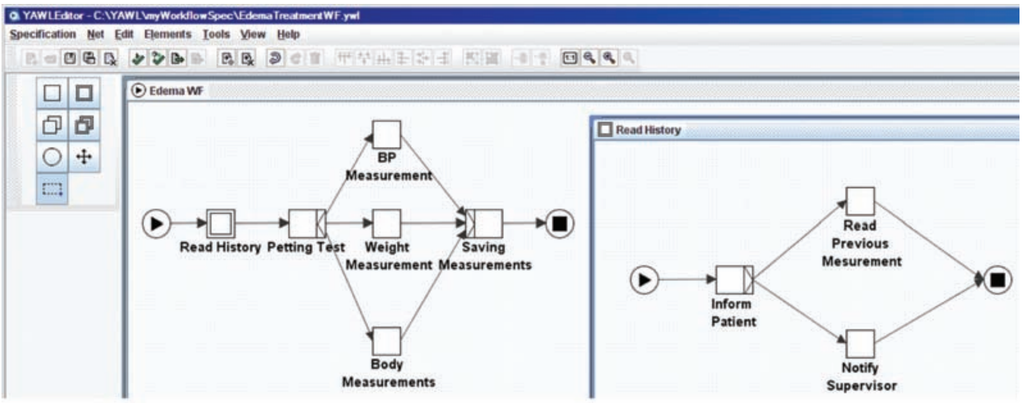


Figure 6. Specification of the workflows using the YAWL editor



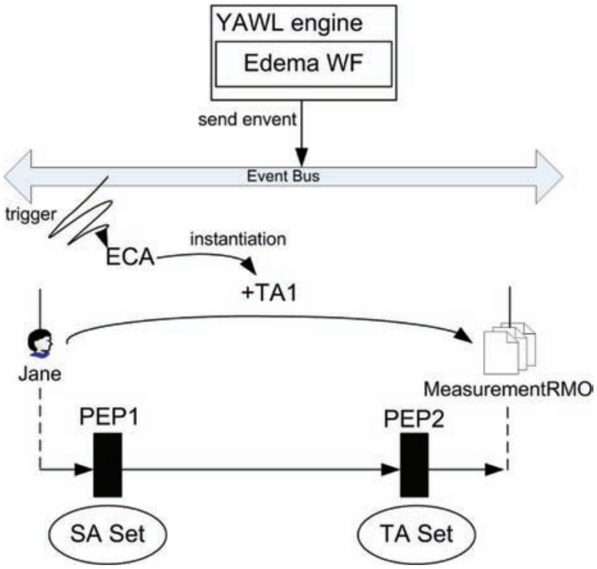
behind this policy is that a patient implicitly allows a subject executing a workflow concerning her health to access sensitive information contained in the EHR. However, the patient can explicitly deny access to one or more subjects involved in the current or any future workflows.

Implicitly allowing subjects executing a medical workflow to access an EHR means that the patient is not required to explicitly specify permissions for the subjects. The system can derive the permissions from the context in which the access is being executed and automatically generate the required permissions. In this way, the **need-to-know** principle is enforced without giving unnecessary burdens to the patients. However, a subject executing a medical workflow should provide information to a patient on each access to the EHR. This means that before the access is performed the subject should explain to the patient which part of the HER needs to be accessed and the motivations that justify such an access. If the patient thinks that the given motivations are not exhaustive or that more information than necessary is being accessed, the consent can be withdrawn.

In our framework, the enforcement of the ICED policy is achieved using the following two mechanisms. In order to inform a patient that an access is going to be executed, the task that represents the access to the previous measurements is divided into sub-tasks. Figure 6 shows the subnet of tasks for the "Read History". The "Inform Patient" task requires the subject to inform the patient that an access to the record containing previous measurement is going to be executed. If the patient consents then the "Read Previous Measurements" task can be executed. However, if the patient denies the access, then alternative tasks need to be executed. For instance, in the case of Figure 6 the subject should inform her supervisor that the patient denied her access. The main workflow is then resumed and completed accordingly. It might be the case the tasks in a workflow do not capture alternative tasks when access is deny to complete a task. If no alternative tasks are available, then the subject executing the workflow can be notified by the workflow engine to manually take some actions. Related research investigating specification and handling of exceptional situations in medical workflows be found in Han *et al.* (Han, 2006).

The automatic provision of access rights is performed by means of Ponder ECA policies. Figure 7 provides an overview of the generation of such permissions. The example shown is that of nurse Jane that wants to read the history measurements of Bob. After nurse Jane obtains Bob's consent to proceed, the ``Read Previous Measurements'' task is declared *executing* by the YAWL workflow engine and an event with this information is sent. The event also carries context-dependent data, such as: the specific instance of the task that is activated, that the task is part of a medical workflow, the subject that is executing it, the target and action that is performed, the location and time. This event triggers an ECA policy and using the data carried by the event generates and activates a positive TA policy. This policy, called +TA1, is shown in Figure 7 as an arrow connecting nurse Jane's SMO to the MeasurementRMO. When the nurse, via her SMO, performs the action of reading the measurements, the access control mechanism captures such an action and enforces authorisation policies at PEP1 and PEP2. The SA policies enforced at PEP1 are specified by the nurse's organisation. We assume that the nurse complies with the organisation policies and that from the point of view of the organisation the action is allowed. Another enforcement of authorisation policies is done at PEP2. Here, the mechanism searched for TA policies. Because policy +TA1 is already in place the action can be authorised. (Although, it could be the case that there are conflicts with other policies previously specified by Bob; we discuss this case later in this section). Another important step that is not shown in Figure 6 is that of automatically disabling the authorisation policy. After the task is concluded,

Figure 7. Generation of authorisation policies by means of ECA policies

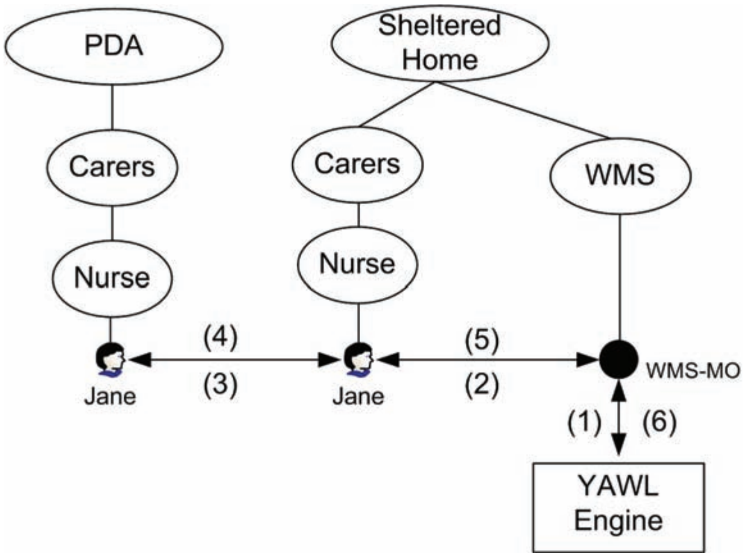


the YAWL engine sends an event that triggers another ECA policy. This ECA policy will take care of disabling policy +TA1. This use of ECA policies guarantees that the permission for accessing the record is available only for the execution of the specific task.

Our framework enables a patient to define negative authorisation policies that deny subjects to access the EHR. Once the SMO reference becomes available into the Carer domain in the EHR, the patient can define a negative TA policy for that specific SMO. When the system generates the positive TA using the mechanism described above, this positive TA will be in conflict with the negative TA created by the patient. In this case, the conflict resolution mechanism will give priority to the patient's negative TA policy. This means that the access is denied and an alternative action must be taken.

The nurse can use her device for following the workflow execution. The YAWL workflow engine is responsible for the enactment of tasks. Figure 8 shows how the engine communicates to the entities involved in the execution of a given instance of a workflow. Let us assume that the nurse completed all the measurement tasks. The only task left is the recording of the measurements into Bob's EHR. The YAWL engine notifies the WMS-MO which is the next task to be executed ("Saving Measurements") (1). The WMS-MO keeps track of which instance of an entity is involved in the execution of a workflow. In this case, the WMS-MO knows that the task is to be executed by the nurse Jane's SMO and therefore it communicates the information about the task to be completed (2). The nurse's SMO in the home domain sends this information to the SMO instantiated in the PDA domain (3) that visualises the information to the nurse via the PDA screen. The nurse checks the measurements are correct and requests the logging of the information by pressing the `log measurements' button that will appear on the PDA screen. Once the operation is completed, the task fulfilment is communicated back to the engine following the inverse path (steps (4), (5) and (6) in Figure 8). The WMS-MO can be also used for adapting the execution of workflows to the actual situation. For instance, if the biometrics of the patient presents an anomaly, the sensors can raise an alarm/event that triggers ECA policies.

Figure 8. Controlling the enactment of tasks



Depending on the situation, the ECA policies can require the WMS-MO to stop the current workflow execution and switch to an emergency workflow to cater for the actual condition of the patient. The changing of the workflow is also notified to the nurse via her PDA.

Leaving the Home Domain

When the nurse completes her visit and leaves the patient's home the resources allocated for her in the home domain must be relinquished. For instance, the Nurse Entity must be removed from the home domain and the policies associated with it deactivated. These operations are executed by means of an ECA policy that is triggered by the event "NurseOutEvt". This event is sent when the system detects that the nurse left the patient's home. When the ECA policy is triggered it disables the policies associated with the entity managed object and invokes the remove action of the domain where the Nurse Entity is contained.

The "NurseOutEvt" event can be sent in several ways. The carer can send it manually by pressing a button on her PDA to notify that the treatment is completed (according to her) and she is ready to leave. Alternatively, the system can recognise that the nurse left the sheltered house. For instance, when the nurse's device is out-of-range from the home PC or after a certain amount of time allocated for the carer expires.

These methods can be used in different situations. For instance, if the nurse has to leave before completing her procedures due to an emergency in another sheltered home, then either the manual disconnection or the out-of-range detection allows the system to promptly react (i.e., the system can report via an alarm that some procedures need to be completed). On the other hand, the time-out disconnection can be used by the system to recover from erroneous situation (i.e. the nurse left behind her device without notifying the system when she departed from the patient's house).

FUTURE TRENDS

Our framework for capturing patients' consent is based on the use of workflow systems to express contextual information when an access is being executed. In future healthcare systems, workflow systems will play a central role as it is analysed in (Dwivedi, 2001). However, one of the main issues of today workflow management systems is their inefficiency in handling *exceptional situations*. An exceptional situation refers to a state not contemplated in the workflow specification. Often exceptions require manual intervention of the subject executing the workflow. Exceptions are logged and if a particular type of exceptions happens too often then the workflow specification can be updated in order to handle it. However, such action can only be taken after execution time. This is acceptable when workflow systems are deployed in low-pace medical environments, as it is the case in the scenario of the case study presented in this chapter. In more demanding environments, such as an Emergency Room in a hospital, workflow systems may become a burden to use for the medical carers and redundant in case that exceptions have to be handle manually. As pointed out in (Han, 2006), research in this area is being investigating solutions for handling exceptions in workflows more dynamically. We also believe that improvements may derive from employing a less fixed structure for workflow specifications. Currently, a workflow specification is represented as a net of tasks that has to be strictly followed during execution. However, a specification where the execution of tasks is expressed in terms of temporal constraints (i.e., interval of time) within the different tasks could prove to be more flexible and suitable for dynamic high-pace environments.

CONCLUSION

Healthcare applications are pervasive systems that facilitate patients and carers access to medical information. In particular, healthcare applications allow electronic storage, transmission, display and analysis of healthcare information that can improve and streamline healthcare delivery. However, it also poses new challenges to individual privacy. Healthcare information contains sensitive personal information that if not properly disclosed can influence decisions about an individual's life. Therefore, it is crucial that healthcare information systems should offer adequate protections to address these concerns.

In this chapter, we presented a framework for pervasive healthcare application where patients' consent has a central role for granting permissions to carers for accessing patients' medical data. Our framework combines a workflow system for deriving contextual information and a policy-based system for automatically generating access rights. Patients can fine tune access rights by creating their own authorisation policies and effectively control the subjects to which consent is given or withdrawn. Additionally, the use of workflows allows us to enforce the need-to-know principle whereby a subject can access the patient's medical data only if there is a specific need. In our framework, this need is associated with the execution of specific workflows.

ACKNOWLEDGMENT

This research was supported by the UK's EPSRC research grant EP/C537181/1 and forms part of the CareGrid, a collaborative project with the University of Cambridge. The authors would like to thank the members of the Policy Research Group at Imperial College for their support.

REFERENCES

Anderson, R. J. (1996a). A security policy model for clinical information systems. *In SP '96: Proceedings of the 1996 IEEE Symposium on Security and Privacy*. IEEE Computer Society, Washington, DC, USA.

Anderson, R. J. (1996b). An Update on the BMA Security Policy. *In Proceedings of the 1996 Cambridge workshop on Personal Information - Security, Engineering and Ethics*.

Ardissono, L., Leva, A. D., Petrone, G., Segnan, M., & Sonnessa, M. (2006). Adaptive medical workflow management for a context-dependent home healthcare assistance service. *Electronic Notes in Theoretical Computer Science*, *146*(1), 59–68. doi:10.1016/j.entcs.2005.11.007

Atluri, V., & Huang, W. (1996). An authorization model for workflows. *In ESORICS* (pp. 44–64).

Becker, M. Y., & Sewell, P. (2004a). Cassandra: Distributed access control policies with tunable expressiveness. *In POLICY. IEEE Computer Society.*

Becker, M. Y., & Sewell, P. (2004b). Cassandra: Flexible trust management, applied to electronic health records. *In CSFW. IEEE Computer Society.*

Dwivedi, A., Bali, R., James, A., & Naguib, R. (2001). Workflow management systems: The healthcare technology of the future? *In the 23rd Annual International Conference of the IEEE Engineering in Medicine and Biology Society, 4*, 3887–3890.

European standards on confidentiality and privacy in healthcare (2007).

Han, M., Thiery, T., & Song, X. (2006). Managing exceptions in the medical workflow systems. *In ICSE '06: Proceeding of the 28th international conference on Software engineering* (pp. 741–750), New York, NY, USA: ACM.

Hassey, A., & Wells, M. (1997). Clinical systems security – implementing the bma policy and guidelines. *In R. Anderson* (Ed.), *Personal Medical Information – Security, Engineering and Ethics*. Springer-Verlag.

Irisys (2007).

Poulymenopoulou, M., & Vassilacopoulos, G. (2002). A web-based workflow system for emergency healthcare. *In Medical Informatics Erope*.

Quaglini, S., Stefanelli, M., Lanzola, G., Caporusso, V., & Panzarasa, S. (2001). Flexible guideline-based patient careflow systems. *Artificial Intelligence in Medicine*, *22*(1), 65–80. doi:10.1016/S0933-3657(00)00100-7

Russello, G., Dong, C., & Dulay, N. (2007). Authorisation and conflict resolution for hierarchical domains. *In POLICY '07: Proceedings of the Eighth IEEE International Workshop on Policies for Distributed Systems and Networks* (pp. 201–210), Washington, DC, USA.

Sandhu, R. S., Coyne, E. J., Feinstein, H. L., & Youman, C. E. (1996). Role-based access control models. *IEEE Computer*, *29*(2), 38–47.

Sloman, M., & Lupu, E. (2002, March). Security and management policy specification. *IEEE Network*, *16*(2), 10–19. doi:10.1109/65.993218

The Ponder2 Project (2008).

Van der Aalst, W. M. P., Aldred, L., Dumas, M., & ter Hofstede, A. H. M. (2004). Design and Implementation of the YAWL System. *In CAiSE 04*, Riga, Latvia, June 2004. Springer Verlag.

Weiser, M. (1991). The computer for the twenty-first century. *Sci. Amer.* 265, 3(Sept.), 94–104.

This work was previously published in Mobile Health Solutions for Biomedical Applications, edited by P. Olla; J. Tan, pp. 245-259, copyright 2009 by Medical Information Science Reference (an imprint of IGI Global).

Chapter 2.15

Alerts in Healthcare Applications:

Process and Data Integration

Dickson K.W. Chiu
Dickson Computer Systems, Hong Kong

Benny W. C. Kwok
The Chinese University of Hong Kong, Hong Kong

Ray L. S. Wong
The Chinese University of Hong Kong, Hong Kong

Marina Kafeza
University Hospital of Heraklion, Greece

S.C. Cheung
Hong Kong University of Science and Technology, Hong Kong

Eleanna Kafeza
Athens University of Economics and Business, Greece

Patrick C.K. Hung
University of Ontario Institute of Technology, Canada

ABSTRACT

Urgent requests and critical messages in healthcare applications must be delivered and handled timely instead of in an ad-hoc manner for most current systems. Therefore, we extend a sophisticated alert management system (AMS) to handle process and data integration in healthcare chain workflow management under urgency constraints. Alerts are associated with healthcare tasks to capture the parameters for their routing and urgency requirements in order to match them with the specialties of healthcare personnel or the functionalities of Web Services providers. Monitoring is essential to ensure the timeliness and availability of services as well as to ensure the identification of exceptions. We outline our implementation framework with Web Services for the communications among healthcare service providers together with mobile devices for medical professionals. We demonstrate the applicability of our approach with a prototype medical house-call system (MHCS) and evaluate our approach with medical professionals and various stakeholders.

INTRODUCTION

Recent advances in Internet technologies have created a global platform for organizations and individuals to communicate with one another, carry out various commercial activities, and provide value-added services. Web Services (Chiu et al., 2003) provide loosely-coupled standard interfaces among autonomous systems within and among organizations in the form of a set of well-defined functions for both programming and human user interfaces. Web Services further support event-driven information integration for timely service provision and interactions (Chiu et al., 2004). In healthcare chain workflow management, both process integration and data integration among health service providers are vital. Besides organizations, individual practitioners (such as physicians and nurses), administrators, and patients are also involved heavily in the workflows. Tasks like medication monitoring, emergency hospitalization of patients, laboratory examination results, shipment of drugs, exchange of patient records among healthcare service providers, etc., produce large numbers of messages. That is, both process integration and data integration are necessary. Further, accurate and timely communication of such information is a key success factor for the provision of quality healthcare chain services. We refer to these urgent messages as *alerts* (Kafeza et al., 2004).

Existing practice of using cellular phones and pagers for communications is inadequate for seamless integration with existing and future healthcare information systems. In particular, healthcare applications must respond actively and timely to patients' needs as this is crucial to life or death. Most healthcare alerts have to be handled within a time period. Apart from service suitability, application specific considerations like costs, waiting time and service time may also be important. Routing, monitoring, and logging the alerts are also mandatory functionalities to shift the burden of these communications from the manual work to an automated system. To take advantage of the connected Internet environment, we extend an alert management system (AMS) for healthcare professionals (Kafeza et al., 2004) across organizational boundaries to become the key mechanism for both healthcare process and data integration with urgency support. The AMS aims to minimize delays by providing a monitoring system. This article generalizes and extends our previous work on workflow modeling (Chiu et al., 1999) and process integration (Chiu et al., 2004) in order to be applied in healthcare applications.

As compared with our previous work (Kafeza et al., 2004), the contributions of this article are the description and analysis of the following: (i) an enhanced conceptual model for specifying alerts based on the requirements of healthcare chain workflow management, which supports programmatic interfaces across organizational boundaries in additional to human users; (ii) alerts as a unified mechanism for capturing the requirements of healthcare process and data integration; (iii) a practical architecture for the AMS based on contemporary Web Services for programmatic interactions, together with multiple-platform support for human users; (iv) a practical prototype Medical House-Call System (MHCS) to demonstrate the applicability of our approach in healthcare chain workflow management.

In order to reach these objectives, we first discuss an overview of our methodology and the overview of a MHCS and compare related work. Then, we describe our system design and implementation as well as how data and process integration works in our system with a typical system walkthrough. Finally, we discuss the advantage of our alert-driven approach before concluding our article with our future work direction.

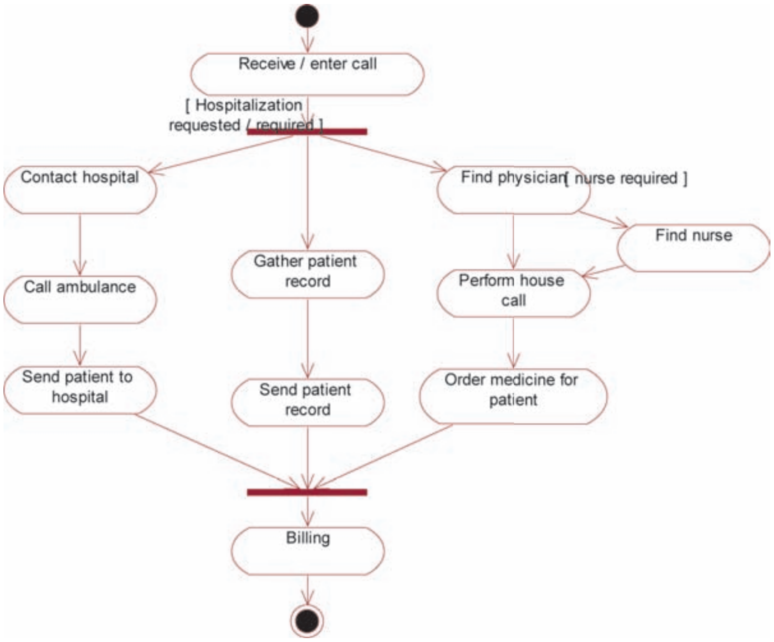
BACKGROUND AND METHODOLOGY OVERVIEW

In Hong Kong, some healthcare corporations provide "House-Call" services. Figure 1 summarizes the main workflow of a typical medical house-call center. Affiliated patients can call (either electronically or by phone) and request a physician to visit their home either immediately or at a requested time. The patients may also request to be sent to a hospital. In this case, the hospital and the ambulance call center are contacted for the delivery. A patient can specify a particular physician or let the call center find the first available physician with the required specialties (if any) from a list of off-duty physicians, then from a list of on-duty physicians, and lastly from a list of physicians from healthcare partners. A nurse may also be assigned in some cases to assist with the physicians' consultation. When the required personnel are contacted, the patient will be confirmed. At the same time, the patient's healthcare records may have to be sent from hospitals and other clinics to the physician's mobile device. After completion, the physician submits a report of the consultation together with any prescriptions. The prescriptions are routed to a pharmacy so that the medication can be delivered (by courier service) to the patient's home. Lastly, the patient or his/her insurance company is charged for the consultation.

However, the above only describes the normal and basic functional requirements. In particular, standard workflow technologies are inadequate to address the urgency and exception handling requirements. Different degrees of urgencies arise from the sickness of the patients as well as the requirements for quality services. Exception situations typically occur when services commitments cannot be fulfilled, e.g., when a physician cannot visit the patient at the specified time. Thus, we propose to augment the workflow with alerts for the modeling of these requirements and implement it with the support of an AMS.

Different from a hospital environment as we previously studied (Kafeza et al., 2004), the AMS

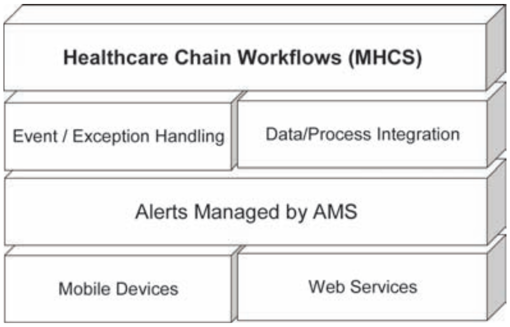
Figure 1. Main medical house-call center workflow in UML activity diagram



in this application is no longer a closed environment. It now requires a much wider coverage across the boundary of different organizations, connecting patients, their homes, medical practitioners, medical partners, and the call center. Thus, not only are communications with various personnel required, programmatic integration with partner organizations are also necessary. Further, as the relationships among different parties are partnerships rather than employee commitments, alert requests are more likely to be rejected because full personal schedules are not available.

Figure 2 summarizes the conceptual architecture of alerts extended from our previous work (Kafeza et al., 2004). The essence of alerts is to capture the urgency requirements as required by the healthcare chain workflows of the MHCS, which typically involves *synchronous* data (e.g., patient record assembly) and process (e.g., physician call) integration as well as *asynchronous* event or exception handling (e.g., physician's lateness or absence after commitment). Remarkably, exceptions are subclasses of events (Chiu et al., 1999; 2001). An *event* is a significant occurrence that affects either the system or a user application. Exceptions often, but not always, have urgency implications. Different from general events, alerts have more specific attributes, in particular, urgency (e.g., the degree of sickness of the patient) and service requirements (e.g., the specialty of the required physician). Different from exceptions, alerts need not be related to abnormal behaviors. That means, alerts can be (i) triggered *asynchronously* to handle an event or exception, or (ii) generated synchronously to satisfy the data or process requirement. Alerts received by a service provider may be *handled* by either (i) rejecting the service, (ii) its internal information systems, (iii) a human service provider through the Web or mobile devices, or (iv) requesting other external service providers in turn through Web services, where programmatic interfaces are usually required.

Figure 2. The role of alerts for healthcare chain workflows



Motivated by these extended requirements, we start off our study by gathering the objectives and requirements of the medical professionals and the medical house-call service provider. Nowadays, the progress in the medical field has resulted in the hyper-specialization of the physicians, the introduction of new and advanced types of examinations and processes, and the increasing request of the patients for better quality of medical care. At the same time, recent advances in information technology are being deployed to facilitate this new complicated healthcare environment. One of the most prominent objectives is the need for accurate, safe, and continuous communications among highly specialized medical professionals and healthcare service providers. There has been a great demand amongst the medical professionals for an alert management system that is *robust, efficient, cost effective, simple,* and *user friendly to* improve the communications.

Based on these objectives, detailed requirements were elicited and formulated into an alert conceptual model. Then we sketched an overall system architecture for the call house management system, with focus on the AMS design. We then worked out the detailed mechanisms for each component of the system. In the design, we also had to pay attention to flexibility so that alert management policies could be adapted to handle various situations for various partners. According to these designs, we built a prototype to demonstrate the functions to the medical professionals for evaluation.

As for deployment, we plan to split it into phases. The first phase is to establish a computerized call center to manage all the alerts for medical personnel, replacing the current manual system. After getting used to the new arrangements and fine tuning of the alert management policies, the second phase is to extend the system to connect to medical partners. In the third phase, we plan to include further intelligence into the system, in particular, with advanced capability reasoning (Chiu et al., 1999), scheduling with mobile location dependent information, service negotiation, and integration with traffic routing.

RELATED WORK

Raghupathi & Tan (2002) point out that new healthcare applications supporting information technology (IT) based strategies are required for meeting competitive challenges and estimated IT expenditure on healthcare in 2002 to be 21.6 billions in the United States. In particular, healthcare applications will take advantages of the technological advances in communications technologies and mobile devices (Olla & Tan, 2006). Ammenwerth et al. (2000) also report that one of the major benefits of mobile technologies is to help hospitals in communication and reachability management among the patients and the message senders as well as to address the urgency requirements. Hripcsak et al. (1996) preliminarily identify the need for event monitors and describe some of the requirements such as tracking healthcare events, looking for clinically important situations, and sending messages to the providers. Eienstadt et al. (1998) further categorize messages as *alerts, results,* and *replies*. The limitation of their approach is that they only focus on alerts that can be handled by 2-way pagers. Ride et al. (1994) argue that the problem of figuring out to whom the message should be sent is a difficult one. They only suggest some ad hoc solutions such as sending a message to whoever has recently examined the patient electronic record.

Although information integration issues are not new in database research communities (Sheth & Larson, 1990), Sheng & Chen (1990) identify that the application of workflow technologies in different hospitals has many unique properties that entail special integration design considerations. The health informatics communities (e.g., the International Medical Informatics Association, http://imia.org) have discussed the application of workflow technologies in health administrative data integration for a period of time. For example, Marsh (1998) presents a multi-model medical information system for demonstrating the virtual medical world. Takeda et al. (2000) present a system architecture for supporting networked electronic patient records. Liu et al. (2001) propose a web-based referral information system for sharing electronic patient records based on eXtended Markup Language (XML). Further, Grimson et al. (2001) propose a Synapses prototype system for supporting federated healthcare records that provides an integrated view of patient data from heterogeneous distributed information systems on the Internet. Al-Ali et al. (2006) propose a prototype system to provide real-time wireless integration of patient information system with mobile devices. However, none of these approaches can provide a seamless integration that permits the use of workflow technologies or alert mechanisms. In particular, the integration with manual access of legacy paper records through workflow management together with electronic records has not been presented as in this article.

Recently, the approach of Web-service-based information and process integration is receiving much attention. For example, McGregor (2007) suggests a framework for the design of Web service based clinical management systems to support inter- and intra-organizational patient journeys. Raghupathi & Gao (2007) explore a UML profile approach to modeling Web services in healthcare.

We have also proposed a methodology based on workflow views and Web services for this purpose (Chiu et al., 2003), where a survey of recent works on Web service composition can be found.

Concerning home-base healthcare monitoring, most of the existing studies focus on the application against long-term and critical diseases, instead of a public general healthcare service perspective. For example, Woodend et al. (2008) demonstrate the effectiveness of tele-home monitoring in patients with cardiac disease who are at high risk of readmission, based on video conferencing and phone line transmission of weight, blood pressure, and electrocardiograms. Pinna et al. (2007) also demonstrate that self-managed home tele-monitoring of both vital signs and respiration is feasible in heart failure patients, with surprisingly high compliance. Logan et al. (2007) develop and pilot-test a home blood-pressure tele-management system with Bluetooth and mobile phone technologies that actively engages patients in the process of care through blood-pressure alerts. However, a systematic approach to handling those alerts and signals collected has not been adequately studied.

Suomi and Tähkäpää (2003) study the requirements of a contact center for public healthcare with a case study in Turku, Finland and identify contact routing as the main system functionality. They also provide a good survey of call centers that run with older technologies. We proceed further to detailed system design and prototyping, with focus on urgency requirements for alert routing, employing additional mobile technologies and healthcare partner process integrations.

In the context of workflow management systems (WFMS), Chun et al. (2002) propose the automatic generation of workflows from domain knowledge. We have recently proposed to separate user alerts from user sessions to improve the system flexibility (Chiu et al., 2002) in our Mobile E-commerce Advanced Object Modeling Environment (ME-ADOME) WFMS. Online users are alerted through ICQ (I seek you) (Weverka, 2000) messages with the task summary and reply Universal Resources Locator (URL) as the message content. If the user is not online or does not reply within a pre-defined period, the WFMS will send the alert by email. At the same time, another alert may be sent via Short Message Service (SMS) to the user's mobile phone. Whatever the alert channel has been, the user may connect to WFMS on any other devices or platforms. For example, after receiving a SMS alert, the user may use his/her handset to connect to the WFMS via Wireless Application Protocol (WAP) or reply with an SMS. Alternatively, the user may find a computer with an Internet connection or use his/her personal digital assistant (PDA) to connect to the WFMS. As an extension to existing process models such as Sheng & Chen (1990), our process model abstracts information regarding roles and their schedules of service providers possessing these roles. We have employed a bottom-up data-driven methodology to extend information systems into Web Services (Chiu et al., 2004) and further incorporated alerts and their routing (Kafeza et al., 2004).

Besides healthcare applications, we have also pioneered in the application of alert management in a wide range of other application domains for process and data integration. For example, in electronic commercial applications, Lee et al. (2007) employ Web services and alerts to enhance workflow automation in insurance underwriting processes. Ng & Chiu (2006) study the feasibility of electronic government process integration with Web services and alerts through an emergency route advisory system. For industrial production, Chung et al. (2007) propose the use of an alert management system for concrete batching plants. Chiu et al. (2008) advocate alert management for ubiquitous support in distance education applications. To our knowledge, there are no other WFMS employing this approach. Further, there has been no other work on alert-driven process integration or data integration at this time.

DESIGN AND IMPLEMENTATION

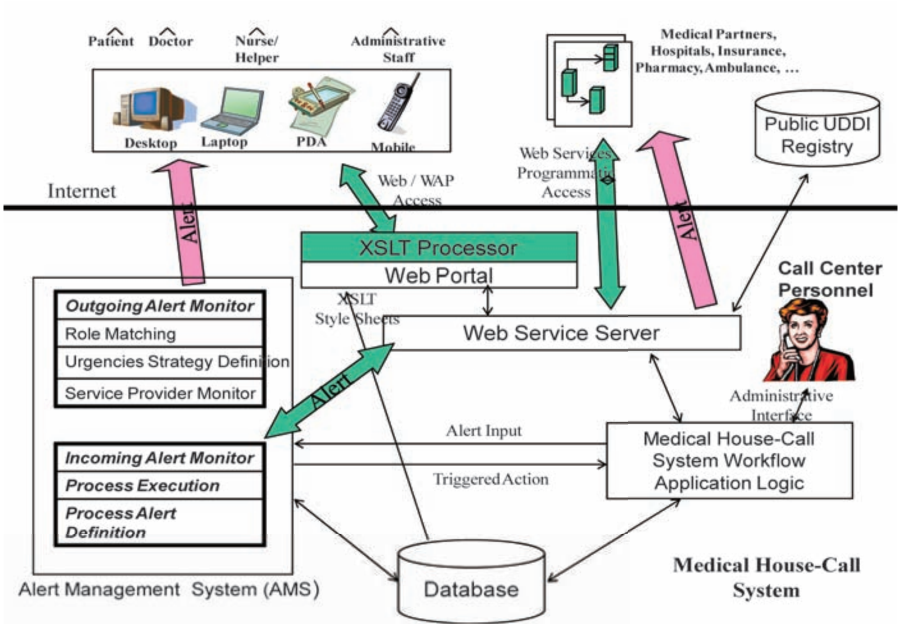
System Architecture

We have built a prototype for the MHCS on the J2EE and Oracle platforms (Price, 2000). Figure 3 depicts the overall implementation architecture of MHCS based on our previous AMS core (Kafeza et al., 2004). As the AMS manages only the alert, domain-specific application logic is required for a complete system. Upon data or process service requests, the application logic generates alerts with the necessary specifications to the AMS. Any subsequent processing that depends on the result of the external service has to wait till it finishes (as signaled by the AMS); otherwise the workflow can continue. On the other hand, the application logic is triggered by the Process Execution Module of the AMS to carry out timely appropriate actions in response to incoming alerts. In addition, the application logic supports an administrative interface for the call center personnel.

Our AMS supports an organization to be both a service provider and a requester. Each organization can use the AMS to both submit and receive alerts. The *Incoming Alert Monitor* is responsible for receiving and queuing alerts and enacting the corresponding services (processes). Incoming alerts are received as (i) invocation of a Web Service, (ii) SMS messages, or (iii) via the Web Portal. They can trigger the execution of the appropriate alert handlers in the application logic through the *Process Execution* module. In addition, the *Process and Alert Definition* module supports a tool with which users may define the tasks and their associated alerts according to their requirements.

The *Outgoing Alert Monitor* subsystem is responsible for creating and submitting the alerts by means of Web services requests to the corresponding service providers as well as monitoring their responses. As for human service providers (such as medical personnel), ICQ, SMS, and email are used instead. As such, a service provider supporting only manual record retrieval may still

Figure 3. System architecture highlighting the AMS

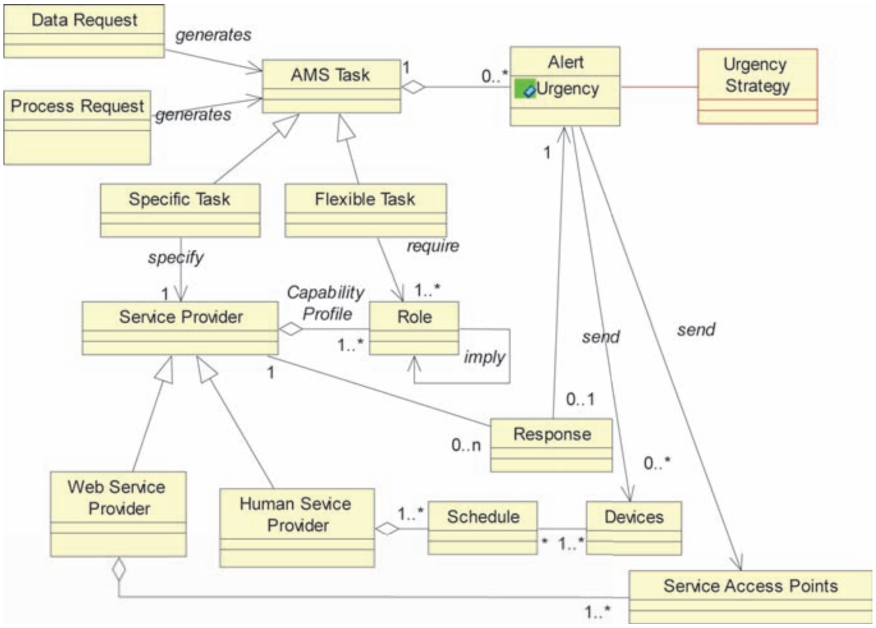


participate in data and process integration through a Web-based *alert response form*, through which a clerk can input manually the required response to an alert. The *Outgoing Alert Monitor* subsystem consists of three modules: the *Urgencies Strategy Definition*, the *Role Matching*, and the *Service Provider Monitor* modules. The *Role Matching* module is responsible for identifying the service providers to which the alert will be forwarded. The *Urgencies Strategy Definition* module specifies the policies that will be followed if the alert is not acknowledged within the deadline. The *Service Provider Monitoring* module is responsible for applying the strategies thus defined. Its functions include sending alert messages, receiving response, maintaining alert status, and logging information. For every response message received, it updates the status information of the associated alert. It tags that the alert has been "taken care of". If the alert message has been sent to several service providers, the first one to confirm is assigned to the task while the others will receive a cancellation message instead. Then for every alert in the *active alert table* with its deadline expired, the module checks the *urgency strategy table*, executes the associated action, and updates the status information accordingly.

Extended Alert Model

Figure 4 summarizes our design of a unified *alert conceptual model* in a class diagram of the Unified Modeling Language (UML) (Object Modeling Group, 2001). We have extended the notion of alerts (see our previous work (Kafeza et al., 2004) for a formal model) to include not only human users but also services with programmatic interfaces. We also include the notion of a flexible and a specific alert as explained below. Figure 5 depicts a typical life cycle of an alert with an activity diagram of the UML. All alert processing and messaging for an alert is logged ("Log alert" node) for auditing purposes. If the alert is a *specific* one (say, when a patient specifies his family doctor), there is no room for matchmaking. Otherwise, if the alert is a *flexible* one (say, when

Figure 4. UML class diagram of alerts with human and Web service support



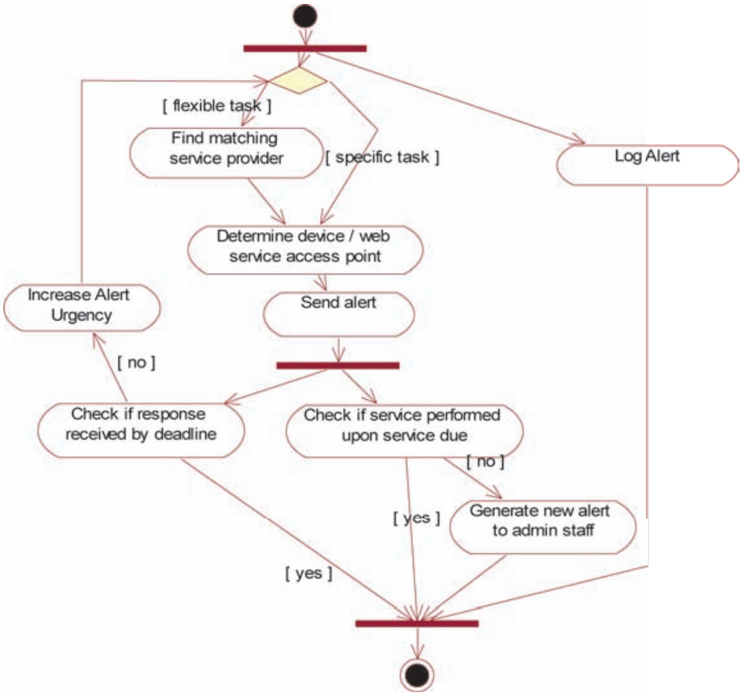
a patient just reports his sickness), a matching algorithm ("Find matching service provider" node) is invoked to search for a suitable service provider (Kafeza et al., 2004; Chiu et al., 1999). The "Determine device / Web Service access point" node determines the device for a human or the Web Service access point for a Web Services provider respectively. Then, the "Send alert" node sends the alert accordingly. If the "Check if response received by deadline" node fails, the AMS will increase the alert urgency, thereby triggering the alert message to be resent to either the same service provider or a different suitable one (as discussed in the next subsection).

The last tolerance level is guided by the "Check if service performed upon service due" node. If the service is not performed within deadline (e.g., the physician does not notify his arrival to the patient's location on time, or a patient record is not received within the deadline), then the AMS generates a new alert to the relevant administrator to notify this exception. In this way, additional manual or system assisted exception handling processes (Chiu et al., 2001) can be carried out.

Web Services Design for AMS

To facilitate cross-organization communication of alerts, we use contemporary Web Services technologies. An alert to a service partner can be requested through the Web Service *requestAlert*. In response, the service partner will send an acknowledgment to the requestor, indicating that the request is confirmed or denied, or the response will be deferred. Deferred responses can be returned through the requestor's service *receiveDeferredResponse*. The requestor may cancel the alert afterwards by calling the service *cancelAlert*. Requestors and services partners involved in an alert can check for the alert status with the service *checkAlertStatus*. In addition, service partners can check with the service *listActiveAlerts* for the list of active alerts in which they are involved. Administrative programs can also

Figure 5. Typical life cycle of an alert in UML activity diagram



use this service to check for list of active alerts associated with individual tasks. A selection of the Web Services is enlisted in Table 1.

SYSTEM WALKTHROUGH

In this section, we explain how data and process integration can be facilitated with the alert mechanism in our system with some typical scenario walkthrough.

MHCS Process Integration

Let us look at a typical scenario of the main workflow of the MHCS at the Call Center (see Figure 1), with focus on the important alerts and how various component of the system functions. A patient enters a request through the Call Center's Web portal through a personal computer or a mobile device (e.g., PDA or phone SMS message). Alternatively, the patient may phone the Call Center and the operator enters the request. The *workflow application logic* analyzes and validates the request, and then generates an alert with urgency according to the patient's condition (so that the system set various deadlines according to the administrator's urgency policy settings) and service requirements according to the sickness and the patient's preferences.

In the AMS, the *incoming alert monitor* receives the patient's alert and triggers an outgoing alert in the *outgoing alert monitor* to request a physician's service, passing the urgency and service requirements. According to our extended alert conceptual model (Figure 4 and Figure 5), the *role matching module* contacts the specific physicians (if the patient has specified them) or finds the appropriate ones by matching the specialties of the physician with the reported sickness. The *service provider monitor* can then handle all the communications with the physicians' devices, acknowledgements, retries, urgency elevation, rerouting (i.e., alternative physicians), and the monitoring of the physician's service (particularly the arrival of the patient's home) automatically. As our extended alert model supports Web Services, if all the appropriate physicians affiliated to this Call Center are not available, the alert can be re-routed to the AMS of other appropriate healthcare partners (as determined by the *role matching module*) via a Web Service. Similarly, an alert is triggered requesting a nurse's service if necessary.

If hospitalization is required, the *service provider monitor* sends an alert to call an ambulance via a Web Service of the ambulance call center, passing the destination hospital, urgency and the necessary information of the patient (particularly the address and sickness). This is now possible as our extended alert model supports Web Services. The *service provider monitor* sends another alert to contact the hospital for admission and any necessary preparation for the patient.

Table 1. Selected list of Web services for AMS communications

Service Name	Input	Response
requestAlert	AlertID, RequestorID, AlertMessage, Roles, Urgency, ResponseRequired (TRUE | FALSE), Deadline, Extra Data	AlertID, ServicePartnerID, Ack (Confirmed | Denied | Deferred), ResponseMessage, AlertReceiptTime
cancelAlert	AlertID, RequestorID	Ack (Confirmed | Denied | Deferred)
checkAlertStatus	AlertID, RequestorID	Alert Status
listActiveAlerts	(TaskID | ServicePartnerID),RequestorID	List of pending alerts associated
receiveDeferred Response	Item AlertID, ServicePartnerID, ResponseMessage, AlertReceiptTime	Ack (Confirmed, NotConfirmed)

In the case where a hospital is full or unable to admit the patient, an alternative hospital can be sought for (as determined by the *role matching module*) and the ambulance will be updated accordingly through another Web Service of the ambulance call center. Similarly, the AMS can automate an order to a pharmacy and the handling of unavailable medication by rerouting the order to an alternate source through Web Services. The *service provider monitor* can also monitor all the progress of these cross-organizational computer-to-computer interactions according to the urgency requirements of the patient.

To extend the availability of the *Web portal* for users on different platforms, eXtended Markup Language Stylesheet Language (XSL) technology is employed (Lin & Chlamtac, 2000). For example, different Hypertext Markup Language (HTML) outputs are generated for Web browsers on desktop PCs and PDAs respectively, while Wireless Markup Language (WML) outputs are generated for mobile phones. Figure 6 illustrates two sample *alert response forms* for a physician through WAP on a mobile phone and a PDA browser respectively.

The *service provider monitor* is responsible for the vital administrative function of monitoring the status of service progress and especially exceptions. Thus, the AMS generates alerts to relevant administrator(s) upon exception. For example, the administrator can monitor house-call status through a customized House-call Status Monitor page (cf. Figure 7) based on a customized view of the AMS's active alert table. Manual manipulations can be carried out through the *administrative interface* if necessary.

As such the AMS can support flexible workflow management and process integration with service partners, involving both human and programmatic interaction. With the support of an AMS, the urgency requirements associated interactions with the medical personnel and the service providers as well as the monitoring requirements of the administrators can be systematically and modularly captured into the AMS, instead of scattering around in the main workflow specification.

Healthcare Data Integration

Since we also model data requests as alerts, a healthcare data integration process ("Gather Patient Record" of Figure 5) can similarly be modeled as workflow, while individual data requests are modeled as alerts. Figure 8 depicts a sample workflow for healthcare data integration.

When the workflow application logic determines a need to gather to records of a patent, an alert is submitted to the AMS. In the AMS,

Figure 6. Sample alert acknowledgement response forms


—AMS House Call—
P: Heart deseases
L: Tsim Sha Tsui
T: 5May2003 13:30

Palm OS Simulator - [NTFull_enUS.rom]

Message 1 of 1

To: 92348374

~ AMS House Call ~

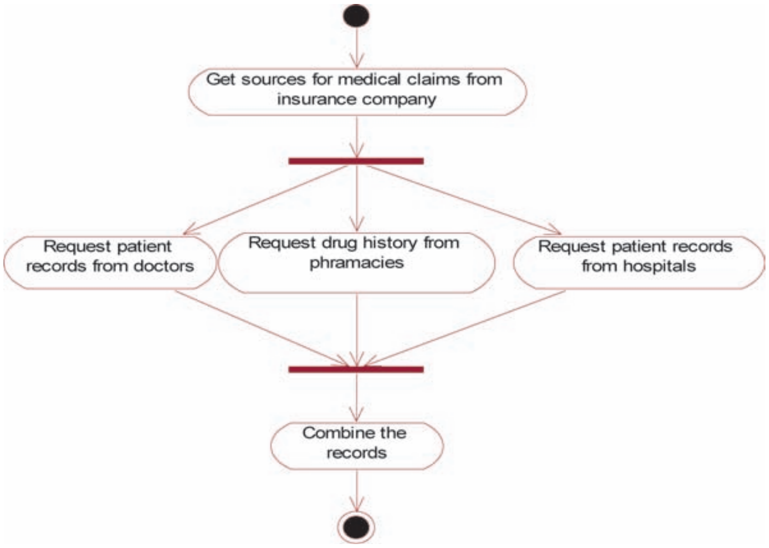
Patient: Heart deseases
Location: Tsim Sha Tsui
Time: 5May2003 13:30
Deadline: 20min

Can you take the house call (y/n) ?

Figure 7. Alerts and status monitoring

Call ID	Patient ID	Doctor	Admin Staff	Start Time	Status
HC0384	PN002993	N/A	N/A	11 May 2003 12:30	Finding Doctor, waiting for doctors' reply
HC3748	PN000392	Dr. Philip Ng	Terence Yeung	11 May 2003 10:05	On the way to local patient
HC1283	PN048737	Dr. Joanne Wong	Cindy Wong	11 May 2003 09:25	Consultation in progress
HC6483	PN009938	Dr. Steven Ip	Cindy Wong	11 May 2003 05:45	Replacement for absence of doctor
HC4588	PN006744	Dr. Amy Chan	May Cheung	11 May 2003 03:15	On the way to oversea patient
HC5448	PN005544	Dr. Gary Lee	Cindy Wong	11 May 2003 01:10	Consultation in progress, need extra help
HC2334	PN006222	Dr. Paul Yip	Gillian Chan	10 May 2003 23:55	Wait for Payment

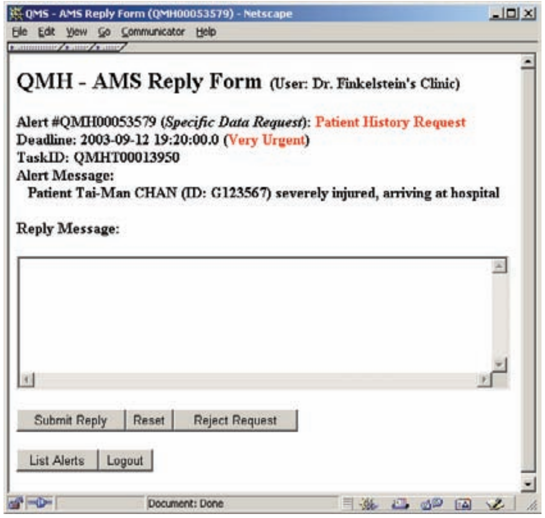
Figure 8. Sample healthcare data integration plan in UML activity diagram



the *incoming alert monitor* receives this alert and triggers an outgoing alert in the *outgoing alert monitor.* The *role matching module* finds out the destination insurance company and the *service provider monitor* sends an alert via Web Services to the insurance company to request the extraction of the list of healthcare service providers from the claim records of the patient. Based on the response, further alerts are sent to each of these healthcare providers again via their respective Web Services to request the relevant patient records. Urgency requirements apply as the physician needs the information by his arrival to the patient's home, while the hospital needs the information by the arrival of the patient. As such, the AMS not only caters for the interactions but also the urgency requirements for data integration.

In case some of these data sources can only support manual procedures, they can still participate in this process as our architecture provides web-based alert response forms (cf. Figure 9). Moreover, humans may be involved as approval may be required for accessing patient records. In this case, though some requests may be rejected or some of them cannot meet the deadline, at least

Figure 9. Sample data request alert response form



QMH - AMS Reply Form (User: Dr. Finkelstein's Clinic)

Alert #QMH00053579 (*Specific Data Request*): Patient History Request
Deadline: 2003-09-12 19:20:00.0 (Very Urgent)
TaskID: QMHT00013950
Alert Message:
Patient Tai-Man CHAN (ID: G123567) severely injured, arriving at hospital

Reply Message:

the data integration process can be speeded up as much as possible.

Handling Urgency and Service Provider Matching

Let us further look at how urgencies are handled by the *outgoing alert monitor* of the AMS. The *role matching module* is responsible for searching a service provider for each alert. The service provider matching algorithm searches for those service providers that can play the role required for the alert. The algorithm then selects those that have a response time that is less than the deadline. This further restricts the set of service providers that can receive the alert. If the matching is successful, one service provider is selected according to a user-supplied cost function (see Kafeza et al., 2004 for further details). In this application, the cost function can be based on the time required for service, distance to be traveled, charges of the service provider, etc. In case no matching is available (i.e., there exists no service provider with the requested role that can meet the deadline), the algorithm upgrades the alert by expanding the roles whenever possible (e.g., request a specialist instead of a general practitioner). After the matching, an *active alerts table* keeps all instantiated alerts and whether the alert has been acknowledged or not.

If an alert is resent, the service provider matching algorithm will take into account of the urgency strategy definition. The urgency strategy definition module is a tool for defining the policies according to which the urgencies of the alert will evolve. Moreover, this module is responsible for keeping and updating status information for the alerts. In our alert model, every alert is associated with an urgency value and a deadline, while every service provider is associated with an average response time for every service that it provides. During the specification phase, the administrator has to specify the *urgency strategy tables*. An *urgency strategy table* defines the policies for every urgency increase and the additional actions that should be taken. The administrator may define different urgency strategy tables for different types of alerts. For example, we could define the urgency values from the ordered set {Low, Normal, Urgent, Very Urgent, Critical, Very Critical} and a default *urgency function* as shown in Box 1.

Box 1.

$$U002(t) = \begin{cases} \text{Urgent} & t \le \mathrm{T} \text{ (default)} \\ \text{Very Urgent} & \mathrm{T} < t \le \mathrm{T} + \mathrm{dt}_1 \\ \text{Critical} & \mathrm{T} + \mathrm{dt}_1 < t \le \mathrm{T} + \mathrm{dt}_1 + \mathrm{dt}_2 \\ \text{Very Critical} & \mathrm{T} + \mathrm{dt}_1 + \mathrm{dt}_2 < t \le \mathrm{T} + \mathrm{dt}_1 + \mathrm{dt}_2 + \mathrm{dt}_3 \end{cases}$$

Table 2. Example urgency strategy table

Urgency002	*Action*
Urgent	default – send a message to the chosen physician
Very Urgent	Submit a second alert to the same physician, notifying about the approaching deadline
Critical	Redirect the alert to another SP that has the best response time
Very Critical	Send the alert to several SPs and accept the results of the one that response first, notify an administrator

Table 2 shows an example urgency strategy table. Here, let us consider the association of an alert with this table. Assume the alert is sent to the chosen physician at the default level *Urgent*. In case there is no response, the *service provider monitor* increases the priority to *Very Urgent* and creates another alert message to notify the physician about the eminent deadline. If still there is no response, the *service provider monitor* increases the priority to *critical* and the *role matching module* tries another find another physician with the same roles and the best response time. If this step also fails, the *service provider monitor* further increases the priority to *Very Critical*, where all available physicians with requested roles will receive the broadcast alert, while an administrator is notified.

APPLICABILITY DISCUSSIONS

Based on the prototype and system descriptions, we have discussed with the major system stakeholders, including medical professionals, patients, and the call center. We explain the significance of the alert mechanism in the MHCS and how various contemporary technologies help.

The main motivation of the MHCS is to solve the existing problems involved in the costly manual procedures required for the provision of quality services to patients effectively and efficiently. There is a strong need for automating the workflow because the processes involved are often urgent and error-prone and there are many possible exception cases, such as, failure of finding suitable personnel, absence and lateness of the personnel, etc. The root of such problems originates from the variety of parties and personnel to liaise with. Once committed to service a call, the call center has to satisfy their information need (in particular electronic patient records), together with the required process support. The AMS help select and communicate with the correct personnel or service partners through their available channel at the correct location with the correct information through the alert mechanisms as detailed in this article. In particular, the AMS automates such communications via various electronic channels as well as attempts alternate service providers (medical personnel via various mobile platforms and different service partners via Web service) in order to minimize the delay and costs involved in inefficient manual calls and retry calls. The AMS further keeps track of such alerts and therefore monitors the call center workflow processes, in order to make sure that the required services are provided on time, meeting the urgency requirements. Thus, the MHCS captures the knowledge and experiences of the call center staff and help them handle the patients' calls correctly and timely.

In particular, the patients' care outcome is the primary concern. With such improvements of the call center, timely and reliable house-call service from healthcare professionals of the required specialties can thus be streamlined. Further, when there are suddenly too many calls, phones may not be able to get through. This is not only frustrating but may also cause addition risks to the patients' health. With multi-channel access to the MHCS, patients can either enter their request through the Web via different (mobile) devices or with a traditional phone call to the call center. Patients with long-term sickness can also call via pre-programmed devices with a simple interface (such as just an electronic button).

Accurate, complete, and timely information routing also helps the care outcome. The MHCS also provides such a paperless distributed environment that minimized human intervention and therefore improves the accuracy and timeliness. We have explained in the previous section how patient records can be routed directly to the patients' house and to the physician in charge of the call via Web services through the alert mechanism. The details of a call (such as the location, patient's symptom, and equipment required) can also reach the physician accurately. Similarly, prescriptions can be routed to pharmacies automatically. In addition, we have explained how such automation and the possible governance provided through the MHCS help reinforce privacy and security.

With our approach, all the data accesses are performed through alerts. The AMS can therefore assure that only the necessary personnel are involved in the process because the matchmaking mechanism in the AMS (Kafeza et al., 2004) verifies the roles of the service providers for the alerts. Further, the scattered patient records can be sent *directly* to the patient's home personal computer or to the physician in charge of the current house-call with this platform. Thus, the privacy of patients can be protected. Further, because all such data access is recorded via the alert mechanism, auditing can be easily performed against possible misuse.

In non-urgent cases, the Web-based system offers new functions. Patients or their family members may search or browse for their desired physicians and hospitals. The MHCS may further help find appropriate hospitals or the clinics that meets the budget from the patients' insurance coverage. The MHCS can schedule examinations within the time duration as well as reduce waiting time in general.

For medical professionals, the MHCS also helps them in their time and schedule management anywhere anytime and helps them communicate with many other parties (such as the call center, hospitals, their own clinic, etc.) for support. In particular, the introduction of the AMS mechanism offers four important advantages. (1) It will make sure that an alert can reach the person who has to be notified. (2) The inclusion of multiple mobile devices and platforms helps both the medical professions and the patients. (3) The implementation of an urgency policy that uses concurrently multiple devices to communicate the alert can increase the probability to inform the person on time. (4) An automated alert can make sure that the information is passed accurately and completely. (5) The AMS allows the choice of received information, reception devices, and desired time slots.

As for adoption, a major problem in migration to the new system is that partner service providers may not be supporting Web Services or even computerization for some tasks. As our system architecture supports humans to be alerted, either the call center staff or personnel of the service provider can help enter information into the system through the interactive web-based *alert response forms* (cf. Figure 9). The worst scenario is that a call center staff is alerted to carry out manual work (e.g., calling a hospital through a phone to notify a patients' arrival) and record the deed through an alert response form.

As organizations are moving towards service-oriented models, service providers currently do not consider such computerization will eventually need to do so in order to enhance their competitiveness. In addition, they will eventually realize the value of such systems. Moreover, the proposed external Web Services interfaces are not complicated at all and can be easily programmed for alert reception and delivery. Moreover, such an AMS is light-weight, highly coherent, and loosely coupled with other sub-systems, enabling it to be plugged into any information system that needs such services. Besides routing alerts to external service providers, the AMS can also route alerts to other AMS within a large organization, such as a hospital. They are orchestrated by Web Services technology to work together seamlessly in the organization and even cross organization boundaries to partner service providers. This architecture is highly scalable and interoperable. Various healthcare partners operating call centers and therefore having similar objectives can therefore effectively form alliances for better services. As such, upgraded systems can provide alert support through an AMS gradually for adequate testing and streamlining the switch-over, which may otherwise be impossible involving a large number of service providers in a *service grid* (Gentzsch, 2002).

CONCLUSION AND FUTURE WORK

In this article, we have combined techniques from the different disciplines of computer science, marketing, and healthcare information systems to address a critical clinical service-based need as well as urgent policy-making challenge on the management of alerts. We have analyzed the requirements and proposed the conveying of alerts to the right service provider at the right time using Web Services and mobile devices, for service provision under urgency constraint. We have introduced a framework of an alert management system (AMS) supporting both human and Web Services providers. This framework supports a flexible alert conceptual model that allows users to specify tasks, alerts, roles, and their inter-relations. We further illustrate how alerts can capture requirements for both data integration and process integration requests. We have also presented our AMS architecture with an implementation outline based on Web Services and mobile technologies with the alert monitoring and routing mechanisms involved. We have demonstrated and discussed the applicability of the AMS in healthcare chain workflow management with a Medical House-call System, supporting both healthcare data and process integration. Because it is hard to promote radical changes to public healthcare services, our MHCS also serves as a pilot showcase for further deployment of AMS.

The main remarkable contribution of the AMS is that process and data integration requests to human service providers (including the physicians and nurses) as well as Web Service providers (such as contacting the hospital, ordering medicine for the patient from a pharmacy) can be uniformly modeled as alerts in this application framework and architecture. The logic for sending, routing, and monitoring these alerts is supported in the AMS and can be heavily reused. Thus application development can be much structured and streamlined.

In addition, because an AMS targets for urgent, asynchronous, unstructured, or even ad-hoc tasks (such as exception handling), it is complimentary to conventional workflow management systems (WFMS) that target at regular synchronous workflows. In fact, the motivation of AMS evolves from the exception handling and user-interface mechanisms of our ME-ADOME WFMS (Chiu et al., 2002), by factoring out and extending, in particular, urgency requirements. The physical execution of individual tasks of regular processes is outside the scope of the AMS and is captured in the application logic of individual information systems (as illustrated in Figure 3), which can be WFMSs as well.

To further evaluate our approach and the system prototype, we are scheduling life trials. In order to evaluate the performance of the system, we compare the service time to the existing practice. We also compare whether the costs are reduced for the patients. Using questionnaires, we also evaluate the patients' satisfaction with respect to the existing policies. We are also planning simulations for scalability and robustness as our future work.

We are incorporating the AMS under our ME-ADOME WMFS (Chiu et al., 2002), aiming to strengthen the support for alerts for general workflow and E-service management. We are also investigating in inter-relations among alerts. In particular, we are looking into alerts due to failure of commitments (Chiu et al., 2004b) and their relation to contract enforcement. We are also interested in further issues of collaborative workforce management, especially managing the diary of healthcare personnel with agents (Chiu et al., 2003). We are also interested in the impact of cancellations, other possible exceptions, tradeoff between quality and cost, and service negotiation (Chiu et al., 2004b). We are investigating in further legal, ethnical, security, and privacy requirements involved in cross-organizational patient record integration. The use of Semantic Web technologies for service composition (Wang & Cheung, 2004) and matching (Xu et al., 2004, Chiu et al., 1999) is also one of our theoretic research directions when we expand from a close system of medical partners to an open service grid in the future.

ACKNOWLEDGMENT

This work was supported by the Hong Kong Research Grant Council with an Earmarked Research Grant (HKUST 6170/03E).

REFERENCES

Al-Ali, A. R., Ozkul, T., & Landolsi, T. (2006). "A Preliminary Study toward Wireless Integration of Patient Information System," International Journal of Healthcare Information Systems and Informatics, 1(4), 1-14.

Ammenwerth, E., Buchauer, A., Bludau, B., & Haux, R. (2000). "Mobile information and communication tools in the hospital," International Journal of Medical Informatics, 57 (1), 21-40.

Chiu, D.K.W. Cheung, S.C., & Kafeza, E. (2002). "Three-tier View-based Support for Mobile Workflow," In Proceedings of the 1st International. Conference on Mobile Business, CDROM, Athens, Greece.

Chiu, D.K.W., Cheung, S.C., Kafeza, E., & Leung, H.-f. (2003). "A Three-Tier View Methodology for adapting M-services," IEEE Transactions on System, Man and Cybernettics, Part A, 33(6), 725-741.

Chiu, D.K.W., Cheung, S.C., Karlapalem, K., Li, Q., Till, S., & Kafeza, E. (2004). "Workflow View Driven Cross-Organizational Interoperability in a Web Service Environment," Information Technology and Management, 5(3-4), 221-250.

Chiu, D.K.W., Cheung, S.C., Hung, P.C.K., & Leung, H.-f. (2004b). "Constrained Based Negotiation in a Multi-agent Information System with Multiple Platform Support," In Proceedings of the 37th Hawaiian Conference on System Sciences, Big Island, Hawaii, USA, CDROM, 10 pages.

Chiu, D.K.W., Cheung, S.C., & Till, S. (2003) "An Architecture for E-Contract Enforcement in an E-service Environment," In Proceedings of the 36th Hawaiian Conference on System Sciences, Big Island, Hawaii, USA, CDROM, 10 pages.

Chiu, D.K.W., Choi, S.P.M., Wang, M., Kafeza, E. (2008) "Towards Ubiquitous Communication Support for Distance Education with Alert Management," Educational Technology & Society, 11(2), 2008.

Chiu, D.K.W., Kwok, B., Wong, R., Kafeza, E., Cheung, S.C., & Kafeza, M. (2004c). "Alert Driven Healthcare Process and Data Integration," In Proceedings of the 37th Hawaiian Conference on System Sciences, Big Island, Hawaii, USA, CDROM, 10 pages.

Chiu, D.K.W., Li, Q., & Karlapalem, K. (1999). "A Meta Modeling Approach for Workflow Management System Supporting Exception Handling," *Information Systems*, *24*(2), 159-184.

Chiu, D.K.W., Li, Q. & Karlapalem, K. (2001). "Web Interface-Driven Cooperative Exception Handling in ADOME Workflow Management System," Information Systems, 26(2), 93-120.

Chun, S. A., Atluri, V., & Adam, N. R. (2002). "Domain Knowledge-based Automatic Workflow Generation," In Proceedings of the 13th International. Conference on Database and Expert Systems Applications (DEXA 2002), Aix en Provence, France, 81-92.

Chung, J.C.S., Chiu, D.K.W., & Kafeza, E. (2007). "An Alert Management System for Concrete Batching Plant," In Proceeding of the 12th International Conference on Emerging Technologies and Factory Automation, Patras, Greece, 591-598.

Eisenstadt, S., Wagner, M., Hogan, W., Pankaskie, M., Tsui, F-C, & Wilbright, W. (1998). "Mobile workers in healthcare and their information needs: are 2-way pagers the answer?" In Proceedings of the AMIA Annual Fall Symposium, 135-139.

Fano, A., & Gershman, A. (2002). "The Future of Business Services in the age of Ubiquitous Computing," Communications of the ACM, 45(12):83-87.

Gentzsch. W. (2002). "Grid computing: a new technology for the advanced web," In Proceedings of the NATO Advanced Research Workshop on Advanced Environments, Tools, and Applications for Cluster Computing, Springer, LNCS2326, 1-15

Grimson, J., Stephens, G., Jung, B., Grimson, W., Berry, D., & Pardon, S. (2001). "Sharing healthcare records over the internet," IEEE Internet Computing, 5(3), 49-58.

Haimowitz, I., Farley, J., Fields, G..S., Stillman, J., & Vivier, B. (1996). "Temporal Reasoning for automated workflow in Health Care Enterprises," In Electronic Commerce: Current Reasearch Issues and Applications, Springer, LNCS 1028, 87-113.

Hripcsak, G.. Clayton, P., Jenders, R.A., Cimino, J.J., & Johnson, S.B. (1996). "Design of a Clinical Event Monitor," Computers and Biomedical Research, 29, 194-221.

Kafeza, E., Chiu, D.K.W., Cheung, S.C., & Kafeza, M. (2004). "Alerts in Mobile Healthcare Applications: Requirements and Pilot Study," IEEE Transactions on Information Technology for Biomedicine, 8(2), 173-181.

Lee, R.C.M., Mark, K.P., & Chiu, D.K.W. (2007). "Enhancing Workflow Automation in Insurance Underwriting Processes with Web Services and Alerts," In Proceedings of the 40th Hawaii International Conference on System Sciences, Big Island, Hawaii, CDROM, 10 pages.

Lin, Y.-B., & Chlamtac, I. (2000). Wireless and Mobile Network Architectures. John Wiley & Sons.

Liu, C. T., Long, A. G., Li, Y. C., Tsai, K. C., & Kuo, H. S. (2001). "Sharing patient care records over the World Wide Web," International Journal of Medical Informatics, 61(2-3), 189-205.

Logan, A. G., McIsaac, W. J., Tisler, A., Irvine, M. J., Saunders, A., Dunai, A., Rizo, C. A. Denice, Feig, S., Hamill, M., Trudel, M., & Cafazzo, J. A. (2007). "Mobile Phone-Based Remote Patient Monitoring System for Management of Hypertension in Diabetic Patients," American Journal of Hypertension, 20(9), 942-948.

Marsh, A. (1998). "The Creation of a global telemedical information society," International Journal of Medical Informatics, 49(2), 173-193.

McGregor, C. (2007). "A Framework for the Design of Web Service Based Clinical Management Systems to Support Inter and Intra Organizational Patient Journeys," International Journal of Healthcare Information Systems and Informatics, 2(2), 21-35.

Ng, C.W.W., & Chiu, D.K.W. (2006). e-Government Integration with Web Services and Alerts: A Case Study on an Emergency Route Advisory System in Hong Kong, In Proceedings of the 39th Hawaii International Conference on System Sciences, Hawaii, CDROM, 10 pages.

Olla, P. & Tan, J. (2006). "An Organizing Framework for Conceptualizing Mobile Health Systems," International Journal of Healthcare Information Systems and Informatics, 1(2), 1-19.

Pinna, G. D., Maestri, R., Andrews, D., Witkowski, T., Capomolla, S., Scanferlato, J. L., Gobbi, E., Ferrari, M., Ponikowski, P., Sleight, P., Mortara, A., & Johnson, P. (2007) "Home telemonitoring of vital signs and cardiorespiratory signals in heart failure patients: System architecture and feasibility of the HHH model," International Journal of Cardiology, 120(2), 371-379.

Price, J. (2002). Oracle 9i JDBC Programming, McGraw-Hill Osborne.

Ride, D.M., Safran, C., Philips, R.S., Wang, Q., Calkins, D.R., Delbanco, T.L., Bleich, H.L., &, Slack, W.V. (1994). "Effect of Computer Based Alerts on the Treatment and Outcomes of Hospitalized Patients," Archives of Internal Medicine, 154, 1511-1517.

Raghupathi, W., & Gao, W. (2007). "Exploring a UML Profile Approach to Modeling Web Services in Healthcare," International Journal of Healthcare Information Systems and Informatics, 2(2), 36-25.

Raghupathi, W., & Tan, J. (2002). "Strategic IT Applications in health care," Communications of the ACM, 45(12), 56-61.

Sheng, O. R. L., & Chen, G. H. M. (1990). "Information Management in Hospitals: An Integrating Approach," In Proceedings of Annual Phoenix Conference, 296-303.

Sheth, A., & Larson, J. (1990). "Federated database systems," ACM Computing Surveys, 22(3), 183-236.

Takeda, H., Matsumura, Y., Kuwata, S., Nakano, H., Sakamoto, N., & Yamamoto, R. (2000). "Architecture for networked electronic patient record systems," International Journal of Medical Informatics, 60(2), 161-167.

Suomi, R., & Tähkäpää, J. (2003). "Establishing a Contact Centre for Public Health Care," In Proceedings of the 36th Hawaiian Conference on System Sciences, Big Island, Hawaii, USA, CDROM, 10 pages.

Weverka, P. (2001) Mastering ICQ: The Official Guide. IDG Books. ICQ Press.

Wang, X., & Cheung, S.C. (2004). "Grammar Based Interface Processing in Web Service Composition," In *Proceedings of the International Workshop on Conceptual Model-directed Web Information Integration and Mining (CoMWIM 2004)*, Shanghai, LNCS 3289, 323-334.

Woodend, A. K., Sherrard, H., Fraser, M., Stuewe, L., Cheung, T., & Struthers, C. (2008). "Telehome monitoring in patients with cardiac disease who are at high risk of readmission," Heart & Lung: The Journal of Acute and Critical Care, 37(1), 36-45.

Xu, C., Cheung, S.C., & Xiao, X. (2004). "Semantic Interpretation and Matching of Web Services," in *Proceedings of the 23rd International Conference on Conceptual Modeling (ER 2004)*, Shanghai, LNCS 3288, 542-554.

This work was previously published in the International Journal of Healthcare Information Systems and Informatics, Vol. 4, Issue 2, edited by J. Tan, pp. 36-56, copyright 2009 by IGI Publishing (an imprint of IGI Global).

Chapter 2.16

Building a Health Care Multi-Agent Simulation System with Role-Based Modeling

Xiaoqin Zhang
University of Massachusetts Dartmouth, USA

Haiping Xu
University of Massachusetts Dartmouth, USA

Bhavesh Shrestha
University of Massachusetts Dartmouth, USA

ABSTRACT

Multi-Agent System (MAS) is a suitable programming paradigm for simulating and modeling health care systems and applications, where resources, data, control and services are widely distributed. We have developed a multi-agent software prototype to simulate the activities and roles inside a health care system. The prototype is developed using a framework called Role-based Agent Development Environment (RADE). In this chapter, the authors present an integrated approach for modeling, designing and implementing a multi-agent health care simulation system using RADE. They describe the definition of role classes and agent classes, as well as the automatic agent generation process. The authors illustrate the coordination problem and present a rule-based coordination approach. In the end, they present a runtime scenario of this health care simulation system, which demonstrates that dynamic task allocation can be achieved through the creation of role instances and the mapping from role instances to agents. This scenario also explains how agents coordinate their activities given their local constraints and interdependence among distributed tasks.

INTRODUCTION

Multi-Agent System (MAS) is a suitable programming paradigm for simulating and modeling health care systems and applications, where resources, data, control and services are widely distributed. We have developed multi-agent software to simulate the activities and roles inside a health care system. Such software can be used to assist the collaborative scheduling of complex tasks that involve multiple personals and resources. In addition, it can be used

DOI: 10.4018/978-1-60566-772-0.ch006

to study the efficiency of the health care system and the influence of different policies.

However, the application of multi-agent system has been limited by the difficulty of developing agent-based systems, and considerable amount of time and highly experienced programmers are required to develop a multi-agent system. After such system is built, it is also difficult to test and maintain the system because of its complexity. The reusability of such system is low; it is unlikely to use an existing system for another application domain with little or minor change. In this chapter, we will describe a role-based approach to building multi-agent systems for health care simulation and modeling. With this approach, we are able to separate the concern on domain knowledge and the concern on intelligent problem-solving capabilities. In this approach, conceptual roles, such as physicians, nurses and patients are defined with the domain related knowledge including goals, permissions, organizational relationship, and interaction protocols, etc; where an agent is a concrete entity equipped with motivations, resources and problem-solving capabilities, which can be used to represent a real person in a health care system. Each agent can be configured based on different specifications according to the real person's situation and needs. Then the agent instance is dynamically generated for the real person who enters the system.

In this chapter, we will also describe an automated agent generation process, which utilizes the existing tools and mechanisms as much as possible. We propose to create agents using a drag-and-drop mechanism where the user can select components to plug into the agent depending on application requirements. We adopt a utility-driven agent architecture with quantitative reasoning capabilities. Besides the logical reasoning on the matching of motivations and the conflicts among different roles, we adapt a quantitative model of motivation named MQ (motivation quantities) framework. Based on the MQ framework, an agent can perform a quantitative reasoning on how important a role instance is, given its preference, its utility function and its current achievement. In the definition of a role, we introduce a formal language called RTÆMS (Role-based Task Analyzing, Environment Modeling, and Simulation) to represent the domain knowledge about how to achieve a goal. RTÆMS language is a hierarchical task network representation language with task interrelationships and quantitative descriptions of different alternatives to achieve a goal. The domain expert can specify how a complicated health service task should be performed with the collaboration of multiple roles inside the system. Each agent is also equipped with the capability for planning, scheduling and cooperation; hence, an agent can schedule its local activities with the consideration of the constraints from other agents. Meanwhile, a user of the system can choose different collaboration rules according to the organizational rules and the specific needs in the system.

In the rest of this chapter, we first discuss related work in several research areas. Afterwards, we describe how to construct a health care simulation system using the approach described above, and show how to define roles and their interrelationships, and how to define agent classes. Then, we present an automatic agent generation tool as well as a rule-based coordination approach. Finally, we use a runtime scenario to demonstrate how new role instances are created, how agents are taking new roles, planning and scheduling their tasks, and collaborating with each other to achieve a complex goal.

BACKGROUND

Researchers have studied a number of approaches for defining and developing autonomous agents and multi-agent system from different directions. Here we discuss related research work in four areas: agent development framework, role-based modeling of agent-based systems, specification of coordination rules, and model-driven development of multi-agent systems.

Agent Development Framework

DECAF (Graham, Decker & Mersic, 2003) and JADE (Bellifemine et. al, 2003) are examples of the frameworks that can be used to generate domain specific agents. DECAF (Distributed, Environment-Centered Agent Framework) developed in University of Delaware, is a toolkit to build multi-agent systems. The toolkit provides a stable platform to design, rapidly develop, and execute intelligent agents to achieve solutions in complex software systems. DECAF provides the necessary architectural services of an intelligent agent: communication, planning, scheduling, execution monitoring, coordination, and eventually learning and self-diagnosis. Plan editor is a GUI that provides the interface for control or programming of DECAF agents. In the Plan editor, executable actions are treated as basic building blocks, which can be chained together to achieve a larger and more complex goal in the style of a hierarchical task network. This provides a software component-style programming interface with desirable properties such as component reuse and some design-time error-checking. The chaining of activities can involve traditional looping and if-then-else constructs. This part of DECAF is an extension of the RETSINA (Williamson, Decker & Sycara, 1996) and TÆMS (Decker, 1996). task structure frameworks. Each action of an agent can also have a performance profile, which is used and updated internally by DECAF to provide real-time local scheduling services.

JADE (Java Agent Development Framework) (Bellifemine et. al, 2003) is a software framework fully implemented in Java language distributed by Telecom Italia. It simplifies the implementation of multi-agent systems through a middleware that complies with the FIPA specifications. The agent platform can be distributed across machines and the configuration can be controlled via a remote GUI. The configuration can be changed at runtime by moving agents from one machine to another, when required. The communication architecture offers flexible and efficient messaging, where JADE creates and manages a queue of incoming ACL messages, private to each agent; agents can access their queue via a combination of several modes: blocking, polling, timeout and pattern matching. JADE implements a full FIPA communication model, and its components have been clearly distinct and fully integrated: interaction protocols, envelope, ACL, content languages, encoding schemes, ontology, and finally, transport protocols. Most of the interaction protocols defined by FIPA are available and can be instantiated after defining the application-dependent behaviour of each state of the protocol. Agent management ontology has been implemented, as well as the support for user-defined content languages and ontology that can be implemented, registered with agents, and automatically used by the framework. JADE has also been integrated with JESS, a Java shell of CLIPS, in order to exploit its reasoning capabilities.

The goals of both these frameworks are to develop a modular platform to allow for rapid development of third-party domain agents, and provide a means to quickly develop complete multi-agent solutions using combinations of domain-specific agents and standard middle-agents. These frameworks specify agents in terms of roles they play, and assume that agents do not change their roles at run time. In contrast, we implemented an automated agent generation mechanism using the RADE framework. Using this framework, we can separate the domain knowledge and the intelligent problem solving capabilities. So an agent can be created with intelligent capabilities and motivations, and can take up different roles dynamically.

Role-Based Modeling

The related work in the second area is to propose role-based methodology for developing multi-agent systems. Approaches like Gaia (Wooldridge, Jenning, & Kinny, 2000; Zambonelli, Jennings & Wooldridge, 2003) and MaSE (DeLoach, Wood, & Sparkman, 2001) can be used to model multi-agent system societies in terms of organizations or groups composed of a collection of roles related to one another and participating in patterns of interactions with other roles. The agents are then specified in terms of a set of roles they play. These approaches explicitly assume that the inter-agent relationships and the abilities of agents do not change at run-time and that all the agents are explicitly designed to cooperatively achieve common goals.

The Gaia methodology can be used to model both the macro aspect and the micro aspect of a multi-agent system. It covers the analysis phase and the design phase. In the analysis phase, the role model and interaction model are constructed. Based on the analysis models, in the design phase, three models, the agent model, service model and acquaintance model are constructed during the initial design of the system, and then are refined during the detailed design phase using conventional object-oriented methodology. The later version of Gaia (Zambonelli, Jennings & Wooldridge, 2003) extends the former one in order to better suit to open multi-agent systems by introducing two new abstractions: (1) organizational rules (explicit identification of relationships and constraints between roles and protocols), and (2) organizational structures (explicit specification of organizations in terms of their topology and control regime).

The MaSE methodology is a specialization of more traditional software engineering methodologies (DeLoach, Wood, & Sparkman, 2001). During the analysis phase of the MaSE methodology, a set of roles are produced, which describes entities that perform some function within the system. In MaSE, each role is responsible for achieving or helping to achieve specific system goals and sub-goals. During the design phase, agent classes are created according to the roles defined in the analysis phase.

In our approach, the components of role instances and agent instances are loosely coupled, where agents can take or release role instances at runtime without knowing the internal structure of role instances. Thus, role classes and agent classes can be designed and implemented independently.

Coordination Rules

The related work in the third area is definition of coordination rules. Projects such as AgenTalk (Kuwabara, Ishida, & Osato, 1995) use scripts and finite state machine to define coordination rules. AgenTalk is a language for describing coordination protocols for multi-agent systems co-developed by NTT Communication Science Laboratories and Ishida Laboratory, Department of Information Science, Kyoto University. It provides an explicit state representation of a protocol, and a finite state machine that allows variables to be used as a basis to describe coordination protocols, called a script. Using this model, states of a protocol are explicitly defined, and actions of an agent can be defined for each state. Protocols can be defined incrementally by extending existing scripts. It provides a programming interface that specifies the portion of a state transition rule that needs to be customized for each agent. The AgenTalk has been implemented in Common Lisp.

In ROPE project (Becht et. al., 1999), cooperation process is built as a separated component from the concrete agents; the ROPE engine provides execution of the cooperation process, which is described as a high-level Petri net class. However, the implementation of ROPE engine is based on shared memory, which is not always feasible for agents that are widely distributed on different machines. Additionally, the cooperation process in ROPE is based on token and transition firing, which is not feasible enough to support more proactive cooperation and collaboration, i.e. agents are able to consider the cooperation and coordination needs when they are planning their own activities.

A set of domain-independent general collaboration mechanisms, Generalized Partial Global Planning (GPGP) (Lesser, et. al. 2004), based on TÆMS language (Decker, 1996) has been developed. We have reused some of GPGP similar mechanisms in RADE (Zhang & Xu, 2006) framework based on RTÆMS language. In framework such as AgenTalk, the emphasis is on the flow of messages and how the dialog between agents is structured. Such framework combines finite state machines with enhancements. In contrast, GPGP focuses on a domain independent and quantitative evaluation of the interactions among tasks and the dynamic formation of temporal constraints to resolve and to exploit these interactions. Our implementation gives a user the freedom to choose the appropriate coordination rule according to the application domain.

Model-Driven Development

Previous work on model-driven development of multi-agent systems can be summarized as follows. Gracanina, Boher and Hincey proposed a model-driven architecture framework as an extension to Cognitive Agent Architecture (COUGAAR) (Gracanin, Bohner & Hinchey, 2004). The Cognitive Agent Architecture is a distributed agent architecture that has been developed primarily for very large-scale, distributed applications that are characterized by hierarchical task decompositions, and as such, it is well suited for autonomic systems. The framework consists of two main parts, General COUGAAR Application Model (GCAM) and General Domain Application Model (GDAM). The GCAM provides representation in its model of the COUGAAR basic constructs, and the GDAM defines the requirements and the detailed design.

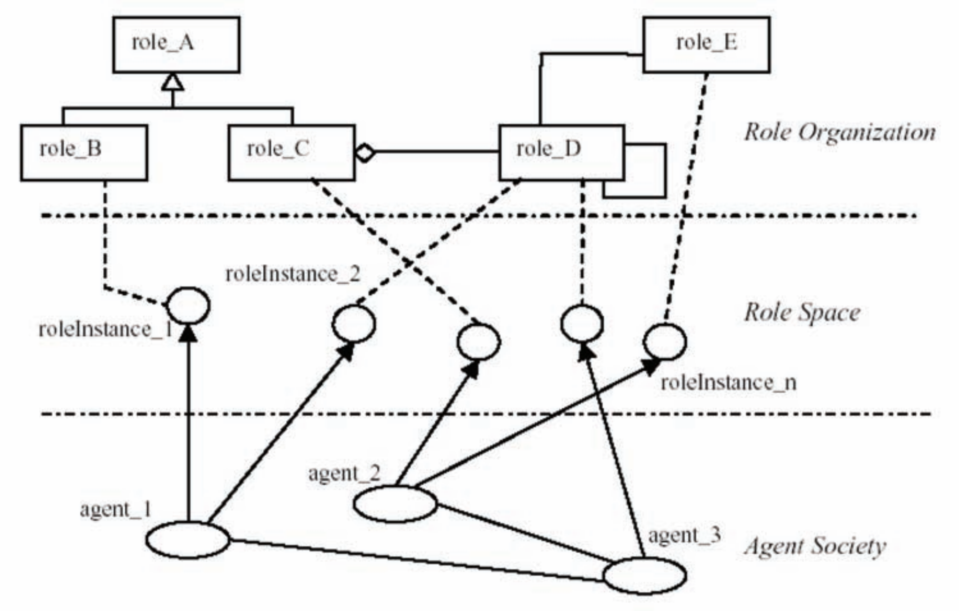
Maria, Silva and Lucena (2005) proposed an MDA-based approach to developing multi-agent systems. They first use MAS modeling language (MAS-ML) to model MAS by creating the platform independent models (PIM). Then the MAS-ML models are transformed into UML models using the ASF framework, which defines a set of object-oriented models for MAS entities specified in MAS-ML. The UML models are then transformed into code.

We have proposed three levels of models for developing role-based open multi-agent systems (Xu, Zhang & Patel, 2007), namely AIPIM (Application Independent Platform Independent Model), ASPIM (Application Specific Platform Independent Model), and ASPSM (Application Specific Platform Specific Model), as a refinement process. In each level of the models, role components and agent components are always separated and designed independently. Role instances and agent instances interact with each other only at runtime through an A-R (Agent-Role) mapping mechanism.

ROLE-BASE MODELING APPROACH

The basic idea of the role-based agent development environment (RADE) is illustrated in ***Figure 1***. The top level is the *role organization*, which defines the conceptual roles and their relationships such as inheritance, aggregation, association and incompatibility. In health care systems, conceptual roles represent all possible job titles in the system, such as *physician* and *nurse*. The relationships describe how these roles relate to each other. The second level is the *role space*, which consists of multiple role instances; each role instance is instantiated from a conceptual role dynamically. For example, whenever there is a need to cure a patient, a new physician role instance is created with the goal to cure a patient. A role instance

Figure 1. RADE Concept (© 2007, Journal of Computational Intelligence Theory and Practice. Used with permission.)



represents the task that needs to be accomplished in the system. The bottom level is the *agent society*, which consists of multiple agent entities. Agent can take or release role instances dynamically, where the mapping from role instances to agents is called A-R mapping, which represents that a real person takes a task in the system.

In an actual software system, agent instances are automatically generated based on the definition of agent classes. Each agent instance is a software entity that performs specific functions and also coordinates and communicates with other agent instances. On the contrary, role classes are defined to incorporate domain knowledge and organizational relationships. Each role class is associated with specific goals and detailed descriptions of how to achieve such goals. The relationships among different role classes also depict the organizational relationships among the real-world entities represented by these roles. Such information is expected to be provided by domain experts rather than software engineers. At system runtime, role instances are created dynamically either by a human user or by an agent when certain goals are needed to be realized. Those role instances mainly carry domain knowledge; however, they do not actually perform any actions like agents. When an agent takes a role instance, the agent uses the knowledge incorporated in the role instance in order to achieve the goals defined in it.

One major advantage of the RADE approach is that it supports the separation of domain knowledge and the agent framework for the simulation system. Any domain knowledge relates to the health care domain can be specified by domain experts through definition of roles and their interrelationships. On the other hand, software engineers are responsible to develop automatic agents that actually perform tasks in the simulation system.

DEFINING ROLES AND ROLE SPACE

The definition of a role class includes the following information:

1. A set of attributes, such as role name and identification.
2. A set of goals; each goal is associated with a plan tree, which is a hierarchal description of the alternatives to accomplish a goal.
3. A set of actions that can be performed by this role, i.e. a *Physician* role can perform an action of *Prescribe Medicine*.
4. Qualification: the requirement needed to take such a role.
5. The permission of this role, which specifies what information and resource are allowed to be access by this role. For instance, a *Physician* role has the permission to access the patient's medical record.
6. A set of protocols, which describe how this role should interact with other roles.

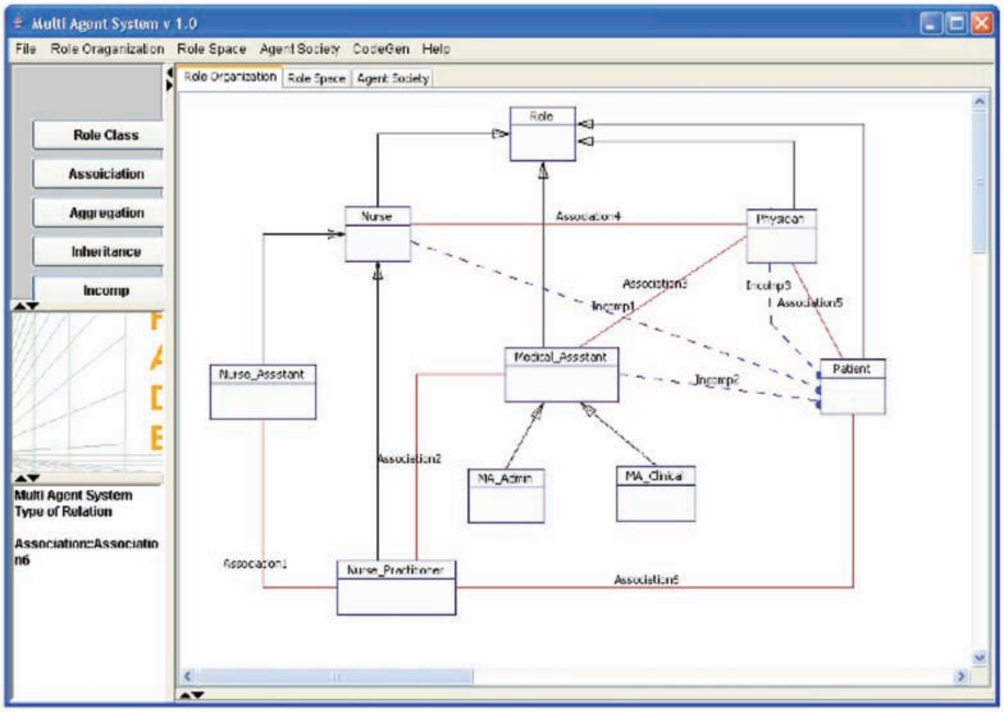
All above information is domain-dependent; hence an expert in health care domain who is familiar with all those rules and regulations can define those role classes. The formal definition of role class in Object-Z can be found in (Xu & Zhang 2005).

In the health care simulation system, we have defined the following role classes:

1. **Patient:** A person who seeks for health care.
2. **Physician:** A person who determines whether diagnostics are to be undertaken, provides prescriptions, performs medical and surgical interventions, has the ability to direct patient care and advance a patient to the next step of care.
3. **Medical Assistant:** A health care professional who performs a variety of clinical, clerical and administrative duties within a health care setting. There are two roles defined as subclasses of this role class:
    a. **Administrative Medical Assistant (MA Admin):** Medical assistant who performs the administrative job.
    b. **Clinical Medical Assistant (MA Clinical):** Medical assistant who performs the clinical job.
4. **Nurse:** There are two roles defined as subclasses of this role class:
    a. **Nurse Assistant:** a nurse who assesses the patient's medical problem, provides care and helps to set up laboratory specimen and medical instruments.
    b. **Nurse Practitioner:** a registered nurse who has completed an advanced training program in primary health care delivery, and may provide primary care for non-emergency patients, usually in an outpatient setting.

Figure 2 shows the RADE interface for a user to create role classes and define the interrelationships among role classes. In this example, the interrelationships include inheritance, association and incompatibility. An inheritance relationship describes the generalization/specification relationship between two role classes. For example, both *MA Admin* and *MA Clinical* inherit the *Medical Assistant* role class since they are specified medical assistants. Association is a very common relationship between role classes; it indicates that an instance of one role class may perform an action on an instance of another role class. Association relationships exist between *Physician* and *Nurse*, *Physician* and *Patient*, etc. Incompatibility relationship describes the constraints that the role instances of two role classes cannot be taken by the same agent in the same interaction scenario. For example, an agent cannot take a Physician role instance for treating a Patient role instance if the agent is already taking this Patient role instance; however, the agent can take another Physician role instance for treating another Patient role instance that is not taken by this agent. The definition of such relationships depends on the domain knowledge, so we feel that the domain experts are the best candidate to use this interface to define the role classes and their interrelationships.

Figure 2. RADE Interface for creating roles (© 2007, Journal of the Brazilian Computer Society. Used with permission)



In this example, Physician role is defined with a goal to provide cure. The plan tree provides domain knowledge of how to accomplish this goal. To represent the domain knowledge, we introduce RTÆMS (Role-Based Task Analyzing, environment Modeling, and Simulation) language as an extension of the TÆMS language (Decker, 1996). TÆMS is a hierarchical task representation language, which supports representation of relationships among goals and sub-goals, the quantitative description of the atomic approaches and uncertainties, and resources. We extend the TÆMS language by introducing a role attribute for task nodes that represent goals and sub-goals. The attribute role specifies what roles are needed to carry out this goal or sub-goal. ***Figure 3*** shows the plan tree for the goal 'Provide Cure', which includes two sub-goals: 'Examine Patient' and 'Provide Treatment'. The goal 'Provide Cure' is associated with a **min** quality accumulative function (**qaf**), which specifies the following relationship:

Quality(ProvideCure) = min(Quality(ExaminePatient), Quality(ProvideTreatment))

Each role is defined with a goal, a plan tree, a motivational quantity production set (MQPS), a certificate and other attributes. A goal represents a task that the role needs to accomplish, and the plan tree specifies the domain knowledge of how to accomplish the goal in terms of decomposing it as sub-goals. Consider the following role class.

ROLE: Physician

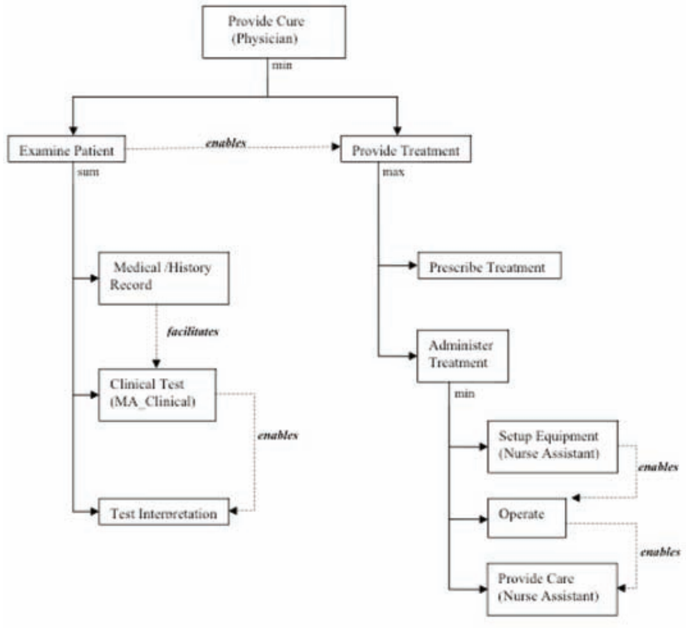
GOAL: Provide Cure

MQPS: (MQ_professional, p1), (MQ_moral, p2), (MQ_experience, p3)

CERTIFICATE: MD (Doctor of Medicine)

This min quality function associated with a

Figure 3. Plan tree for goal Provide Cure in RTÆMS representation (© 2007, Journal of the Brazilian Computer Society. Used with permission)



goal means that the success of this goal depends on the success of all of its sub-goals. Meanwhile, the use of max quality function specifies that there are several alternatives to achieve the goal. For instance, to 'Provide Treatment' for the patient, the Physician can choose either 'Prescribe Treatment' or 'Administer Treatment'. Other available quality accumulation functions in RTÆMS language are: *sum* and *seq_sum*.

Each sub-goal can be decomposed into smaller goals, i.e. 'Examine Patient' consists of three sub-goals: '(Read) Medical History Record', 'Clinical Test 'and 'Test Interpretation'. For those non-local goals, where the tasks need to be performed by other roles, the specification of other roles is included in the plan tree description. For example, 'Clinical Test' should be performed by a Clinical Medical Assistant (MA Clinical), and task 'Setup Equipment' and 'Provide Care' belongs to the Nurse Assistant role. The dash lines represent the interrelationship between goals/sub-goals. For example, 'Clinical Test', which enables 'Test Interpretation,' means that the first goal 'Clinical Test' needs to be achieved successfully before it is possible to implement the second goal 'Test Interpretation'. In addition, '(Read) Medical History Record' facilitates the 'Clinical Test' process because it can provide some useful information about the patient. Other types of interrelationships defined in TÆMS include *disables* and *hinders*. The primitive goal (lowest-level goal) in the TÆMS representation can be specified with more details in another plan tree that is associated with another role. For example, the plan tree for the sub-goal 'Provide Care ' is described in ***Figure 3***, this information belongs to the role Nurse Assistant. The plan tree represented in RTÆMS shows all possibilities to achieve a goal and the interrelationship among goals/sub-goals. It provides fundamental knowledge for agents to plan and schedule its local activities, and it also supports the collaboration and cooperation among agents. More details about the plan tree will be discussed later in the Section of Coordination.

Each goal is associated with a motivational quantity production set (***MQPS***): MQPS = {(MQi, qi), (MQj, qj), (MQk, qk)...}, which represents the success accomplishment of the goal that generates qi amount of MQi, qj amount of MQj, qk amount of MQk, etc. The MQPS describes how this goal contributes quantitatively to some higher-level goals (abstract goals), which are built in an agent's motivation. For instance, when an agent fulfills a goal 'Provide Cure', it collects p1 units of MQ_professional, p2 units of MQ_moral and p3 units of MQ_experience. The agent uses the MQPS specification in the goal definition and its motivation to determine whether it is interested in a role instance, and how interested it is.

The *Qualification* defined in a role class describes the requirements for a particular role. Only an agent who has the specified certificate can take a role instance of that role class. For example, Physician role is defined with a certificate of MD (Medical Doctor); only an agent with a MD certificate can take a Physician role instance.

DEFINING AND DEVELOPING AGENT CLASSES

Agents are the real programmed entities running in the system. In the health care simulation system, each agent represents a personal assistant for a human user in the real world. The agent is responsible for scheduling a user's daily tasks according to the user's preference and constraints. The agent is also responsible for coordinating with other agents when coordination is needed between its own user and other users. A formal definition of agent class in Object-Z can be found in (Zhang, Xu & Shrestha 2007). An agent class definition includes: a set of attributes, motivations, utility function, sensor data, a set of reasoning mechanisms, and execution mechanisms.

Agent attributes include agent names, user, identification, and other descriptive characteristics. The values of these attributes are set when an agent instance is instantiated from the agent class. Different agent instances have different attribute values.

Motivation is defined as "any desire or preference that can lead to the generation and adoption of goals, and which affects the outcome of the reasoning or behavioral task intended to satisfy those goals" (Luck & d'Inverno, 1995). Motivation is the key for an agent to decide which goals it should pursue and how to pursue a goal. We adopt a quantitative view of motivation in our practice. Motivation is defined as a set of motivation quantities (MQs) (Wagner & Lesser 2002).) that the agent tracks and accumulates. Each MQ is associated with a preference function and represents progresses towards an abstract goal. An abstract goal is a long-term commitment to make progress toward certain direction but not a concrete task with a specified plan. For example, a user creates an assistant agent

named Adam. The user specifies his preference on choosing tasks by defining the motivation of this agent as:

Motivation: {MQ_Professional, 0, 0; MQ_Moral, 1, 1; MQ_Experience, 2, 2}

The motivation specifies three long-term goals the user has: professional achievement, moral achievement and experience achievement, which are represented by three types of MQs due to the user's Physician role. The two numbers following the MQ name is the function index and the initial amount of this type of MQ. The function index specifies a utility function that maps a certain number of units of MQ of this type into the agent's local utility. Since the function could be a non-linear function and is also context sensitive, the initial amount of this type MQ is also important. The user also provides this agent his qualification MD, so this agent can be qualified for a Physician role.

Each agent collects sensor data from the environment. For software agents built in this system, sensor data refers to the messages and information the agent receives from the environment including other agents. Based on the sensor data it collects and its motivation, the agent uses its reasoning mechanisms to make decisions. The decisions are made at different levels: selection of roles, selection of goals, and selection of the approach to fulfilling the goals. The first issue is resolved by A-R mapping mechanisms, and the later two issues are inter-related, which are solved by planning /scheduling mechanisms. Given the formal definition of motivations, goals and the detailed description of alternatives to achieve a goal, it is possible to build some general, domain-independent reasoning mechanisms/toolkits. The user can select appropriate components from such toolkits and add them to the agent; the user can also customize these general mechanisms and toolkits by setting up certain parameters. These general mechanisms and toolkits are reusable for agents in different application domains.

Each agent is equipped with some execution mechanisms that can be used to generate the output, which changes the environment. For software agents, the execution mechanisms are the primitive actions to change the environment state. Some of these execution mechanisms are domain-dependent. For example, in our health care simulation system, an agent representing a hospital worker is built with an execution mechanism to set up medical equipment, which is an action the person can perform in real world. Other execution mechanisms could be application-independent, such as sending a message to another agent.

AUTOMATIC AGENT GENERATION PROCESS

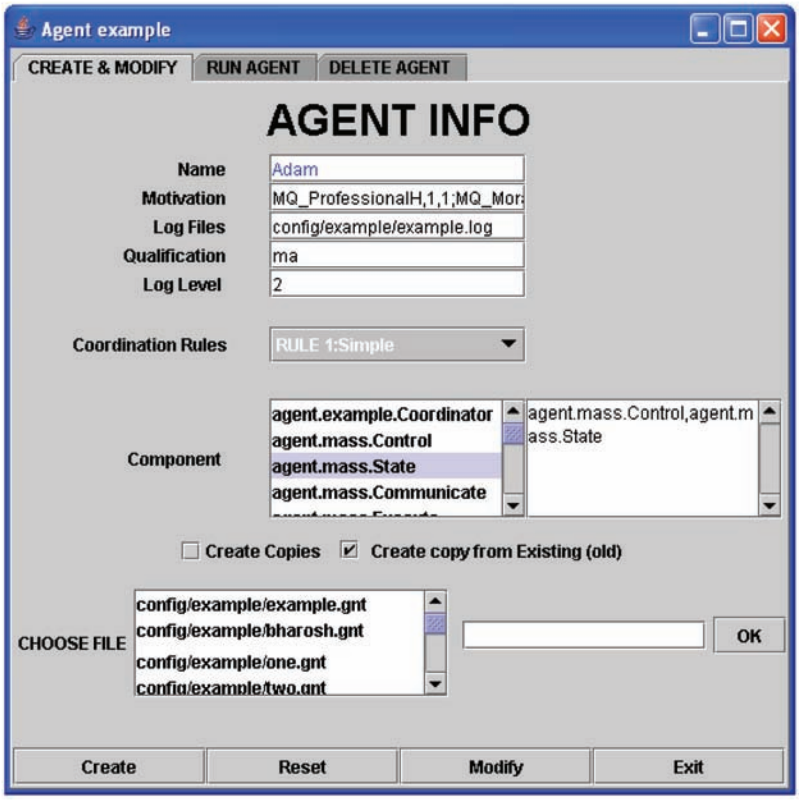
After the user has defined role classes and agent classes, agent can be automatically created using a tool we developed. The basic idea of automatic generation of agents is to use component-based agent architecture, where the user can select the components to be included in this agent, and specify a set of attributes of the agent.

The designer or the user of the agent needs to decide what reasoning tool should be built in and select the appropriate execution tools for the agent according to the design purpose of the agent. It is assumed that there are a set of reasoning and execution mechanisms available in the toolkit, which can be selected and plugged into the agent seamlessly.

Based on the general agent architecture, we developed a tool to support the automatic agent generation process. This tool is created by extending the JAF framework (Vincent, Horling & Lesser, 2001) developed by MAS lab at University of Massachusetts, Amherst. This tool includes a graphic user interface (GUI), which can be used to create new agents, modify existing agents, run agents and delete agents. A screen shot of the graphic user interface is shown in ***Figure 4***.

The user also defines the agent's reasoning and execution mechanisms by selecting a number of ready-to-plug-in components such as: planning, scheduling, communication, etc. The user can select what coordination rule should be used by this agent. We will discuss more about the coordination rule in the next section. After an agent class is created, one or multiple agent instances (the executable programs) can be created from this class definition. Each agent instance is an independent program, and the agent is named after its class with a unique number ID. For example, when a user creates an agent class "X" and three agent instances of this class, the three agents are named as "X_1", "X_2" and "X_3," respectively. The user can run agents from this interface by clicking on the "RUN AGENT" menu box on the top, and selecting a number of agents to run from a list of agents that have already been created. Multiple agents can be created and run on difference machines. The user can choose to delete existing agents by clicking on the "DELETE AGENT" menu box. Finally, the user has an option to choose the coordination rules from three types of rules, namely simple rules, hard and soft relationships based rules, and priority based rules.

Figure 4. Automatic agent generation interface (© 2007, Journal of the Brazilian Computer Society. Used with permission



Name: Adam
Motivation: MQ_ProfessionalH,1,1;MQ_Mor
Log Files: config/example/example.log
Qualification: ma
Log Level: 2
Coordination Rules: RULE 1:Simple
Component: agent.example.Coordinator, agent.mass.Control, agent.mass.State, agent.mass.Communicate
agent.mass.Control,agent.mass.State
☐ Create Copies ☑ Create copy from Existing (old)
CHOOSE FILE: config/example/example.gnt, config/example/bharosh.gnt, config/example/one.gnt, config/example/two.gnt

AGENT COORDINATION AND COOPERATION

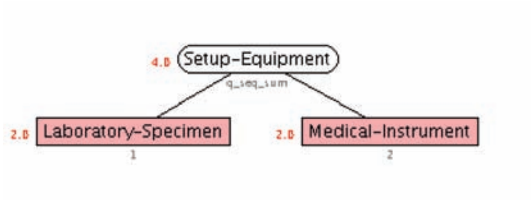
In a health care simulation system with complex activities, distributed information and resources, agents need to coordinate and cooperate on their actions. Efficient coordination and cooperation mechanisms are important for the performance of the system. An agent should coordinate its own actions with those of other agents when there are constraints and interdependencies among their actions.

The RTÆMS language supports collaborations and cooperation by specifying interrelationship among goals and sub-goals, so agents know when and with whom they need to collaborate and cooperate. A set of domain-independent general collaboration mechanisms (GPGP) based on TÆMS language (Lesser et. al., 2004), has been developed, where some of GPGP similar mechanisms are reused in RADE framework based on RTÆMS language. Agents can coordinate and cooperate with each other using the set of mechanisms according to the protocols defined in the role, which specify how the interaction between roles should proceed.

Figure 3 and ***Figure 5*** illustrate pictorially the information that are captured in a RTEAMS representation, which include:

1. Top-level goals that an agent intends to achieve including the deadline for their completion. In ***Figure 3***, 'Provide Cure' is the top-level goal that needs to be completed and in ***Figure 5***, 'Setup Equipment' is the top-level goal that needs to be completed.

Figure 5. Plan tree for 'Setup-Equipment' in RTÆMS representation

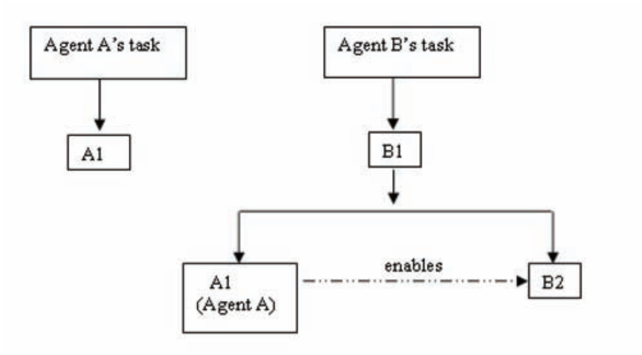


2. One or more of the possible ways of achieving goals is expressed as an abstraction hierarchy whose leaves are basic action instantiations, called methods. In ***Figure 5***, the top-level goal 'Setup Equipment' has sub-goals "Laboratory Specimen' and 'Medical Instrument', which are the methods. These sub-goals need to be completed before the top-level goal can be achieved.
3. Quantitative definition of the degree of achievement in terms of measurable characteristics, such as solution quality and time, is called the quality accumulation function (qaf). In ***Figure 5***, there exits a quality accumulation function *seq_sum* between the sub-goals "Laboratory Specimen' and 'Medical-Instrument'. The total quality of the goal "Setup Equipment" is the sum of the quality of its sub-goals "Laboratory Specimen' and 'Medical Instrument', and these two sub-goals need to be accomplished in a sequence order.
4. Task relationships indicate how basic actions or abstract task achievement affect task characteristics such as its quality and time, elsewhere in the task structure. In ***Figure 3***, there exits a "facilitates" relationship between the task 'Medical History Record' and 'Clinical Test'. A *facilitates* relationship indicates that if the task 'Medical History Record' is completed before the start of task 'Clinical Test', it will increase the quality, and reduce the cost and duration of task 'Clinical Test' by some value.

Task relationships represent a measure view of temporal constraints among activities as a result of information sharing relationships. An *enables* relationship is a hard relationship that essentially acts as a binary switch. In this case, the target method or task cannot accrue quality until the enabling interrelationship is active. A *disables* relationship indicates the exact converse of an *enables* relationship, which precludes the possibility of performing an activity when another activity is performed,. Both a *facilitates* and *hinders* relationship are soft relationships. When a 'facilitates' relationship is active, the targets' quality is increased by some quality power, and the duration and cost are reduced by the duration power and cost power, respectively. Similarly, when a 'hinders' relationship is active, the target's quality is reduced, while the duration and cost are increased. These relationships are called non-local effects if they are relationships between tasks situated in different agents for coordination. Relationships among tasks in the same agent are not of direct concern of the coordination component. The measured view of these relationships indicates how the quality of the information generated by an activity will affect the performance characteristics of the activity using this information, such as the length of its execution and the quality of its resulting solution.

There is a strong connection between the coordination module and a local scheduler module that is part of each agent's architecture. In our work, the agent's local optimization expert is the Design-to-Criteria Scheduler (DTC) (Wagner, Garvey & Lesser, 1998). During the coordination

Figure 6. Agent A and Agent B's initial task view with enables relationship



process, the coordination module queries the DTC scheduler repeatedly to explore the implications of constraints. The coordination and DTC module present in each agent can guide the agent's activities using knowledge of its own local situation and partial knowledge of the activities being carried by other agents. The coordination component in each agent also coordinates with that of other agents to generate constraints on local control that leads to more coherent agent activities.

Each agent starts its coordination component by constructing its own local view of the activities that the agent intends to pursue, as well as the relationships among these activities (Lesser et. al., 2004). The RTÆMS representation is used by the problem solving, coordination and scheduling components as a common communication language. The coordination component helps to construct a global view for an agent, and to recognize and respond to particular inter-agent task structure relationships by making commitments to other agents. The commitments result in coordinated behavior by affecting the tasks an agent executes and the results transmitted. The DTC scheduler, based on commitments, agent's goal, the local and non-local values of tasks, and other agent activity constraints, creates a schedule of activities for the agent, which must meet the real-time deadlines. The coordination component coordinates the activities of an agent through modulating its local control as a result of placing commitments and constraints on the local scheduler.

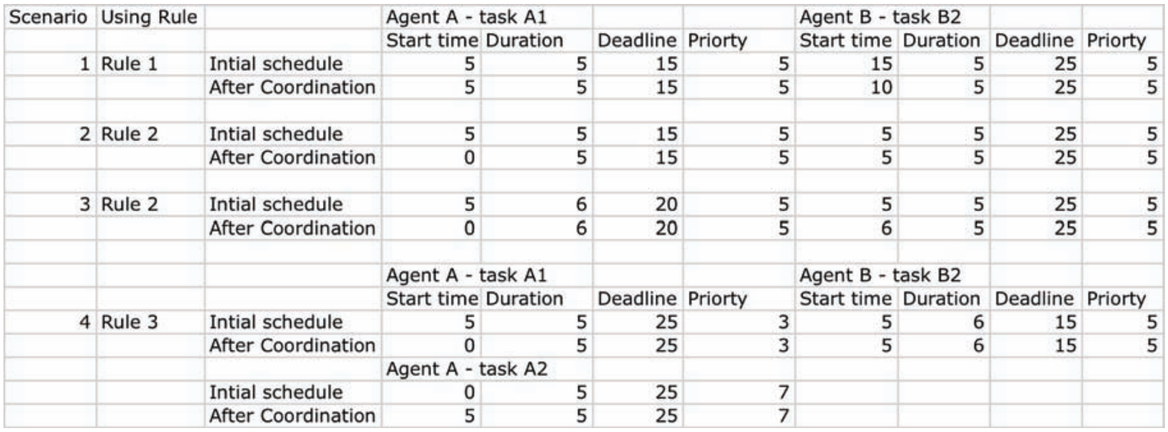
The coordination component uses the RTÆMS task structure representation to add an extension of local and non-local commitments to task achievement. The coordination includes the goals that the agent is currently pursuing, the goals it will likely pursue in the near future, the characteristics of the abstract tasks and basic actions available to achieve these goals, their relationships to other tasks, and the degree of achievement necessary for each goal.

A user can choose a coordination rule from three types of coordination rules, namely Rule1 (simple), Rule 2 (hard and soft relation), and Rule 3 (priority based). The coordination mechanism between agents depends on selection of a specific rule.

Suppose we have two agents A and B shown in ***Figure 6***. Agent B is performing task B1. Task B1 has subtask A1 and B2. Subtask A1 is performed by agent A and subtask B2 is performed by agent B itself. There is an 'enables' relationship from A1 to B2.

When a user selects Rule 1 (simple), the agents use a very simple coordination mechanism - they only consider the quality accumulation function but not the hard and soft relationships between the tasks. As shown in *Figure 6*, suppose there is a *seq_sum* quality accumulation function associated with task B1, agent B recognizes that the quality

Figure 7. Coordination scenarios using different rules



Scenario	Using Rule		Agent A - task A1				Agent B - task B2			
			Start time	Duration	Deadline	Priorty	Start time	Duration	Deadline	Priorty
1	Rule 1	Intial schedule	5	5	15	5	15	5	25	5
		After Coordination	5	5	15	5	10	5	25	5
2	Rule 2	Intial schedule	5	5	15	5	5	5	25	5
		After Coordination	0	5	15	5	5	5	25	5
3	Rule 2	Intial schedule	5	6	20	5	5	5	25	5
		After Coordination	0	6	20	5	6	5	25	5
			Agent A - task A1				Agent B - task B2			
			Start time	Duration	Deadline	Priorty	Start time	Duration	Deadline	Priorty
4	Rule 3	Intial schedule	5	5	25	3	5	6	15	5
		After Coordination	0	5	25	3	5	6	15	5
			Agent A - task A2							
		Intial schedule	0	5	25	7				
		After Coordination	5	5	25	7				

achievement of B1 depends on the accomplish of task A1 and it has to be performed before task B1, it then sends a message to agent A asking it to perform task A1 by a given deadline. Agent A replies with the start time and finish time for task A1 according to its local schedule. Upon receiving this message agent B reschedules the start time of its task B1 to the finish time of task A1. This is the Scenario 1 described in *Figure 7*.

Rule 2 deals with both hard and soft relationships together with the quality accumulation functions and non-local tasks. Hard relationships include the *enables* and *disables* relationship, and soft relationships include *facilitates* and *hinders* relationships.

As shown in ***Figure 6***, task A1 has *enables* relationship with task B2. Agent B sends a message to agent A saying that task B2 has an *enables* relationship with task A1 and should complete task A1 by a given deadline. Agent A checks the start time of task A1. If the start time of task A1 is less than or equal to the start time of task B2, then agent A makes a commitment to agent B that it can finish the task B2 by the given deadline. If the finish time of task A1 is greater than the start time of task B2, agent A then moves task A1's start time to task A1's earliest start time. Agent A sends the new start time and finish time of task A1 to agent B. If the finish time of task A1 proposed by agent A is less than or equal to the start time of task B2, agent B follows its normal schedule. Otherwise, agent B temporarily sets task B2's start time to the finish time of task A1 as proposed by agent A and calculates its new finish time for task B2. If the new finish time falls within the deadline of task B2, then agent B reschedules its task B2 with new values. Otherwise, task B2 is not performed.

Scenario 2 in *Figure 9* explains how agents coordinate with each other using Rule 2. In the initial schedule for task B2, the start time is 5. Agent A sets its start time to its earliest start time (0). Now the new finish time for task A1 is 5. Since the new finish time for task A1 is equal to the start time of task B2, the schedule for task B2 remains unchanged.

Scenario 3 shows a different case. In the initial schedule for task B2, the start time is 5. Agent A sets its start time to its earliest start time (0). Now the new finish time for task A1 is 6. Since the new finish time for task A1 is greater than the start time of task B2, rescheduling of task B2 is needed. Task B2 has a new start time as 6 after rescheduling.

Rule 3 is based upon priority of a task, which takes into consideration the hard and the soft relationships. Rule 3 is useful when an agent is performing more than one task. In the RTÆMS

Figure 8. Plan tree for 'Get-Cure' in RTÆMS representation

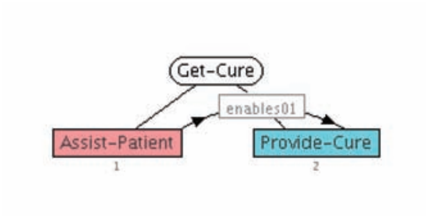
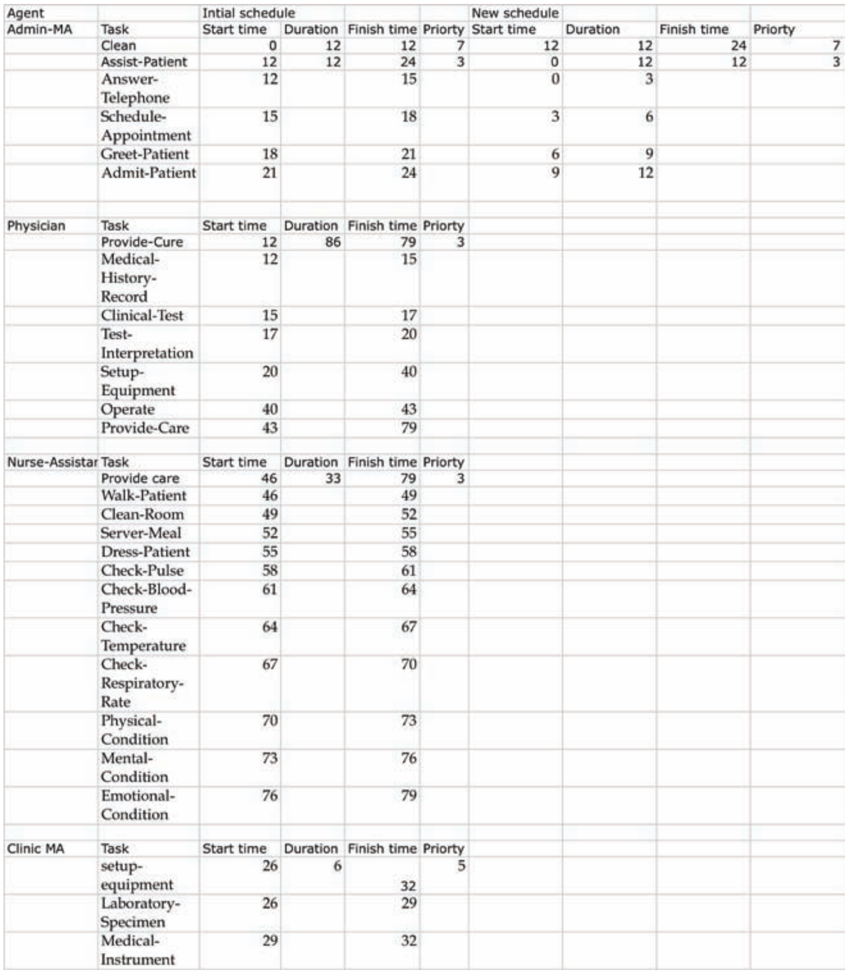


Figure 9. Task schedules



Agent		Intial schedule				New schedule			
Admin-MA	Task	Start time	Duration	Finish time	Priorty	Start time	Duration	Finish time	Priorty
	Clean	0	12	12	7	12	12	24	7
	Assist-Patient	12	12	24	3	0	12	12	3
	Answer-Telephone	12		15		0	3		
	Schedule-Appointment	15		18		3	6		
	Greet-Patient	18		21		6	9		
	Admit-Patient	21		24		9	12		
Physician	Task	Start time	Duration	Finish time	Priorty				
	Provide-Cure	12	86	79	3				
	Medical-History-Record	12		15					
	Clinical-Test	15		17					
	Test-Interpretation	17		20					
	Setup-Equipment	20		40					
	Operate	40		43					
	Provide-Care	43		79					
Nurse-Assistar	Task	Start time	Duration	Finish time	Priorty				
	Provide care	46	33	79	3				
	Walk-Patient	46		49					
	Clean-Room	49		52					
	Server-Meal	52		55					
	Dress-Patient	55		58					
	Check-Pulse	58		61					
	Check-Blood-Pressure	61		64					
	Check-Temperature	64		67					
	Check-Respiratory-Rate	67		70					
	Physical-Condition	70		73					
	Mental-Condition	73		76					
	Emotional-Condition	76		79					
Clinic MA	Task	Start time	Duration	Finish time	Priorty				
	setup-equipment	26	6	32	5				
	Laboratory-Specimen	26		29					
	Medical-Instrument	29		32					

representation, each task has a new attribute called "priority", with its value ranging from 1 (i.e., the highest priority) to 10 (i.e., the lowest priority).

Let us assume that agent A has two tasks A2 and A1. Task A1 has *enables* relationship with task B2. Agent B sends a message to agent A saying that task A1 has an *enables* relationship with task B2 and requires task A1 to be completed by a given deadline. Agent A checks the start time of task A1. If the start time of task A1 is less than or equal to the start time of task B2, agent A makes a commitment to agent B that it can finish the task B2 by the given deadline. If the finish time of task A1 is greater than the start time of task B2, agent A then checks the start time and finish time of task A2. If task A2 is performed before task A1, agent A compares the priority of task A1 and A2. If the priority of task A1 is higher than that of task A2, agent A reschedules task A1 to be performed before task A2, and the new start time and finish time of task A1 is sent to agent B. Otherwise, agent A sets the start time to task A1 to its earliest start time. Agent A sends its new start time and finish time to agent B. If the finish time of task A1 proposed by Agent A is less than the start time of task B2, agent B follows its normal schedule. If the proposed finish time of task A1 is greater, agent B temporarily sets B2's start time to A1's finish time and calculates the new finish time for task B2. If the new finish time is no later than the deadline of task B2, agent B reschedules its task B2 with new values; otherwise, task B2 is not performed.

Scenario 4 in Figure 8 shows how Rule 3 works. The initial start time of task B2 is 6 and agent A cannot complete the task A1 before 6. Hence, agent A compares the priority of task A2 and A1. Since priority of task A1 is higher, A1 is performed before A2, and the new schedule is sent to agent B.

Similarly, these coordination rules can be used to support other non-local relationships, including disables, facilitates and hinders.

RUNTIME SCENARIO

Now we present a runtime scenario for a hospital organization to describe how the health care simulation system works. The scenario demonstrates how the dynamic task allocation is accomplished through the A-R mapping mechanism, and how agents coordinate with each other in their activities. In this scenario, a special agent role space is first created. Role space agent is initially not taking any active role in the system; rather, it is mainly responsible for maintaining and managing the role instances in the system. The role space checks the plan tree of a role instance, when this role instance is taken by an agent, which recognizes the needs to create new role instances. The role space selects the appropriate agent for the role instance after verifying the qualification and consistency of the candidates.

When the system is initialized, the system administer creates several Patient role instances to express the expected service requirements from patients. The number of Patient role instances depends on the capability of the hospital. These patient role instances are posted in the role space and are not active until they are taken by some agents. When a (real) patient Bryan enters the hospital for services, a personal assistant agent named Bryan is created for this patient, and the agent takes one Patient role instance. In this case, Bryan uses the coordination Rule 3, which is specified when the user defines the Patient agent class.

When agent Bryan takes the Patient role instance, it has one goal to achieve: 'Get Cure'. The plan tree of this goal describes that two sub goals 'Assist Patient' and 'Provide Cure' must be achieved so that the goal 'Get Cure' can succeed. The goal 'Assist Patient' belongs to a MA Admin (Administrative Medical Assistant) role and the goal 'Provide Cure' belongs to a Physician role. Based on this information, a Physician role instance and an MA Admin role instance are created by the role space.

Four other agents, Adam, Cathy, Kevin and David that represent four medical professionals are also created and active in the system. Both agent Adam and the remaining agents are initialized with coordination Rule 3. They have been idle and sent requests to the role space for available role instances. When the MA Admin and Physician role instances are created in the role space, all three agents who are interested in taking any additional role instances receive a message for this update. After receiving the message, the agent checks the goal associated with the role instance, especially the MQPS, to see if it matches its own motivation. If the MQPS contains the same type of the agent's MQ in its motivation, the agent is said to be interested in taking that role instance.

For example, the Physician role instance has MQPS as: (MQ_professional, p1), (MQ_moral, p2), (MQ_experience, p3), all these three types MQ's belong to agent Adam's motivation. So Adam is interested in this role instance. How interested Adam is for this role instances depends on the actual values of p1, p2 and p3, the exact structures of the mapping functions with index 0, 1, and 2, and the current accumulation of these MQ's for agent Adam.

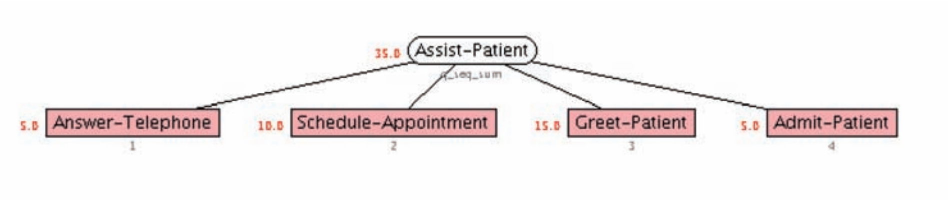
If agent Adam is interested in multiple role instance openings, it will compare the degree of interests in these role instances and select the most interested ones, and send requests to the role space. It is also possible that the role space receives requests from multiple agents for the same role instance. In this case, the role space verifies the qualification of each agent by matching the agent's qualification with the certificate requirement defined in the corresponding role class. For example, agent Adam is qualified for this role instance because it has a MD qualification that matches the certificate requirement of the Physician role class. The role space also checks if this role instance is compatible with other role instances the agent is taking right now. For instance, suppose agent Bryan has a MD qualification and it is also interested in this Physician role instance; however, according to the incompatibility relationship between the Physician role and the Patient role, agent Bryan cannot take this role instance because it takes the Patient role instance related to this Physician role instance.

After verifying the qualification and checking the consistency, the role space selects an appropriate agent (agent Cathy) for the MA Admin role instance, whose goal is to 'Assist Patient'. The role space then tells agent Cathy that the task 'Assist Patient' has an *enables* relationship with the task "Provide Cure'. The plan tree for the goal 'Assist Patient' consists of four sub goals: 'Greet Patient', 'Schedule Appointment', 'Admit Patient', and 'Answer Telephone'. All of these sub-goals can be performed by the same agent who takes the MA Admin role instance, so no new role instance has to be created.

After assigning the MA Admin role instance to agent Cathy, the role space assigns the Physician role instance to another appropriate agent - Adam, based on its qualification. The role space then tells agent Adam that task 'Assist Patient' enables its task 'Provide Cure'. The goal of taking the Physician role by agent Adam is to 'Provide Cure'. The role space reads the plan tree associated with the goal, and finds that in order to accomplish this goal, sub-goals 'Setup Equipment' and 'Provide Care' must be accomplished by other roles. In response to this need, new role instances Nurse Assistant and MA Clinical (Clinical Medical Assistant) are created. The role space then selects appropriate agents Kevin and David to take these role instances respectively. This process will continue until no more new role instance is needed, and all role instances have been taken. After a goal defined in a role instance is accomplished, the agent will collect the utility as defined in the MQPS of this role instance, and release the role instance, which will be further deleted by the role space.

After all role instances have been assigned to appropriate agents, the role space sends a table of roles to the agent who is performing that role, followed by a message to start the coordination.

Figure 10. Plan tree for 'Assist-Patient' in RTÆMS representation



The agents can now begin the coordination process. For example, as shown in *Figure 8*, Patient Bryan a goal to 'Get Cure", which has two non-local subtasks 'Assist Patient' and 'Provide Cure' performed by MA Admin Cathy and Physician Adam, respectively. Patient Bryan sends a message to both agents to ask them to complete the task within the deadline. Agents Cathy and Adam reply to Patient Bryan with their scheduled execution time. The Physician Adam coordinates with MA Admin Cathy using coordination Rule 3 to schedule the task 'Assist Patient' before 'Provide Cure'. There is a *facilitate*s relationship between task '(Read) Medical History Record' and task 'Clinical Test'. Since both tasks belong to the same agent, so the 'facilitates' relationship is taken care of by agent Cathy's local scheduler.

Since task 'Assist Patient' has an *enables* relationship with task 'Provide Cure', Physician Adam requests MA Admin Cathy to complete the task by 12. However, Cathy has another task 'Clean' that is scheduled for time 0 to 12, and the task 'Assist Patient' is scheduled for time 12 to 24. Cathy compares the priority of task 'Assist Patient' and task 'Clean': priority of task 'Assist Patient' is higher so this task is rescheduled before the task 'Clean'. Nurse Assistant Kevin can perform the task 'Provide Care' after task 'Operate' performed by Physician Adam. Similarly, Clinical MA David can perform the task 'Setup Equipment' before task 'Operate' and meet the deadline requested by Physician Adam. So no more rescheduling is necessary. The initial schedule for all tasks and new schedule for task 'Clean' are shown in *Figure 9*.

After the coordination is complete the agents can now begin execution, Patient Bryan can now begin executing its task 'Get Cure', which has subtasks 'Assist Patient' and 'Provide Cure'. The task 'Assist Patient' should be performed by MA Admin Cathy. Patient Bryan agent sends a message to MA Admin Cathy to begin the task 'Assist Patient'. MA Admin Cathy then begins executing the task 'Assist Patient', which has the subtasks 'Answer Telephone', 'Schedule Appointment', 'Greet Patient' and 'Admit Patient'. The quality of the task 'Assist Patient' is defined by the quality accumulative function "seq_sum", which is the total quality of all of its sub-tasks performed in sequence. Since MA Admin Cathy itself can perform all of the subtasks, it starts the execution immediately. After Cathy completes the task 'As-

Figure 11. Plan tree for updated 'Get-Cure' in RTÆMS representation

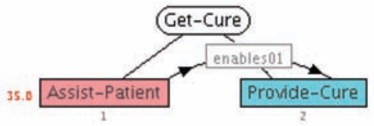
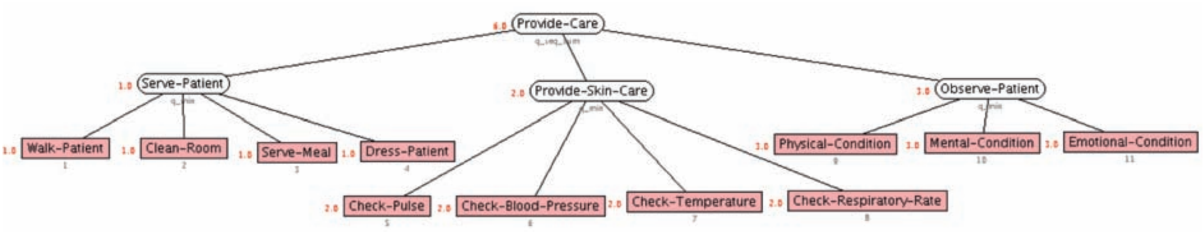


Figure 12. Plan tree for updated 'Provide Care' in RTÆMS representation.



sist Patient', it collects the motivation quantities as defined in the MQPS of this role instance. (See Figures 10 and 11)

Upon receiving this message, patient Bryan updates its own task structure. MA Admin Cathy has rescheduled this task after the task 'Assist Patient'. So when Cathy completes the task 'Assist Patient', it begins executing the task 'Clean'. Now Patient Bryan can start executing the task 'Provide Cure'. Since the task 'Provide Cure' is performed by Physician Adam, so Patient Bryan sends a message to Physician Adam saying that it can start the execution. Physician Adam begins the execution of the task 'Provide Cure'. The task 'Provide Cure' has subtasks 'Examine Patient' and 'Provide Treatment' as shown in ***Figure 3***.

Physician Adam begins executing 'Examine Patient', which has subtasks '(Read) Medical History Record', 'Clinical Test' and 'Test Interpretation', which can all be performed by Physician Adam. After completion of these subtasks, it then begins executing task 'Provide Treatment', which has subtasks 'Prescribe Treatment' and 'Administer Treatment' with the quality accumulative function "max", which means only one of these two subtask needs to be accomplished.

If Physician Adam decides to perform the task 'Administer Treatment', then the three subtasks 'Setup Equipment', 'Operate' and 'Provide Care' need to be accomplished. The task 'Setup Equipment' is performed by MA Clinical agent David. So Physician Adam sends a request to Clinical MA David to perform the task 'Setup Equipment'. David starts executing the task 'Setup Equipment', which has subtasks 'Laboratory Specimen' and 'Medical Instrument'. After the completion, David sends a message to Physician Adam, saying that the task has been completed, together with the quality accumulated, cost accrued and the time taken. Upon receiving this message, physician Adam updates its task structure and begins executing 'Operation', which is performed by itself.

Similarly, the task 'Provide Care' is performed by Nurse Assistant Kevin. Physician Adam sends a request to Kevin to execute the task. Kevin begins executing the task 'Provide Care', which has the subtasks 'Serve Patient', 'Provide Skin Care' and 'Observe Patient'. Nurse Assistant Kevin itself can perform all of these subtasks. (See Figure 12)

After the completion of the task, Kevin sends a message to Physician Adam, saying that the task has been completed, together with the quality accumulated, cost accrued and time taken. Upon receiving this message, physician Adam updates its task structure. Since task 'Provide Cure' has now been completed, Adam sends a message to Patient Bryan that the task has been completed, together with the quality accumulated, cost accrued and time taken. Upon receiving this message, Patient Bryan updates its task structure.

FUTURE TRENDS

The future work includes further development of the system based on the current prototype. Especially, we are interested providing support for users to define interaction protocols in role classes, and integrating those domain-dependent protocols with domain-independent communication mechanisms in agents. We are also interested in experimenting with large systems, more complex scenario and analyzing the system performance.

CONCLUSION

In this chapter, we describe a multi-agent health care simulation system built using RADE framework. The integrated framework supports role-based design of multi-agent systems as well as implementation of utility-driven agents that can use a variety of existing agent reasoning and coordination mechanisms. We describe how the roles are defined, how agents are created, and how the role instances are mapped to agents. We also describe the rule-based coordination mechanisms and present a runtime scenario that shows how the simulation system works and how agents coordinate with each other to schedule their local activities. This work verifies the feasibility of modeling health care system with multi-agent approach and demonstrates the strength of automatic coordination, planning and scheduling.

REFERENCES

Becht, M., Gurzki, T., Klarmann, J., & Muscholl, M. (1999). ROPE: Role-Oriented Programming Environment for Multi-Agent Systems. *Conference on Cooperative Information Systems* (pp. 325–333).

Bellifemine, F., Caire, G., Poggi, A., & Rimassa, G. (2003). JADE A White Paper. *EXP in search of innovation - Special Issue on JADE, TILAB Journal, 3*, 6-19.

Decker, K. (1996). TAEMS: A Framework for Environment Centered Analysis and Design of Coordination Mechanisms. In G. O'Hare & N. Jennings (Eds.), *Foundations of Distributed Artificial Intelligence* (pp. 429-448). Wiley Inter-Science.

DeLoach, S., Wood, M., & Sparkman, C. H. (2001). Multiagent Systems Engineering. *International Journal of Software Engineering and Knowledge Engineering*, *11*, 231–258. doi:10.1142/S0218194001000542

Gracanin, D., Bohner, S. A., & Hinchey, M. (2004). Towards a Model-Driven Architecture for Autonomic Systems. *Proceeding of 11th IEEE International Conference and Workshop on the Engineering of Computer-Based Systems (ECBS'04)* (pp. 500-505).

Graham, J. R., Decker, K. S., & Mersic, M. (2003). DECAF – A Flexible Multi Agent System Architecture. *Autonomous Agents and Multi-Agent Systems*, *7*(1-2), 7–27. doi:10.1023/A:1024120703127

Kuwabara, K., Ishida, T., & Osato, N. (1995). AgenTalk: Describing Multiagent Coordination Protocols with Inheritance. *Proc. 7th IEEE International Conference on Tools with Artificial Intelligence (ICTAI '95)* (pp. 460-465).

Lesser, V., Decker, K., Wagner, T., Carver, N., Garvey, A., Horling, B., Neiman, D., & Podorozhny, R., NagendraPrasad, M., Raja, A., Vincent, R., Xuan, P., & Zhang, X.Q. (2004). Evolution of t he GPGP/TAEMS Domain- Independent Coordination Framework. *Autonomous Agents and Multi-Agent Systems*, *9*(1), 87–143. doi:10.1023/B:AGNT.0000019690.28073.04

Luck, M., & d'Inverno, M. (1995). A Formal Framework for Agency and Autonomy. *Proceedings of the First International Conference on Multi-Agent Systems (ICMAS-95)* (pp. 254-260). AAAI Press/ MIT Press.

Maria, D. B. A., Silva, V. T., & Lucena, C. J. P. (2005). Developing Multi-Agent Systems Based on MDA. *Proceedings of the 17th Conference on Advanced Information Systems Engineering (CAiSE'05).* Porto, Portugal.

Vincent, R., Horling, B., & Lesser, V. (2001). An Agent Infrastructure to Build and Evaluate Multi-Agent Systems: The Java Agent Framework and Multi-Agent System Simulator. *Lecture Notes in Artificial Intelligence: Infrastructure for Agents, Multi-Agent Systems and Scalable Multi-Agent Systems, 1887*.

Wagner, T., Garvey, A., & Lesser, V. R. (1997). Complex Goal Criteria and its Application in Design-to-Criteria Scheduling. *Proceedings of the Fourteenth National Conference on Artificial Intelligence*.

Wagner, T., & Lesser, V. (2002). Evolving Real-Time Local Agent Control for Large-Scale MAS. In J.J. Meyer & M. Tambe (Eds.), *Intelligent Agents VIII (Proceedings of ATAL-01), Lecture Notes in Artificial Intelligence*. Springer-Verlag, Berlin.

Williamson, M., Decker, K. S., & Sycara, K. (1996). Unified information and control flow in hierarchical task networks. *Proceeding of the AAAI-96 workshop on Theories of Planning, Action and Control*.

Wooldridge, M., Jennings, N., & Kinny, D. (2000). The Gaia Methodology for Agent-Oriented Analysis and Design. *Journal of Autonomous Agents and Multi-Agent Systems*, *3*, 285–312. doi:10.1023/A:1010071910869

Xu, H., & Zhang, X. (2005). A Methodology for Role-Based Modeling of Open Multi-Agent Software Systems. *ICEIS, (3),* 246–253.

Xu, H., Zhang, X., & Patel, R. J. (2007). Developing Role-Based Open Multi-Agent Software Systems. [IJCITP]. *International Journal of Computational Intelligence Theory and Practice*, *2*(1), 39–56.

Zambonelli, F., Jennings, N., & Wooldridge, M. (2003). Developing Multiagent Systems: The Gaia Methodology. *ACM Transactions on Software Engineering and Methodology*, *12*, 317–370. doi:10.1145/958961.958963

Zhang, X., & Xu, H. (2006) Towards Automated Development of Multi-Agent Systems Using RADE. *Proceedings of the 2006 International Conference on Artificial Intelligence (ICAI'06)* (pp. 44-50). Las Vegas, Nevada.

Zhang, X., Xu, H., & Shrestha, B. (2007). An Integrated Role-Based Approach for Modeling, Designing and Implementing Multi-Agent Systems. *Journal of the Brazilian Computer Society (JCBS) . Special Issue on Software Engineering for Multi-Agent Systems*, *13*(2), 45–60.

This work was previously published in Multi-Agent Systems for Healthcare Simulation and Modeling: Applications for System Improvement, edited by R. Paranjape; A. Sadanand, pp. 90-111, copyright 2010 by Medical Information Science Reference (an imprint of IGI Global).

Section III
Tools and Technologies

This section presents extensive coverage of the technology that informs and impacts health information systems. These chapters provide an in-depth analysis of the use and development of innumerable devices and tools, while also providing insight into new and upcoming technologies, theories, and instruments that will soon be commonplace. Within these rigorously researched chapters, readers are presented with examples of the tools that facilitate and support the emergence and advancement of health information systems. In addition, the successful implementation and resulting impact of these various tools and technologies are discussed within this collection of chapters.

Chapter 3.1

Capturing Data in Healthcare Using Patient-Centred Mobile Technology

Sarah Pajak
Brunel University, UK

Lorraine H. De Souza
Brunel University, UK

Justin Gore
Northwick Park Hospital, UK

Christopher G. Williams
General Dynamics, UK

ABSTRACT

This chapter outlines and discusses how an increasingly popular approach of incorporating patient perspectives and experience in research can be used to inform the development of user-centred technology in healthcare, with particular emphasis on hand-held mobile devices. The chapter draws on a programme of research and technological developments between an acute hospital trust and the Schools of Health Sciences and Social Care (SHSSC) and Information Systems, Computing and Mathematics (SISCM) at Brunel University in West London. The authors critically review existing literature and discuss the development of a new prototype mobile device for use by healthcare professionals in capturing patient information at the front end of hospital care.

DOI: 10.4018/978-1-59904-777-5.ch004

INTRODUCTION

A three year research project, funded through the Knowledge Transfer Partnership (KTP), due for completion by the end of 2007, has focused upon evaluating patient and staff experiences in relation to the radical redesign of an acute district general hospital. A key aim of the research is to benefit these groups in an accident and emergency (A&E) environment, through the identification and development of technological tools designed to improve the patient journey which can be utilised by clinicians. Patients and staff have been observed in real-time field settings to establish positive outcomes, as well as areas that could be improved through the introduction of these evidence-based tools. The acute trust's redevelopment programme, recognised at national level, is a consequence of a forward thinking approach to developing and evaluating hospital services and is underpinned by current National Health Service (NHS) policy and reform.

Motivation for the research project is fuelled by the potential in disseminating the lessons learnt and benefits afforded by the tools across the NHS on a national basis. One key output has been the development of a prototype mobile device (in the form of a personal digital assistant (PDA)) for recording and sharing patient information in an emergency care environment. The impetus for this development arose out of the initial findings of the research that highlighted two key issues of concern to patients and staff: 'communication' and 'waiting times'. It was evident that the ways in which patient information and data were recorded during emergency consultations, and then relayed to staff who needed to use the information for clinical decision making could be problematic, thereby impacting on the patient journey. Hence, we have recommended a possible technological solution.

Rather than focusing on the detailed findings of the main research, this chapter is centred upon describing how the research is being used to feed into the technological development. The chapter begins with the political context surrounding the advent of patient-centred care and associated NHS reform. This leads into an account of the redevelopment programme at the hospital trust involved. The methodology employed in studying staff and patient perspectives at the hospital is presented, followed by a brief account of the key findings around collection and communication of patient information. The application of technology to address the identified issues is then proposed which includes a review of existing systems. The advantages of the utilisation of hand-held mobile technology with its flexibility of application, portability and potential for linking with other systems, steers direction for the subsequent proposal of the patient-centred PDA 'proof of concept'. The chapter concludes with a look towards future trends in the field.

NHS Policy and Reform

As healthcare has a strong political component, it is important to place the advent of patient-centred care and healthcare redevelopment in political context. The election of a new Labour Government in 1997 brought a pledge to alter perceived 'failures' in the NHS, and to build upon and learn from areas of success where they occurred (nhs.uk website). The Labour party had been particularly critical of the market approach of the previous Conservative administration. They aimed to remove competition but maintain the purchaser-provider spilt (Levitt et al., 1999). The approach by the new government to commit to bringing to an end internal markets was viewed as "eclectic and pragmatic." (Ham, 2004; p.54)

The 1997 White Paper, The New NHS: Modern, Dependable, set out the new political approach which was focused on partnership and integrated working, and was driven by performance (although these concepts and new ways of working were being established across certain organisations in health and social care before this time). This created the basis for further NHS reforms outlined in the NHS Plan (Department of Health 2000) and Delivering the NHS Plan (Department of Health 2001). It appeared that efforts were being made to give greater authority and decision making power to patients and frontline staff. Ham (2004) outlined how the policies to deliver the NHS Plan, whilst offering important differences, were to some extent "similar in a number of respects to those that lay behind the internal market (p.67), and this is particularly the case with offering greater patient choice" (Ham, 2004).

However, establishing the patient position at the centre of the NHS goes beyond simply offering greater choice in a healthcare environment. Not only the desire for patient involvement, but the general expectation of this participation has perceptibly intensified in the development and design of NHS services. This is both a political and social shift which is reflected not only by governmental approaches to policy and reform, but change programmes developed by certain public agencies and awareness raising by various user groups. The heart of the NHS Plan being presented as a vision of "a patient-centred service" (Department of Health, 2000 p.8) is a testament to this.

The evolution of thinking away from clinicians primarily holding the power and control over patient care, is in part a consequence of a number of well publicised NHS scandals. Kennedy (2001) in the Bristol Royal Infirmary Inquiry, a seminal report on certain failings surrounding children's heart surgery at the hospital, showed how NHS culture may directly impact on the patient experience, for better or worse. This report highlighted how cultures of nursing, medicine and management, for example, can be seen as traditionally distinct and internally closely-knit.

Kennedy (2001) surmises that his report is:

> *"an account of a hospital where there was a 'club culture'; an imbalance of power, with too much control in the hands of a few individuals. It is an account in which vulnerable children were not a priority, either in Bristol or throughout the NHS." (p.2)*

This statement is important as it clearly indicates that the issues identified were not unique to Bristol but may apply to the NHS as a whole. This does not necessarily mean that the majority of clinicians were not delivering good quality care to their patients, but the consequence of such a view is that patients are now being offered greater responsibility over their care.

The NHS Improvement Plan (Department of Health 2004), along with the plans presented in 2000-2003 outlined previously, proposed new targets centred upon increases in workforce and new structures within both the NHS and the Department of Health. This formed part of a 10 year reform process. The NHS Plan set out how increased funding and reform aimed to redress geographical inequalities, improve service standards and extend patient choice. It outlined a new delivery system for the NHS, as well as changes for social services and a range of professional groups.

The Healthcare Commission's statutory duty to assess the performance of healthcare providers and include the use of patient surveys further mirrors the importance placed upon patient involvement in national standards. The Healthcare Commission asserts that Patient Focus (a domain in its own right) should have the following specific outcome: "Healthcare is provided in partnership with patients, their carers and relatives, respecting their diverse needs, preferences and choices" (Healthcare Commission website, 2004).

Attempts have been made in the NHS to translate the principles around user-centred services and integrated working into front-line care. Change management models such as those under the umbrella of process redesign have become particularly popular (Iles & Sutherland, 2001, McNulty & Ferlie, 2002). Old professional cultural barriers are to be knocked down in favour of modernised services built around the patient. We focus here on one organisation that has attempted to put the rhetoric into practice.

The Acute Hospital Trust

Whilst it is becoming more common-place to find evidence within hospital trusts of involvement and consultation with patients in the design of services, it is less so the case that efforts are explicitly made from the outset to achieve an outcome which goes beyond the realms of the service provision itself. In this respect, the redevelopment programme presented in this chapter, and associated research project focusing on patient experience, may be unique in their end-point ambition. The project involves a trust that has gained a reputation for its clinically-led innovation (recognised in the NHS Plan) and has attempted to develop a transformational change model designed to be an 'exemplar' for modernising local hospitals

(Fig 1). With various external NHS pressures and changes in strategy aside, the trust is keen on using the research findings for further service innovation and the collaboration with the university is aimed at producing technological development that may be used more widely to improve staff working practices, care processes and patient care across the NHS.

The redevelopment programme has focused upon integration of hospital and community services, rapid throughput and expert teams. Ensuring more appropriate and timely referrals to the hospital from more highly trained general practitioners (GPs) and community services, is a key aim of the hospital model (which incorporates a smaller hospital bed base). This approach has been developed, at least in part, in conjunction with expert clinicians and public and patient groups via public feedback sessions and involvement of committees that include user representatives. These consultations have suggested that the desire expressed for patients to be cared for and treated in their own homes (where appropriate), would be medically more beneficial. Staff satisfaction levels and views towards the working environment are also expected to improve as a result of the changes taking place at the hospital. Our evaluation of the model will assess to what extent these aims are being fulfilled.

On a departmental level, the A&E model has introduced systems which revolve around specialist teams incorporating multi-skilled staff (e.g. nurse practitioners), with the aim to reduce unnecessary delays and improve the overall emergency service for patients. In addition, multi-disciplinary working is a central philosophy of the programme and we focus here on a key theme related to this: sharing of information between professionals.

RESEARCH METHODOLOGY

Nationally, research identifying patient and staff views relating to hospital services is mainly conducted through regular patient and staff surveys, the results of which are collated and published with free availability for all (e.g. Healthcare Commission surveys). The distinguishing feature which sets the current research aside from this bulk collection of data is the in-depth qualitative exploration of experiences and pathways within the hospital setting, from the patients' and staffs' perspectives. Appropriate NHS ethical approval has been granted for this ongoing project.

The various phases of data collection involved many hours of observations and tracing of patient pathways within the 'majors' A&E department. Researchers, in teams and individually, gradually built up a picture of the key elements of the patient pathway. Combining this with interviews with patients, who gave informed consent to participate, and staff views, it was possible to establish areas of concern which lent themselves to potential technological development.

Patients were traced whilst on the 'majors' section of the A&E department from the point of admission to either discharge home or onto a ward, where appropriate. Patient notes were also studied to establish aspects of patient care which may have been missed in patient interviews, or to confirm observations. The periods of observation began in 2003 and have been carried out during a number of updates leading to the present day. Current findings are based upon 73 patient maps conducted so far in the A&E department.

Where possible all elements of patient care were observed. This commonly included interactions between patients and a range of health professionals. In particular, we focused on the assessments made by staff of the patient's condition (known as 'clerking'); from nurses who carried out initial assessments to doctors taking histories and requesting further assessment. Patients were observed having cannulas fitted, drips topped up, blood samples taken, being referred to the x-ray room, waiting for test results, and exchanging information with doctors, nurses, healthcare assistants and porters. Doctors also were observed

Figure 1. Key hospital model objectives

A major drive for improved patient care and better health for the local population by providing services that deliver care to patients at the right time in the right place

Developing a 'whole systems' approach where effective health services can be provided locally by harmonising primary care, local hospital and more specialist services (e.g. chronic disease management) to prevent inefficiencies, gaps in provision, delays and duplication of effort

Staff, patients and the local community to be involved in the development, implementation and communication of the project

writing up patient notes and accessing previous assessment results.

CAPTURING PATIENT INFORMATION: THE PATIENT/ STAFF PERSPECTIVE

Through collation of observations and interviews to the point of 'saturation' (where we felt no new findings would emerge), key themes evolved regarding the A&E patient pathway. As mentioned previously, we are focusing here only on a limited number of initial findings that have been used by the research team to develop a technological prototype. The evaluation project is an ongoing process and further data collection is due to take place.

An understanding of the structure of staffing has been achieved as a result of the research. The A&E team consists of a nurse manager, nurse practitioners who may specialise in emergency care or surgery, and generic nursing staff. The A&E doctors are headed by a consultant (who is available for consultation) and also include higher level doctors such as registrars and staff grade doctors and junior doctors (Senior House Officers and House Officers). The junior doctors such as Senior House Officers (SHOs) working on the unit are typically on six month placements, rotating across specialities, whilst the senior doctors are more permanently based in A&E. The porters and administrators are the remaining staff component and critical to the smooth running of the service. The hospital model itself relies upon integration between this team of staff which makes up A&E and doctors from other specialties, such as medicine or surgery, who are referred to when necessary.

When doctors carry out the initial clerking of a patient this involves taking a full history and carrying out an examination, ordering tests and so forth (this procedure may last approximately 10 to 25 minutes depending on the individual patient). If a different speciality is required following a visit from the A&E doctor, the patient may be expected to repeat elements of the procedure which has already taken place. For example, the notes recorded by a junior doctor in A&E from an initial clerking procedure may be repeated by a doctor from the surgical team who requires the same information, perhaps with additional facts included.

All patients who enter A&E are issued with a hospital identification number. These numbers, along with basic information including a patient's name, address and date of birth, are printed onto a sheet of stickers which is placed within the patient file. The stickers are to be attached to patient notes and samples such as blood or urine which have been taken from the patient, as required. A trolley positioned in the centre of the majors department holds all patient notes and is located adjacent to the white board which tracks which bay a patient is in, their time of arrival and doctor/ nurse responsible for their care. This is particularly relevant in the context of the 4-hour governmental target for A&E outlined in the NHS Plan (2000) and implemented in 2004, as a means to manage waiting times.

As highlighted, a key philosophy of the hospital model is to integrate working, modernise the environment and enhance the patient journey. There is much evidence that these attempts are improving both staff and patient experiences (to be reported elsewhere). One area for improvement is that some patients have voiced some concerns with the clerking phase of their journey, and sharing of information between professionals. During this interaction between patient and clinician, observations were made by the researchers, and patients openly commented, that there was some repetition of questions asked and information requested from various professionals. This issue is known to be a general problem across the NHS and other health and social care systems. Being asked to repeat information resulted in patients experiencing frustration and some concern over the quality of their care, along with causing potentially unnecessary delay to the patient journey.

Following observations and discussions between the researchers and clinicians, the reasons suggested for such repetition became clear. Clinicians commented that some repetition was necessary in order to confirm certain clinical suspicions, but that due to poor note taking skills and/or a lack of communication between some of their colleagues, elements of clerking had, at times, to be unnecessarily repeated and notes re-written. In addition, the problem of lost notes was also raised as leading to delay and potential repetition for patients and staff.

TECHNOLOGICAL POSSIBILITIES

These findings led us to consider one of a number of possible technological outputs from our KTP project. In collaboration with colleagues from Brunel University and the trust, discussions took place to formulate a solution to the problems around recording and sharing clerking information as reported by patients and staff. Establishing a proof of concept to lead, ideally, to a handheld mobile prototype will be explored in the following sections.

Handheld Computer Systems in Healthcare

Problems and attempted solutions around capturing patient information have been addressed by others and are not unique to our project. The research described above, however, has uncovered a need to harness or develop a system that is more efficient at managing relevant information within a busy emergency scenario (i.e. during clerking). In this context, clinicians need quick and easy access to a system that can record and produce detailed data on an ongoing basis at the point of care. We have postulated that this could be achieved with the use of a Personal Digital Assistant (PDA). PDAs are often used in implementations within hospitals due to their user-friendly size, cost and ability to communicate via fixed and wireless networks. It is important to provide some context of previous work in this area to see how our developmental idea fits into the evidence base.

Using PDAs to Record Data

A typical example of such an application could be seen in the work of Oyama et al., (2002) in their implementation of a piece of software that enabled clinicians to enter historical and laboratory patient data at the point of care. Once entered onto the PDA's database, patient records would then be merged with a centralised patient record database located on a server, and could be printed to provide reports for inclusion in clinical notes (Oyama et al., 2002).

A slightly different approach was taken by Bird & Lane (2006), as their system was used with 12 first-year medical students in more controlled settings and with the aim of assessing whether or not the use of PDAs would result in benefits in emergency care, via improved access to procedural and patient documentation (Bird & Lane, 2006). PDAs were provided to all 12 of the students and criteria set for the recording of patient information. The trial was conducted over a three-year period and compared to a previous, totally paper-based trial that also lasted for three years. It was concluded that utilising PDAs did not alter emergency medicine procedures or patient resuscitation documentation, when compared to the equivalent paper-based trial.

Another system for documenting patient procedures and resuscitation information was developed by Rosenthal & Wolford (2000). They cited the limitations of many existing systems as being cumbersome or prone to data loss, and developed a piece of software for use with PDAs that allowed clinicians to enter basic demographic information (although evidence supporting an explanation of this claim was not wholly apparent). Clinicians typically entered their details onto the PDA in around one minute where the information was transferred to a desktop computer and onto a pre-existing database. The researchers concluded that the system presented a cost-efficient method of improved data capture, a reduction of burden upon secretaries and increased tracking capabilities (Rosenthal & Wolford, 2000).

Lapinsky et al., (2001) designed and implemented a system using PDAs for an Intensive Care Unit (ICU) team at Mount Sinai Hospital, Canada. It included hospital and medical reference materials and enabled patient details to be captured using the PDAs specialist application through the use of a customised template. The use of templates proved cumbersome as they merely provided an outline for the information to be entered and did not assist the user with data entry. Lapinsky et al., (2001) found that the lack of a network interface restricted the benefits of the system, as the information contained on the PDAs was isolated. Access to external data sources could have benefited both the patient records and reference applications.

The work of Serif et al., (2005) is also relevant to this discussion. This study involved the development of a system that enabled back pain data to be captured and visualised in mobile form through the use of a PDA. The system encapsulated pain drawings that allowed patients to locate the source of pain and also an appropriate scoring system for evaluating the degree of pain. The detailed documentation of the design, implementation and evaluation of the system showed that tried and tested methods of documenting patient conditions could be successfully digitised. The use of a wireless LAN also aided the usefulness of this system.

While some limitations have been identified, the above studies, in particular those by Oyama et al., (2002), Rosenthal & Wolford (2000) and Serif et al (2005) indicate the possibility that PDAs could be an effective way to enhance the capture of patient information in certain healthcare environments. However, despite being the closest set of examples to our development (particularly as they facilitated the entry of patient information at the point of care), the above devices mainly originated from outside the UK. Further, more development is required focusing on the clerking phase of the patient journey.

Using PDAs for Monitoring or Reference

The above examples illustrate how PDAs can be developed to assist the recording of patient data. However, it appears that these are rare and most developments centre around the use of PDAs mainly for monitoring and reference purposes.

Newlan et al., (2002) developed software for commercially available PDAs which displayed real time physiological outputs from a patient monitor. The software had the ability to display several waveforms at once and operated over a Wireless Local Area Network (WLAN) within a hospital or outside a hospital via the General Packet Radio Service (GPRS), thus allowing carers to monitor patients remotely. The software also had the ability to store the information being conveyed onto the PDA's removable memory. The implications of this with regard to patient confidentiality meant that security had to form a core part of the software. The authors described the use of hybrid public key cryptography for the encryption of data, of individual user logins in authenticating members of staff, and of firewalls to regulate access through the wireless network. This included handshake protocols and encryption algorithms to protect the transmission of usernames or passwords and to prevent data corruption or modification (Newlan et al., 2002).

The PDA-based reference system for clinicians developed at the Western General Hospital in Edinburgh used a WLAN that was constructed with particular attention paid to the implications such a network would have on sensitive medical equipment within the hospital. These PDAs were used to provide functions such as access to the hospital's patient database, x-ray and endoscopic images, medical reference materials and guidelines, papers and journals. Other features included note taking at the point of care, and the experimentation of digital note taking for speech recognition or transcription by secretaries, however the system did not enable details to be captured, only accessed (Turner et al., 2005). The use of off-the-shelf packages did not compromise the final system, as was initially expected by the authors. Usability problems were averted through the use of 'pick lists' to speed up data entry and standard interface widgets to aid familiarisation. Interference with hospital equipment was not an issue, nor was security with the use of Virtual Private Network (VPN) technology in establishing secure communication links.

The previous example is highly relevant given the nature of the research presented in this chapter, and the hospital context within which the developments would be employed. However, despite the authors' detailed account of the design and implementation of the system, their description of the evaluation of both the project and system lacked sufficient detail. Furthermore, the availability of detailed electronic medical information for use by any computer system is quite unique within a UK hospital. This was in part due to the sporadic development and procurement of hospital information systems within the UK NHS since its inception in the late 1940s.

The Mobile Medical Data (MOMEDA) system (Pattichis et al., 2002) provided both clinicians and patients with mobile access to information. Patients were able to access information regarding medical conditions and expected treatments both before and after hospital attendance (Pattichis et al., 2002). Clinicians were able to obtain medical records and images using a mobile phone, which meant that those who regularly travelled between different hospitals could still access patient details offsite using the mobile phone network. This is particularly relevant within the context of the hospital model we are focusing on where integration with community services and flexible, multi disciplinary working is fundamental.

The importance of the MOMEDA system is its ability to operate outside hospital premises using the commercial mobile phone network. Despite this being a highly attractive feature, particularly for mobile clinicians, the associated cost of transmitting detailed images across the mobile network would more than likely attract a high cost due to the volume of data that would need to be transmitted. Systems such as the PDA-based medical records system outlined by Turner et al. (2005) had a distinct advantage over systems such as MOMEDA, in that communication costs did not escalate as system usage increased, as the WLAN was a privately operated network.

Part of the work carried out by Sommers et al., (2001) at Virginia Commonwealth University (VCU) was in providing 15 medical students with PDAs for use as a reference tool. The results of the study indicated that students felt the PDAs had many benefits including accessing medical reference and documentation, treatment guidelines and patient monitoring (Sommers et al., 2001). This system was developed with the specific needs of a university hospital medical school in mind. The PDA software was heavily customised for use by students and designed and constructed in an entirely different way to the PDA-based system developed by Turner et al., (2005) at Edinburgh's Western General Hospital. Despite the evaluation highlighting the perceived usefulness of the system at VCU, caution should be exercised, as students are much more likely to be familiar with the use of mobile devices, removing the usability barrier typically encountered by researchers in such applications where user acceptance may be a more prominent obstacle.

The work carried out by Aziz et al., (2005) at St. Mary's Hospital, London looked at the possible use of PDAs to replace the current system of pagers used by a hospital surgical team. The study looked at efficiencies that could be gained in communication between team members, and assessed this through the length of time members took to respond to calls using PDAs compared to pagers. The PDAs used also functioned as mobile phones and provided access to the Internet and reference materials preloaded onto each of the PDAs. Results of the trial showed that the bi-directional PDA-mobile phones enabled faster communication between the team when compared to pagers. It was also found that initially there was some aversion from members of the team to embracing new technology and change (Aziz et al., 2005). This, in contrast with the results of the trial at VCU (Sommers et al., 2001), highlights the impact end-users can have on the system under development.

In summary, this section presents a comparative discussion of current PDA systems used to manage patient information in a healthcare context. Some studies have shown the potential for the use of handheld mobile devices in recording patient data. However, from studying the relevant literature, it appears these are rare developments. Most other applications of handheld technology within healthcare in the UK or abroad seem to facilitate monitoring procedures (e.g. patients' vital signs) or the provision of reference materials for clinicians often in terms of conveying specific clinical information. These studies, nonetheless, also provide an insight into the possibility of using PDAs in conjunction with wider data systems. This previous work has led us to begin developing a technology that may be applied to solve the problems around capturing patient information at the front end of care, and information that needs continually updating. How can clinicians record clear and valid patient information during clerking procedures that can be used in a busy and ever-changing emergency setting?

A TECHNOLOGICAL SOLUTION

As highlighted above, published findings suggest the use of PDAs in electronically capturing patient details is an emerging field, both within the UK and abroad, and is one which is conducive to further development. Most developments are related to non-UK contexts and capture only a small subset of patient information. Further, the systems may not be customisable to other areas of medicine, where often only patient resuscitation details are recorded (see, for example, Bird & Lane (2006), Rosenthal & Wolford (2000)). Many systems involve more primitive components and may not be accepted as industry standard, or particularly robust given the nature of each application.

This evidence has reinforced the aim of our research project to develop a piece of software to record patient information on attendance to the A&E department of an acute hospital, particularly during clerking phases. The software is intended to form part of a proof-of-concept that can be extended to other areas of healthcare by being customisable, robust in design, and above all, applicable to an NHS hospital where procedures and IT infrastructures often differ.

The need for this type of mobile technology is elicited directly from the experiences of the patients and staff in our study. The findings suggest that repetition of assessments may occur because previous assessments have not been recorded in the notes properly or communicated effectively. Further, doctors and nurses continually move around the hospital system, as do patients. For example, an attendance to A&E may result in patients being referred to an assessment area, then referred for investigations such as x-ray (where results need to be relayed to doctors quickly), and possibly being admitted to a ward. Further referrals may then follow (e.g. outpatient referrals, or discharged back to community care settings).

The PDA mobile device may not only have the capability of keeping up with changeable physical locations, but also benefit clinicians through immediate provision of and sharing of information between and within various services throughout the hospital (potentially throughout the UK, given the existence of the national electronic records programme). Note-taking problems as observed in some instances during our research such as illegibility and loss of documentation would also be overcome. Additionally, and most importantly in terms of clinical governance issues, having the ability to track which clinician has been responsible for clerking or treating a patient through a user sign-in feature when utilising the PDA, would be of significant benefit over the relatively fallible system currently in operation.

The proposed PDA solution is based upon the digitisation of the 'clerking form' (called the 'Adult Inpatient Assessment Protocol') currently used in the A&E department at the hospital. Clinicians complete the protocol following completion of a full history and examination of the patient. The protocol may not be completed in its entirety, as the latter part requires the recording of various test results and patient observations. During completion, the protocol is kept with the patient's notes in the A&E department. It is currently only available in paper form, and following patient discharge is stored in the hospital's archive together with other patient notes.

During development of the proof of concept, specific requirements were obtained from a combination of primary documentation used at the hospital and interviews undertaken with staff. The current IT developments within the trust were established with a meeting with the relevant Director of Information Management and Technology.

This technology addresses a number of key requirements:

- Mobility of device
- Ability to record patient information gathered during the clerking phase incorporating extended text-based notes and diagrams
- The ability to produce the equivalent paper-based records for inclusion in patient notes
- Consideration of appropriate security measures
- Adaptability in the device to allow for revisions to protocol and software

The PDA idea was developed using a simulation model on a computer where certain sections of the paper-based 'clerking protocol' were mapped onto the model to mirror the key stages of the clerking phase of the patient journey. When transformed to the PDA, it was envisaged that this process would guide the clinician through required fields and clarify the current stage of the patient journey while allowing the clinician to clearly record detailed relevant information. This illustrates the patient-centred nature of this proposed device. Figures 2 and 3 outline the process through which the PDA would operate in a hospital setting. An administrator would have access to the XML (Extensible Mark-up Language) document defining the appearance of the

Figure 2. Overall system architecture design

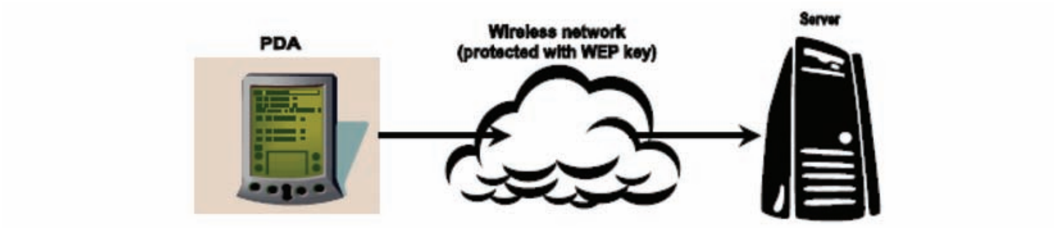
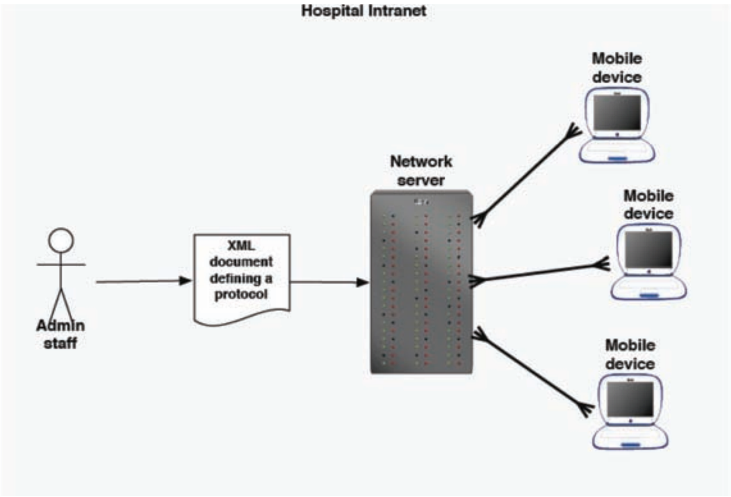


Figure 3. PDA use in context of hospital intranet



protocol (thus allowing alterations to be made). The hospital intranet would be used to link the system together.

PDA EVALUATION

With an outline system specification formulated from the original initial research findings (indicating patients have concerns with repetition, whilst clinicians are concerned with poor notes) further clarification was sought on these issues with the system's prospective end-users through direct observation at the hospital and interviews with relevant staff (n=7). This qualification was sought with full consideration being given to the pressures typically encountered each day by clinical staff. Outlining the PDA concept to staff also proved useful in determining the general opinion amongst clinicians in the application of technology to this area.

IT managers at the trust indicated that the development of modular, web-based systems would be the best option in future IT developments. It has been ascertained that the majority of patient data held by the trust is contained in information 'silos' on legacy systems, most of which were command line-based systems. Recent work focused on developing interfaces between a new web-based system and the existing data structures. The system would retrieve patient details from the underlying legacy systems and generate views of patient information. The extensible design of a new system, shortly due to go live at the time of writing, would be able to accommodate the inclusion of patient data from other sources. This therefore, would mean that any data captured by the new system could be successfully included in the trust's web-based system through the generation of an additional web page.

Clinicians interviewed reported a willingness to take on board the concept of shifting from paper based to the proposed electronic based clerking protocol. However, the issue of training for the use of the PDA was raised as being necessary for some staff and an issue which requires consideration in future development.

The utility of the PDA tool would be greater still if a barcode reading facility was able to record and check the details found on a patient identification sticker. This would be an added level of security in ensuring that the correct patient is being treated. In the context of the electronic patient record system, this would create a seamless link between clinician clerking and the generic patient record. Data protection issues also would need to be fully addressed, as in any new data collection system.

FUTURE TRENDS

The PDA developments discussed in this chapter may contribute to UK wide efforts to collect patient information and transfer patient records to an electronic format, although more research and testing is required. The National Programme for IT (Connecting for Health website, 2007) aims to modernise the current computer systems used within the NHS, thereby improving the flow of patient care and services. This, together with the aim of giving patients access to their personal health and care information, and an ambition to transform the way the NHS works, shows there is some clear synergy with the subject of this chapter.

The highly publicised financial constraints currently facing many parts of the NHS and current issues that have been cited in the media around the National Programme for IT clearly have significant implications for any IT programme which would require financial backing to be developed fully. However, it is important not to be overly short-sighted in perspective towards such a project. Despite initial costs to support the establishment of the use of a PDA, the long term potential for saving money may be substantial. The opportunity of a reduction in clinicians' need to repeat their colleagues' previous note taking, in conjunction with the reliability of a system which protects patients' notes from getting mislaid and the reduction in delays for patients, amongst other factors, may carry considerable financial benefits.

CONCLUSION

We have shown that patient experience research can uncover 'critical areas' in the patient journey where improvements are required (e.g. clerking phase in A&E), thereby providing scope and detail to develop patient-centred technology for use at the front end of care. The PDA software prototype described here for capturing patient data has the potential to reform the way hospital clinicians currently record and share patient clerking details. This may be a further step towards revolutionising healthcare systems within the field of hand-held mobile technology. More evaluation of the use of such a development and how it may link in with current and new hospital IT systems across the NHS is required, but the implications for staff working and patient experience have the potential to be far reaching. In the context of the national IT programme for electronic patient records and the political emphasis on patient-centred care, these observations are particularly salient.

FUTURE RESEARCH DIRECTIONS

There are many varied opportunities related to the work presented by the authors in this chapter for consideration as future research directions.

As the NHS continually evolves and hospital and healthcare services are further developed, opportunities for developing advanced technologies will continually present themselves.

Another focus of the authors' research is the organisational culture of hospital services, and in particular how cultures may vary between specialist and non-specialist areas within a hospital. Related to this is the role of the patient and the perceived control they have over their care and treatment. Traditional clinical boundaries are being challenged in this era of patient-centred modernisation and there is a need for providing healthcare professionals with tools for addressing the cultural shift. This is especially relevant in respect to hospital redevelopments, particularly as they often seek to build services around the patient journey. These insights, both from within our evaluation and across other studies, may enable the development of further technologies in a comparable way to the work described here. For example, computer-based interactive training tools focusing on optimum care pathways and multi-disciplinary working may be developed, where professionals can learn how to implement the best approaches and assess how various clinical scenarios may lead to different outcomes (such as in the case of 'simulation modelling').

In addition, with particular emphasis on the topic of this chapter, future research opportunities may relate to the potential for investigation of working towards an entirely paper-free environment within an accident and emergency department context. Support for the smooth integration of such a system may include elements such as bar code readers on PDAs which link together patient information in a more seamless manner. The addition of barcode scanners or other peripheral devices (depending on the intended application) may assist in data capture and help minimise clerical errors. The longer term implication might be for the majority of services across this and other UK hospitals to utilise electronic protocols, provided they were properly evaluated and proved successful. This could contribute to an evidence base that indicates the possibility of a hospital-wide paper-free environment.

Other important work may include the way in which data entered should be validated or verified. The challenge in this area is that although it should improve the accuracy of the data entered it should do so without compromising the dynamic and user-friendly way in which protocols are designed, deployed and displayed. Furthermore, future developments could include a simple tool for the quick and concise creation of new protocols for use with this system. Work could also focus on system integration issues, such as software metrics and security measures as both would assist the integration of such a system into existing information systems at other hospitals and health trusts.

The scope for the application of technology within healthcare is near limitless and changes occurring in the NHS today are cutting edge. In addition to the clear patient and staff benefits resulting from such applications, the potential financial considerations and commitments would also be substantial. As a consequence of this, research which either evaluates the potential efficacy of proposed devices or provides an increased evidence base for the success of existing tools is fundamental to the ongoing 'modernisation' of the NHS.

ACKNOWLEDGMENT

The authors would like to express their thanks to the following people who contributed to and supported this work: Professor Zahir Irani, Professor Ewan Ferlie, Professor Les Mayhew, Lynne Greenstreet, Paul Parkin, David Powell, Sir Graham Morgan, Mr Michael Burke, Dr John Riordan, Yvonne Slater, Dr Vincent Mak, Dr Alan Warnes, Dr Nicki Panoskaltsis, Dr David King, Doug Irish, Manil Chouhan, Pooja Goel, Harnaik Johal, Sajita Sachchithanantham, Rick Juniper and all the staff and patients who kindly took part in the research. We would also like to extend our appreciation to the Department of Health for funding the project through the Knowledge Transfer Partnership (KTP) scheme and NHS R&D Support Funding.

REFERENCES

Aziz, O., Panesar, S. S., Netuveli, G., Paraskeva, P., Sheikh, A., & Darzi, A. (2005). Handheld computers and the 21st century team: a pilot study. *BMS Medical Informatics and Decision Making, 5*(28).

Bird, S. B., & Lane, D. R. (2006). House officer procedure documentation using a personal digital assistant: a longitudinal study. *BMC Medical Informatics and Decision Making*, *6*(5).

Connecting for Health. Retrieved 01/04/2007, from http://www.connectingforhealth.nhs.uk/

Department of Health. (2000). *The NHS plan: A plan for investment, a plan for reform.* London: HMSO.

Department of Health. *The creation of the National Health Service*. Retrieved 13/4/2006, from http://www.dh.gov.uk/AboutUs/HowDHWorks/HistoryOfDH/HistoryOfDHArticle/fs/en?CONTENT_ID=4106108&chk=ujPIOa

Ham, C. (2004). Health Policy in Britain: *The politics and organisation of the National Health Service* (5th ed.). Hampshire: Palgrave Macmillan.

Healthcare Commission. (2004). Retrieved 13/4/2006, from http://ratings2004.healthcarecommission.org.uk/

Iles, V., & Sutherland, K. (2001). *Organisational Change*, NCC SDO.

Kennedy, I. (2001). *Learning from Bristol: Public inquiry into Children's heart surgery at the Bristol Royal Infirmary 1984–1995.* London: The Stationery Office.

Lapinsky, S. E., Weshler, J., Mehta, S., Varkul, M., Hallett, D., & Stewart, T. E. (2001). Handheld computers in critical care. *Critical Care (London, England)*, *5*(4), 227–231. doi:10.1186/cc1028

Levitt, R., Wall, A., & Appleby, J. (1999). *The reorganized National Health Service* (6th ed.). UK: Stanley Thornes Ltd.

McNulty, T., & Ferlie, E. (2002*). Reengineering Health Care: The Complexities of Organisational Transformation*, Oxford, Oxford University Press.

Newlan, S. P., van Dam, T. B., Klootwijk, P., & Meij, S. H. (2002). Ubiquitous Mobile Access to Realtime Patient Monitoring Data. *Computers in Cardiology* 2002, 22-25 Sept. 2002, pp. 557-560.

NHS Modernisation Agency. (2005). Improvement Leaders' Guide: Process mapping, analysis and redesign. London: HMSO.

NHS.UK. (2006). *About the NHS*. Retrieved 12/04/2006, from http://www.nhs.uk/england/aboutTheNHS/history/default.cmsx

Oyama, L., Tannas, H. S., & Moulton, S. (2002). Desktop and Mobile Software Development for Surgical Practice. *Journal of Pediatric Surgery*, *37*(3), 477–481. doi:10.1053/jpsu.2002.30870

Pattichis, C. S., Kyriacou, E., Voskarides, S., Pattichis, M. S., Istepanian, R., & Schizas, C. N. (2002). Wireless Telemedicine Systems: An Overview. *IEEE Antenna's and Propogation Magazine*, *44*(2), 143–153. doi:10.1109/MAP.2002.1003651

Rosenthal, M., & Wolford, R. W. (2000). Resident Procedure and Resuscitation Tracking Using a Palm Computer. *Academic Emergency Medicine*, *7*(10), 1171.

Serif, T. Ghinea, G., & Frank, A. O. (2005). *A Ubiquitous Approach for Visualizing Back Pain Data*. Proceedings of the International Conference on Computational Science and its Applications (ICCSA 2005), LNCS 3481, pp. 1018-1027.

Sommers, K., Hesler, J., & Bostick, J. (2001). *Little Guys Make a Big Splash: PDA Projects at Virginia Commonwealth University*. Proceedings of the 29th annual ACM SIGUCCS conference on User services, pp. 190-193.

Turner, P., Milne, G., Kubitscheck, M., Penman, I., & Turner, S. (2005). Implementing a wireless network of PDAs in a hospital setting. *Personal and Ubiquitous Computing*, *9*(4), 209–217. doi:10.1007/s00779-004-0322-7

ADDITIONAL READING

Ancona, M., Dodero, G., Minuto, F., Guida, M., & Gianuzzi, V. (2000) *Mobile computing in a hospital: the WARD-IN-HAND project.* Symposium on Applied Computing. Proceedings of the 2000 ACM symposium on Applied Computing (SAC '00). pp. 554-556.

Andrade, R., Wangenheim, A., Bortoluzzi, M. K., & De Biasi, H. H. (2003, June). A strategy for a wireless patient record and image data. *International Congress Series*, *1256*, 869–872. doi:10.1016/S0531-5131(03)00422-9

Beach, M., Miller, P., & Goodall, I. (2001). Evaluating telemedicine in an accident and emergency setting. *Computer Methods and Programs in Biomedicine*, *64*, 215–223. doi:10.1016/S0169-2607(00)00141-3

Berglund, M., Nilsson, C., Révay, P., Petersson, G., & Nilsson, G. (2007). Nurses' and nurse students' demands of functions and usability in a PDA. *International Journal of Medical Informatics*, *76*(7), 530–537. doi:10.1016/j.ijmedinf.2006.02.003

Campbell, C.S., Clark, L.A., & Loy, D., KEENAN, J.F., MATTHEWS, K., WINOGRAD, T., et al. (2007). The bodily incorporation of mechanical devices: Ethical and religious issues (part 1). *Cambridge Quarterly of Healthcare Ethics*, *16*(2), 229–239. doi:10.1017/S0963180107070259

Editorial. (2005). *Journal of Visual Communication in Medicine, 28*(3), 101-101.

Honeybourne, C., Sutton, S., & Ward, L. (2006). Knowledge in the palm of your hands: PDAs in the clinical setting. *Health Information and Libraries Journal*, *23*(1), 51–59. doi:10.1111/j.1471-1842.2006.00621.x

Kho, A., Henderson, L. E., Dressler, D. D., & Kripalani, S. (2006). Use of handheld computers in medical education. A systematic review. *Journal of General Internal Medicine*, *21*(5), 531–537. doi:10.1111/j.1525-1497.2006.00444.x

Kuziemsky, C. E., Laul, F., & Leung, R. C. (2005). A review on diffusion of personal digital assistants in healthcare. *Journal of Medical Systems*, *29*(4), 335–342. doi:10.1007/s10916-005-5893-y

Lee, T. (2007). Patients' perceptions of nurses' bedside use of PDAs.article. *CIN: Computers, Informatics . Nursing*, *25*(2), 106–111.

Luo, J. S. (2006). Mobile medical sources: Medical information anytime and anywhere. *Primary Psychiatry*, *13*(10), 19.

Luo, J. S. (2007). The medical evolution of personal digital assistants. *Primary Psychiatry*, *14*(1), 20–22.

May, C., Finch, T., Mair, F., & Mort, M. (2005). Towards a wireless patient: Chronic illness, scarce care and technological innovation in the United Kingdom. *Social Science & Medicine*, *61*, 1485–1494. doi:10.1016/j.socscimed.2005.03.008

Patel, N. V. (2002) *Health Informatics Governance: Researching Deferred IS/IT Mechanisms.* Proceedings of the 36th Hawaii International Conference on Systems Sciences (HICSS'03).

Reynolds, P. A., Harper, J., Dunne, S., Cox, M., & Myint, Y. K. (2007). Portable digital assistants (PDAs) in dentistry: Part I. *British Dental Journal*, *202*(7), 409–413. doi:10.1038/bdj.2007.274

Smordal, O., & Gregory, J. (2003). Personal digital assistants in medical education and practice. *Journal of Computer Assisted Learning*, *19*(3), 320–329. doi:10.1046/j.0266-4909.2003.jca_033.x

Sugden, B., & Wilson, R. (2004). Integrated care and electronic transmission of prescriptions: experience off the evaluation of ETP pilots. *Health Informatics Journal*, *10*(4), 277–290. doi:10.1177/1460458204048510

Swarts, J. (2005). PDAs in Medical Settings: The Importance of Organization in PDA Text Design. *IEEE Transactions on Professional Communication*, *48*(2), 161–176. doi:10.1109/TPC.2005.849648

Van Sinderen, M. J., van Halteren, A. T., Wegdam, M., Meeuwissen, H. B., & Eertink, E. H. (2006). Supporting context-aware mobile applications: An infrastructure approach. *IEEE Communications Magazine*, *44*(9), 96–104. doi:10.1109/MCOM.2006.1705985

Ward, M. (2007). The doctor's PDA and smartphone handbook: A guide to handheld healthcare. *Journal of Telemedicine and Telecare*, *13*(3), 162–162. doi:10.1258/135763307780677578

Wilcox, R. A., & Whitham, E. M. (2003). Reduction of medical error at the point-of-care using electronic clinical information delivery. *Internal Medicine Journal*, *33*(11), 537–540. doi:10.1046/j.1445-5994.2003.00465.x

Willmot, M., & Sullivan, F. (2000). NHSNet in Scottish primary care: lessons for the future. *British Medical Journal*, *321*, 878–881. doi:10.1136/bmj.321.7265.878

Yi, M. Y., Jackson, J. D., Park, J. S., & Probst, J. C. (2006). Understanding information technology acceptance by individual professionals: Toward an integrative view. *Information & Management*, *43*(3), 350–363. doi:10.1016/j.im.2005.08.006

This work was previously published in User Centered Design for Medical Visualization, edited by F. Dong; G. Ghinea; S. Chen, pp.73-88, copyright 2008 by Medical Information Science Reference (an imprint of IGI Global).

Chapter 3.2

Managing Mobile Healthcare Knowledge

Physicians' Perceptions on Knowledge Creation and Reuse

Teppo Räisänen
University of Oulu, Finland

Harri Oinas-Kukkonen
University of Oulu, Finland

Katja Leiviskä
University of Oulu, Finland

Matti Seppänen
The Finnish Medical Society Duodecim, Finland

Markku Kallio
The Finnish Medical Society Duodecim, Finland

ABSTRACT

Incorporating healthcare information systems into clinical settings has been shown to reduce medication errors and improve the quality of work in general by improving medical decision making and by saving time. This chapter aims to demonstrate that mobile healthcare information system may also help physicians to communicate and collaborate as well as learn and share their experiences within their work community. Physicians' usage of a mobile system is analyzed through a knowledge management framework known as the 7C model. The data was collected through the Internet among all of the 352 users of the mobile system. The results indicate that frequent use of the system seemed to improve individual physicians' knowledge work as well as the collective intelligence of a work community. The guide for acute care, evidence-based medicine guidelines and information related to drug interactions supported the knowledge creation to a large extent. As such, mobile healthcare information systems may be capable of supporting the different sub-processes of knowledge creation and the knowledge work of individual physicians, and through this also improving the collective intelligence of the work community. Overall, knowledge management seems to be a prominent approach for

DOI: 10.4018/978-1-60566-332-6.ch006

studying healthcare information systems and their impact on the work of physicians.

INTRODUCTION

Personal digital assistants and mobile applications are promising tools for managing medical information and accessing it at the point of care (Ebell et al., 1997). They have been shown to assist in evidence-based practice in a clinical setting and support the educational needs of physicians, nurses and other clinical staff, while drug information, medical calculations, guideline information and administrative tasks have been identified as the most useful resources (Honeybourne et al., 2006). Topics such as e-prescribing (Kushniruk et al., 2005) and patient tracking (Lapinsky et al., 2001) have gained a lot of attention recently. On the other hand, access to medical literature and electronic pharmacopoeias, i.e. drug information, seem to be excellent tools for providing physicians with knowledge at the point of care (Fischer et al., 2003).

Incorporating healthcare information systems into clinical settings has been also shown to reduce medication errors (Grasso & Genest, 2001) and improve the quality of work in general by improving medical decision making and by saving time. Mobile versions of these systems are relatively easily incorporated into the workflow of the physicians (Rothschild et al., 2002) as they can be carried around and used when ever needed, for example during home visits or ward rounds.

In the information systems field the topic of knowledge management has received a lot of attention recently (for an excellent review on the subject, see (Alavi & Leidner, 2001)). Our view on knowledge management is through a conceptual framework known as the 7C model (Oinas-Kukkonen, 2004). It suggests that the seven Cs or knowledge creation sub-processes, namely Connection, Concurrency, Comprehension, Communication, Conceptualization, Collaboration, and Collective intelligence, play a central role in knowledge management. According to the 7C model, going through the key phases of Comprehension, Communication, Conceptualization and Collaboration repeatedly, in a seamless and spiral-like way leads into the growth of the organizational or social knowledge, i.e. Collective intelligence.

This paper focuses on mobile access to medical literature and electronic pharmacopoeias, aiming to demonstrate that these may help physicians to communicate and collaborate as well as learn and share their experiences within their user community. There are relatively few scientific studies on managing knowledge with mobile healthcare information systems. Moreover, only a small number of articles provide knowledge about the actual use of mobile medical applications (Fischer et al., 2003). We will present a case study among the users of Duodecim mobile healthcare information system. The data was collected through the Internet among all of the 352 physicians (with the response rate of 66.5%, n=234), who were users the case system.

The article is organized as follows. Chapter II describes the background for the study. Chapter III presents the 7C model for knowledge creation and management, Chapter IV introduces the case system, Chapter V discusses the results, and finally Chapter VI concludes the article.

BACKGROUND

Systematic processing of health-related data, information and knowledge focusing on the study of information processing principles and solutions in healthcare is referred to as *health informatics*, while the scientific discipline related to it is called medical informatics (Hasman et al., 1995). The terms are often used synonymously, even though some differences exist in their use between countries. For instance, medical informatics in Germany also includes nursing informatics and dental informatics, while in other countries medical informatics primarily focuses on solutions from the physicians' viewpoint (Hasman et al., 1996). In general, health informatics is often examined from different perspectives such as information technology or user needs.

A healthcare information system (HIS) is defined as an application of information technology in healthcare, encompassing a wide range of applications from disciplines such as medicine, computer science, management science and statistics (Raghupathi, 1997). Based on the interaction between the medical personnel and the patient, HISs may be categorized as customer supporting systems, interaction supporting systems, consultation systems, decision support systems, process supporting systems, economic systems, preparation tools and administrative tools (Suomi, 2001).

According to Siau (2003), *mobile healthcare information systems* are among the basic tools employed in the healthcare industry, the other two being Internet applications and enterprise systems. Mobile HISs offer two distinct advantages for the healthcare sector: firstly, they are important for the success of telemedicine, and secondly they enable physicians to access information whenever and wherever needed. Access to real-time information is important for physicians and hospitals because information is often needed immediately to enable accurate decision making (Siau, 2003).

Fischer et al. (2003) classify the main uses of mobile applications for medicine as: accessing medical literature, electronic pharmacopoeias, patient tracking, medical education, research data collection, e-prescribing, business management and specialty-specific applications. Other classifications have also been suggested, such as those ones by Adatia and Bedard (2003) and Embi (2001).

Providing *access to medical literature* increases the extent to which evidence will be sought and incorporated into patient care decisions (Sackett et al., 1998). The access to medical literature through a mobile application will allow decisions to be made by the bedside or at the point of care. This could further improve the decisions made by physicians (Sackett et al., 1998). Mobile devices containing decision-making tools and summaries of evidence may also improve learning in evidence-based medicine (Honeybourne et al., 2006) and reduce patients' length of stay in hospitals (Sintchenko et al., 2005). Usually, evidence-based information is presented in a guideline form to further support decision-making.

Pharmacopoeias are drug information databases and drug interaction guides. Drug information refers to information such as adult and paediatric dosing guidelines or common side effects, while drug interaction guides contain information about possible interactions that two or more drugs used together can have (e.g. drug A may influence the absorption of drug B). Access to drug information may reduce medication errors (Grasso and Genest, 2001) as it is impossible in practise to know all conceivable drug interactions by heart. Thus providing an easy manner to double-check these interactions should indeed help the work of physicians at the point of care. The survey conducted by Rothschild et al. (2002) with palmtop drug information guide users suggests that mobile systems may save time in information retrieval and improve drug-related decision making and can be relatively easily incorporated into the workflow of physicians. This is important, as it could improve technology acceptance and save time.

Patient tracking systems aid medical staff in ward rounds by keeping them informed about the patient's condition. Medical education applications are designed to help medical students in their studies, e.g. by monitoring their clinical experience or by finding gaps in their education. Mobile applications used for data collection have also been found promising for research purposes (Fischer et al., 2003). Using mobile applications for electronic prescribing has been found to decrease medication error rates (Grasso & Genest, 2001) and business management applications help the efficiency of hospitals, e.g. by improving coordination and billing (Fischer et al, 2003). Finally, different specialties (for example family medicine) have their own specific mobile applications.

Usually medical literature includes not only descriptions of treatment methods but also evidence supporting each method. This form of decision making is referred as *evidence-based medicine* and is defined as "the conscientious, explicit and judicious use of current best evidence in making decisions about the care of individual patients" (Sackett et al., 1996). For example, mobile decision support systems have contributed a significant reduction in antibiotic prescribing (Sintchenko et al., 2005), i.e. physicians' have been able to see better when to prescribe antibiotics and when not to.

There are two approaches to applying evidence to medicine (Eddy, 2005). The first approach is to use evidence-based guidelines. Twenty years ago medical guidelines were based on experts' consensus but over the years most of the guidelines have changed into evidence-based. Quite interestingly the new guidelines have been dramatically different than the previous ones (Eddy, 2005). The second approach is to apply evidence in individual decision making (Evidence-based Medicine Working Group, 1992). The difference to evidence-based guidelines is that this approach aims to "educating physicians to help them bring more research and evidence into their individual decisions about individual patients" (Eddy, 2005).

Knowledge management is "a business concept which includes concerted, coordinated and deliberate efforts to manage the organization's knowledge […] and applying it to enhance organizational performance" (Bose, 2003). Because of the growing costs of healthcare various knowledge management solutions have been applied in hospitals and medical centers to enhance performance and e.g. provide better care.

Yet the healthcare sector has been said to be data rich but knowledge poor (Abidi, 2001). That is to say different healthcare organizations generate huge amounts of data from hospital reports to clinical trials but not much of the data is transformed into strategic decision-support knowledge (Abidi, 2001).

Thus most of the knowledge management solutions in healthcare have been concentrating on transferring data into knowledge. One way of doing this is to utilize data mining (Fayyad et al., 1996). By using data mining we can find e.g. correlations or dependencies from the vast amounts of data available to us. This way the data could be transformed into a more usable form (i.e. knowledge) for e.g. evidence-based medicine. An example could be to use data mining to predict patients' length of stay in hospital (Kraft et al., 2003).

Clinical decision support systems (Teich & Wrinn, 2000) have also been used to utilize the data. Usually, they combine population statistics with existing knowledge to offer real-time information to support physicians' daily work (Teich & Wrinn, 2000). They can also facilitate evidence-based medicine (Jadad et al., 2000).

Recently, information systems focusing on the knowledge and relationships between patients and hospitals have also been introduced to healthcare settings. This solution is called patient relationship management (Siau, 2003) and through it healthcare unit can provide better care to patients by allowing the unit to get an increased understanding of patients' needs.

Besides the abovementioned the use of knowledge management based solutions on healthcare offers other benefits, too. For example if we had knowledge management based healthcare systems we could better analyze different types of knowledge found in healthcare organizations (e.g. clinical knowledge stored in repositories) as well as achieve significant organizational productivity improvements (Bose, 2003).

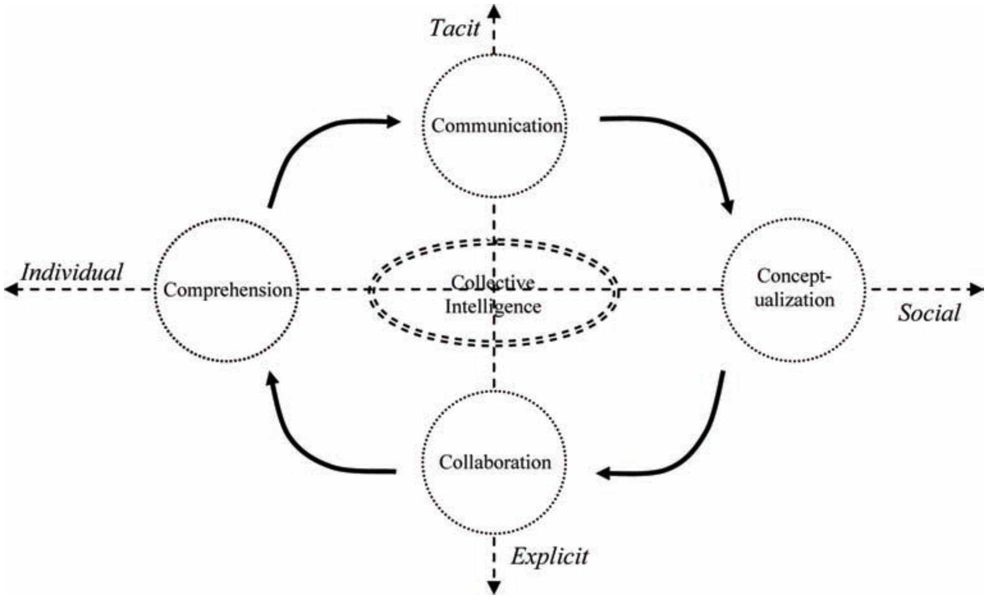
Our goal is not to define new ways to facilitate knowledge creation through healthcare information systems but rather to investigate knowledge reuse. Using the 7C model of knowledge creation and management we argue that over time through knowledge reuse healthcare organization do not only generate new knowledge but get better at their work, too. The next chapter will present the 7C model used in this study.

7C MODEL OF KNOWLEDGE CREATION AND MANAGEMENT

The *7C model* suggests that the following seven Cs play a critical role in the creation of organizational or social knowledge: Connectivity, Concurrency, Comprehension, Communication, Conceptualization, Collaboration, and Collective intelligence (Oinas-Kukkonen, 2004). The 7C model follows Nonaka and Takeuchi (Nonaka & Takeuchi, 1995) in that the integration of individual and social orientations (individual and organizational in their terminology) is emphasized, and that knowledge is assumed to be created through interaction between tacit and explicit knowledge. The model follows Engelbart (1992) in the outcomes of the Comprehension, Communication and Conceptualization sub-processes.

The framework assumes that *connectivity* of all stakeholders with the joint information space (the 1st C) and with people potentially *concurrently* (the 2nd C) is provided in a technologically sound manner, e.g. through the Web, Internet, wireless, mobile and other technologies. These may promote options and allow freedom of choice with contextual support, providing users with a rich environment for *comprehending* (the 3rd C) and *communicating* (the 4th C) the information they find. Knowledge is *conceptualized* (the 5th C) as artifacts, which serve as a vehicle for *collaboration* (the 6th C) through interaction between information producers and consumers, within a team of co-workers or among other stakeholders. All of these six preceding Cs contribute to the growth of "togetherness" or *collective intelligence* (the 7th C). The creation of organizational knowledge is

Figure 1. Knowledge creation sub-processes (Oinas-Kukkonen 2004)



not a linear process, but rather a multi-cycle spiral process (Oinas-Kukkonen, 2004). See Figure 1.

The four central sub-processes in knowledge creation are comprehension, communication, conceptualization and collaboration (Oinas-Kukkonen, 2004). *Comprehension* is a process of embodying explicit knowledge in tacit knowledge by surveying and interacting with the external environment on an ongoing basis in order to identify problems, needs and opportunities (e.g. learn by doing or re-experiencing).

Communication is a process of sharing experiences between people and thereby creating tacit knowledge in the form of mental models and technical skills, producing dialogue records which emphasize needs and opportunities, and integrating the dialogue and resulting decisions with other project knowledge on an ongoing basis.

Conceptualization is a collective reflection process articulating tacit knowledge to form explicit concepts and rationales and systematizing these into a knowledge system, which are iteratively and collaboratively developed, possibly including proposals, specifications, descriptions, work breakdown structures, etc., but rarely a one-shot effort.

Collaboration is a team interaction process of using the resulting conceptualizations within teamwork and other organizational and social processes.

Each of the sub-processes may also be regarded as the building of an artifact and reasoning over why it has been built in the way it has, i.e. capturing the knowledge rationale. Repeatedly going through these phases in a seamless and spiral-like way leads to the growth of *collective intelligence.* Support for capturing deep individual thinking and recording the dialogue between team members may help create truly innovative knowledge products. The learning involved in the comprehension and communication processes is closely related to the attitudes of the participants, i.e. whether they understand their weak points in the sense of individual learning styles, for example.

It is important to notice that the 7C model does not try to define how information systems should manage knowledge. Rather, it models the processes of how individuals interact with information and knowledge (and with each other) to increase the collective intelligence of the organization. In a hospital physicians and nurses can learn and understand new things (Comprehension) while they perform their daily work. They can then share their work related experiences with their colleagues (Communication). As they share they can collectively add to the knowledge of the group and create e.g. best practice guidelines (Conceptualization) to help them perform their work better in the future (Collaboration). Over time, as these processes go around over and over again the hospital unit could get better at providing care for its patients (Collective intelligence).

In spite of receiving a lot of attention recently among practitioners, relatively little knowledge management research has discussed the evaluation of the solutions suggested (Oinas-Kukkonen, 2005). This kind of evaluation may be carried out at the individual, work unit (group, team, or department), or overall organizational levels. The increase in the sharing and dissemination of information and the increase in varied interpretations are obvious and in any case by no means the most important measures of the success of knowledge management solutions. The truly important measure is the identification of underlying non-obvious, complex problems and issues (Oinas-Kukkonen, 2005).

Evaluation of the Comprehension and Communication sub-processes means, for instance, assessment of whether the following goals are achieved: better understanding of current and potential future customers, the key organizational business processes, the product portfolio, product features and potential future products and markets in general. Quite naturally, an improvement in any of these will lead to either an increase in new ideas or the achievement of better ideas for future business, and it may also help solve some of the problems that the organizations are faced with over time (by being more capable of defining the core processes and their key challenges) or even avoid some of the pitfalls they might suffer from. (Oinas-Kukkonen, 2004).

CASE DUODECIM

The *mobile healthcare information system* under investigation is evaluated at the individual and work unit levels. The system comprises a set of medical information and knowledge databases developed by Duodecim Publications Ltd (the Finnish Medical Society Duodecim is a scientific society with over 18,000 of Finnish doctors and medical students - almost 90% - as its members.). The system emphasizes the role of evidence-based medical guidelines (EBMG), i.e. a collection of clinical guidelines for primary care combined with the best available evidence. The collection includes almost 1,000 concise primary care practice guidelines covering a wide range of medical conditions and including both diagnosis and treatment, over 2,700 high-quality evidence summaries supporting the recommendations, a library of 900 high-quality photographs and images of all common and many rare dermatological conditions, electrocardiograms and eye pictures as well as abstracts from the Cochrane Library (which is a collection of databases in medicine and other healthcare specialties).

The system also contains the *pharmacology database Pharmaca Fennica* with a wireless update service for a complete medicine price list, a *drug interaction database* for drug-related decision making, the international diagnosis code guide known as The International Classification of Diseases ICD-10, an acute care guide, a medical dictionary of over 57,000 terms, and a comprehensive database of healthcare-related addresses and contact information for pharmacies, hospitals and health centres. The system is described in Table 1. It is typically used through smartphones and it is delivered to users as a memory card that includes a search engine, user interface software and the core databases.

The knowledge base is planned to support physicians in their day-to-day activities. It can be carried around and applied in the bedside or at the point of care. As physicians apply and reuse the knowledge they may be better equipped with the tasks at hand. This knowledge may also support their medical decision making as well as help them to learn new things. Some earlier studies of the system (see Han et al., 2004a, Han et al., 2005) have demonstrated that physicians have a positive perception of it and intend to use it, and that the most frequently requested mobile content entities were EBMG, Pharmaca Fennica and ICD-10.

Table 1. The Duodecim mobile HIS under study

Duodecim database	Description / functionality
Evidence-based medical guidelines	Search for evidence-based guidelines including literature references and abstracts from the Cochrane Library.
Pharmaca Fennica	Drug lists, adult and paediatric dosing guidelines, common side effects.
ICD-10	International Statistical Classification of Diseases and Related Health Problems. Codes for classifying diseases and a wide variety of signs and symptoms.
Acute Care Guide	Pathogenesis, causes, symptoms, differential diagnosis.
Drug Interaction Database	Possible interaction effects of selected drugs.
Medical Picture Database	Descriptions of symptoms and pictures.
Contact Information	Search for contact information on pharmacies, hospitals and health centres.

Data Collection

The data were collected through the Internet during a two-week period from January 23 to February 7, 2007. The key knowledge creation issues under investigation were Comprehension, Communication, Conceptualization, Collaboration and Collective Intelligence. The technological viewpoints of the 7C model (Connection and Concurrency) were omitted as they are beyond the scope of this research. Medical performance was not measured either. The questionnaire contained 18 questions. See Appendix 1. Five-point Likert scale from "Completely disagree" to "Completely agree" with the choice "I don't know" in the middle was utilized. Physicians were very familiar with this scale, as it had already been used in previous studies of the same system (cf. Han et al., 2004b, Han et al., 2006).

The respondents were approached by email with a link to the online questionnaire. The questionnaire was sent to all of the 352 users of the mobile system. They were all physicians who had a smartphone of their own and the software installed in it, donated by a large international medical company. It should be mentioned that while all of the users were members of the Finnish Medical Society Duodecim, they were not necessarily working at the same hospital. The response rate was 66.5% (n=234). Two responses were deleted from the data set because the respondents did not actually use the system, and one was deleted because the respondent did not answer any of the main questions related to this study. Thus the final data set consisted of 231 replies.

RESULTS

62.3% (n=144) of the respondents were men and 37.2% (n=86) women. 61.9% (n=143) were specialists, 27.3% (n=63) general practitioners, and 10.4% (n=24) researchers or working in administrative positions. Most of the respondents had more than 20 years of experience of working as a physician (55.8%, n=129), while 32.0% (n=74) had over ten years of experience and only 12.1% (n=28) had less. The majority of the physicians worked daily with patients (80.5%, n=186), nurses (86.6%, n=200) and other physicians (85.3%, n=197).

45.9% (n=106) of the physicians used the information system daily, 37.7% (n=87) several times a week, 11.7% (n=27) once a week, 3.9% (n=9) once a month and only two used it less often than once a month. The two most frequently used parts were Pharmaca Fennica drug information (96.5%) and EBMG (88.7%). The least used was the Picture Database (n=46, 19.9%). It was the most recent addition to the system and not all physicians had access to it yet which at least to some extent explains its low usage (the medical society estimated that about half of the users had the picture database installed). Besides using the mobile HIS, 27.7% (n=64) of the physicians read emails through the mobile device and 36.4% (n=84) used it for other Internet services. Quite naturally, the less experienced physicians more often felt that the system helped them to learn new things, and they also found it more useful to some extent than did the more experienced physicians (see Table 2).

Interestingly, there was a slight difference in how specialists and general practitioners felt about the system's ability to support learning of new things. 62.9% (n=39) of the general practitioners felt that the mobile HIS helped them to learn, while 47.9% (n=68) of the specialists felt that way (Chi-Square=3.902, p=0.048). The explanation may be simple fact that the specialists' area of expertise is more focused while general practitioners have to treat patients with wide variety of symptoms.

The four Cs of the knowledge creation spiral correlated with each other strongly. Interestingly, the highest correlations were between Comprehension and Communication, i.e. the individual side of the model (r=0.626) and Conceptualization and Collaboration, i.e. the social side of the model

Table 2. Experience affected the perceived usefulness and learning

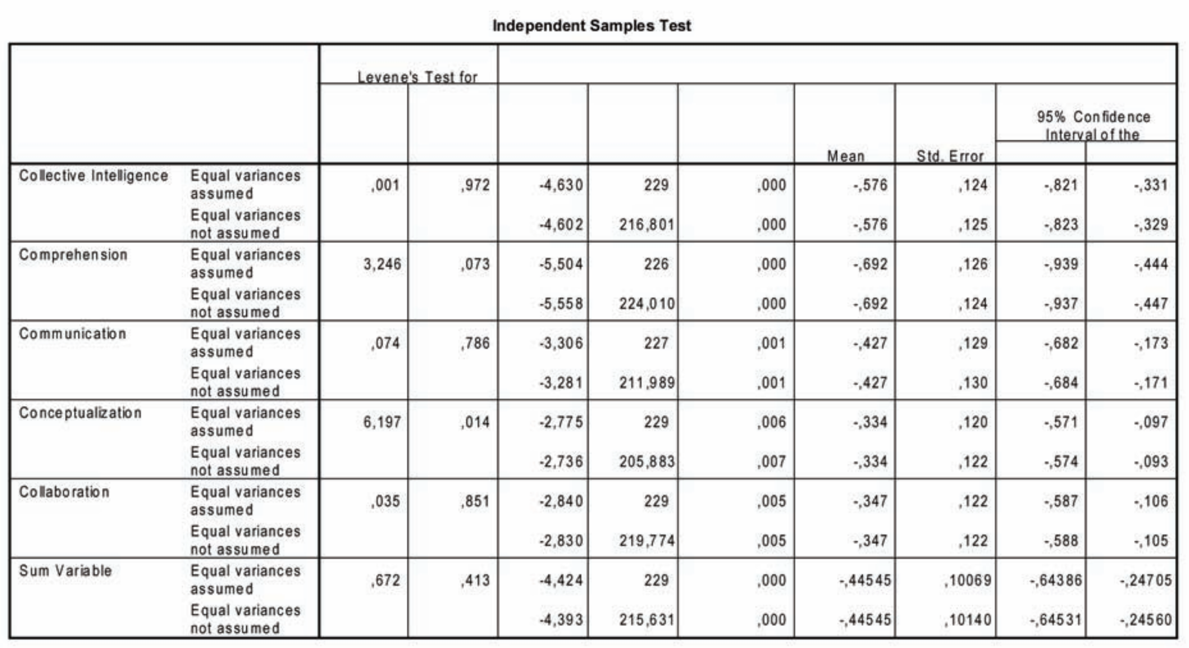
Experience	**Learning** **(Chi-Square=15.445, p=0.000)**	**Usefulness** **(Chi-Square=7.459, p=0.024)**
under 10 y (n=28)	81.5%	92.9%
10-20 y (n=74)	58.1%	86.3%
over 20 y (n=129)	42.2%	74.2%

(r=0.675). This supports the individual-social dichotomy in the knowledge creation model. The next strongest correlation were between Communication and Conceptualization (r=0.554), Comprehension and Conceptualization (r=0.538), and Communication and Collaboration (r=0.534) while the lowest correlation was between Comprehension and Collaboration (r=0.514).

To investigate the *knowledge creation spiral* a sum variable was constructed, representing the Comprehension, Communication, Conceptualization and Collaboration sub-processes (referred to later simply as the "sum variable"). We used the sum approach as each of the 7C sub-processes may be treated equally important. Since five responses had one or more missing data items related to these, the missing data were replaced by means from similar respondents. The sum variable has a high reliability (Cronbach's α=0.841) and correlates strongly with Collective Intelligence (0.629). This seems to confirm the interplay among the four Cs, i.e. the spiral, indeed leads to the growth of Collective Intelligence.

A comparison between those who used the system daily and those who used it less frequently indicates that the daily use improves all *knowledge creation* sub-processes as well as the sum variable (see Figure 2). This seems to indicate that it actually helps physicians to perform their jobs better and it eventually may increase the Collec-

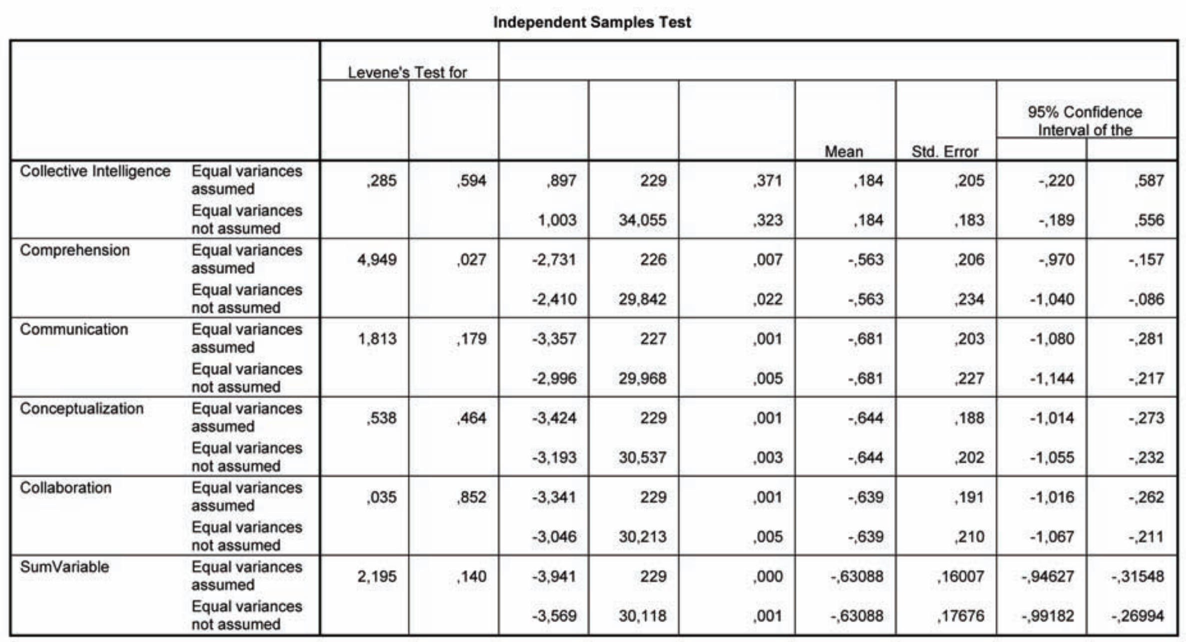
Figure 2. A mobile HIS may improve all key knowledge creation sub-processes



Independent Samples Test

		Levene's Test for					Mean	Std. Error	95% Confidence Interval of the	
Collective Intelligence	Equal variances assumed	,001	,972	-4,630	229	,000	-,576	,124	-,821	-,331
	Equal variances not assumed			-4,602	216,801	,000	-,576	,125	-,823	-,329
Comprehension	Equal variances assumed	3,246	,073	-5,504	226	,000	-,692	,126	-,939	-,444
	Equal variances not assumed			-5,558	224,010	,000	-,692	,124	-,937	-,447
Communication	Equal variances assumed	,074	,786	-3,306	227	,001	-,427	,129	-,682	-,173
	Equal variances not assumed			-3,281	211,989	,001	-,427	,130	-,684	-,171
Conceptualization	Equal variances assumed	6,197	,014	-2,775	229	,006	-,334	,120	-,571	-,097
	Equal variances not assumed			-2,736	205,883	,007	-,334	,122	-,574	-,093
Collaboration	Equal variances assumed	,035	,851	-2,840	229	,005	-,347	,122	-,587	-,106
	Equal variances not assumed			-2,830	219,774	,005	-,347	,122	-,588	-,105
Sum Variable	Equal variances assumed	,672	,413	-4,424	229	,000	-,44545	,10069	-,64386	-,24705
	Equal variances not assumed			-4,393	215,631	,000	-,44545	,10140	-,64531	-,24560

Figure 3. Use of EBM Guidelines improves physicians' Communication, Conceptualization and Collaboration



Independent Samples Test

		Levene's Test for								
							Mean	Std. Error	95% Confidence Interval of the	
Collective Intelligence	Equal variances assumed	,285	,594	,897	229	,371	,184	,205	-,220	,587
	Equal variances not assumed			1,003	34,055	,323	,184	,183	-,189	,556
Comprehension	Equal variances assumed	4,949	,027	-2,731	226	,007	-,563	,206	-,970	-,157
	Equal variances not assumed			-2,410	29,842	,022	-,563	,234	-1,040	-,086
Communication	Equal variances assumed	1,813	,179	-3,357	227	,001	-,681	,203	-1,080	-,281
	Equal variances not assumed			-2,996	29,968	,005	-,681	,227	-1,144	-,217
Conceptualization	Equal variances assumed	,538	,464	-3,424	229	,001	-,644	,188	-1,014	-,273
	Equal variances not assumed			-3,193	30,537	,003	-,644	,202	-1,055	-,232
Collaboration	Equal variances assumed	,035	,852	-3,341	229	,001	-,639	,191	-1,016	-,262
	Equal variances not assumed			-3,046	30,213	,005	-,639	,210	-1,067	-,211
SumVariable	Equal variances assumed	2,195	,140	-3,941	229	,000	-,63088	,16007	-,94627	-,31548
	Equal variances not assumed			-3,569	30,118	,001	-,63088	,17676	-,99182	-,26994

tive intelligence of the whole work community. This is an important finding and provides some empirical evidence for the usefulness of mobile information systems in healthcare in general. Thus, a mobile healthcare information system would be of benefit not only for patient safety (Honeybourne et al., 2006) but for the professional skills of the physicians as well.

We also analysed the different parts of the system to find out which functionalities had on effect on different knowledge creation sub-processes. As 96.5% of the physicians used the drug information (only eight did not use it) we could not compare users and non-users with it. The Independent Samples T-tests between those who used EBMG and those who did not suggest that *EMBG* use improves user perception on the mobile system's help to Communicate (F=1.813, p=0.001), Conceptualize (F=0.538, p=0.001) and Collaborate (F=0.035, p=0.001). See Figure 3. It improves the spiral (F=2.195, p=0.000), and to some extent it also affects Comprehension (F=4.949, p=0.022).

The ICD-10 improved Collective Intelligence (F=1.550, p=0.000) and the spiral (F=0.084, p=0.003). Whereas ICD-10 is packed with four-letter abbreviations of various diseases and it seems impossible for anyone to know all diseases and their codes by heart, it is surprising that there was no correlation with it and Comprehension. It may well be that these abbreviations are really used only for healthcare management and they do not involve diagnosing or modelling the groups of diseases.

Use of Acute Care Guide improved all knowledge creation sub-processes: Collaboration (F=10.312, p=0.000), Comprehension (F=6.067, p=0.000), Collective Intelligence (F=0.339, p=0.000), Communication (F=1.730, p=0.001), Conceptualization (F=0.001, p=0.008), as well as the sum variable (F=1.560, p=0.000). As such, the use of the Acute Care Guide seems to improve each of the knowledge creation sub-processes.

Table 3. Usage of the different parts of the system and their impact on the 7C processes

Duodecim database	Frequencies	CI	Comp	Comm	Conc	Coll	Sum var
Acute Care Guide	39.8%	X	X	X	X	X	X
Drug Interaction Database	54.5%	X	X		X	X	X
Evidence-based medical guidelines	88.7%			X	X	X	X
Contact Information	74.5%					X	X
ICD-10	57.6%	X					X
Medical Picture Database	19.9%						X
Pharmaca Fennica	96.5%						

Use of *Drug Interaction Database* improved Collaboration (F=1.218, p=0.000), Conceptualization (F=0.979, p=0.001), Comprehension (F=0.095, p=0.001), Collective Intelligence (F=0.073, p=0.010), as well as the sum variable (F=0.922, p=0.000). Quite interestingly, it did not affect Communication. Maybe the drug interaction information is useful in places where communication is not required, e.g. the physicians has already decided that he will prescribe drug A and he uses the system to check out possible interactions with existing medication.

Use of Medical Picture Database improved only the sum variable (F=0.000, p=0.009). The results concerning the Picture Database may be little inconclusive due to its low usage. Contact Information improved Collaboration (F=1.724, p=0.002) and the sum variable (F=0.025, p=0.004). Interestingly it did not improve Communication, even if it provided contact information.

Table 3 summarizes the correlations between parts of the system and knowledge creation subprocesses.

DISCUSSION

From the five Cs addressed in this study *Comprehension* was improved by the use of the Acute Care Guide and Drug Interaction Database. The Acute Care Guide was used slightly more often by the less experienced physicians, as 33.3% (n=43) of those who had more than 20 years of experience used it, compared with 48.0% (n=49) of the rest of the physicians (Chi-Square=5.140, p=0.023). Quite obviously, the less experienced physicians still have more to learn and comprehend. Maybe this is especially true in acute medical situations. The fact that Drub Interaction Database improves Comprehension seems feasible too, since there are a large number of different drugs and their combinations that it is practically impossible to know all of their interactions. Thus an easy way of checking these interactions should indeed help physicians and over time they may comprehend something new. Interestingly, EBMGs did not affect Comprehension. This might be because most of the physicians were experienced and thus familiar with the guideline information. On the other hand, most of the users (61.9%, n=143) had specialized in certain medical domains, which implies that their knowledge needs might have been more specialized than what is provided through the evidence-based medical guidelines.

Communication was improved by the EBMGs and the Acute Care Guide, which both are well-structured and evidence-based. Thus, they contain guideline information that is relatively easy to deliver. For example, all guidelines in the Acute care guide are organized in the same format, i.e. pathogenesis, causes, symptoms and differential diagnosis.

Conceptualization was improved by the EBMGs, Acute Care Guide and Drug Interaction

Database. Indeed, evidence-based information may help a group of physicians to reach a consensus in making medical decisions.

Collaboration was improved by the EBMGs, Acute Care Guide, Drug Interaction Database and Contact Information. It seems natural that guidelines help physicians to collaborate. Similarly providing Contact Information helps find the right people.

Collective Intelligence was improved by ICD-10, Acute Care Guide and Drug Interactions. Interestingly, 65.0% (n=93) of the specialists used ICD-10, but only 39.7% (n=25) of the general practitioners. This could mean that specialists have a greater need for the ICD-10 than general practitioners, but as such it does not explain why the use of ICD-10 improves Collective Intelligence. One reason for this could be that hospitals are very bureaucratic by nature and these classifications of diseases are needed in many situations, e.g. when a patient checks in, when a patient's treatments are entered into hospital records, or when a patient is discharged. The use of a mobile ICD-10 application can provide practical support in these situations.

From the different subsystems the Acute Care Guide improved all knowledge creation sub-processes. Mobile applications such as the Acute Care Guide combine the "any time, anywhere" possibilities of mobile applications with actual needs in acute medical situations, where knowledge must be acquired and applied swiftly. Thus, instead of concentrating on any time and anywhere mobile applications in knowledge work context might need to concentrate more on exact situations where knowledge is needed, e.g. in healthcare at the point of care.

Of the other subsystems *Evidence-Based Medical Guidelines* and *Drug Interactions* seem to support the knowledge creation sub-processes to a greater extent. Overall, guideline information seems to provide a good fit with knowledge creation. Guidelines contain information about diagnostic procedures that may be used with certain symptoms as well as suggestions for which drugs might work best for different illnesses. Physicians may also find them helpful when consulting other physicians, as the guideline information may provide a basis for communicating and collaborating. A general practitioner may first check the information found in the mobile HIS, for example, and then use it as a reference when consulting a specialist.

FUTURE RESEARCH

Future research should be directed towards empirical testing of the knowledge processes in more detail, e.g. what type of communication do the evidence-based medical guidelines really support and how can the transfer of tacit knowledge into explicit be better supported. Also multiple sources of data would help obtain deeper understanding.

We are also planning a longitudinal study on the case system described in this paper. With the longitudinal data we can see e.g. how the regular use of the system affects the 7C knowledge creation processes. For example the collective intelligence of the hospital units should increase over time.

We would also like to compare the case system to other ways of obtaining the same information and knowledge. For example, how does the usage of the mobile system compare to e.g. books or desktop information systems (Duodecim also has the desktop version of the case system). We are especially interested in finding out does the case system really offer better support at the point of care?

Another line of research we are interested in is what kind of features of functionalities would support the processes of the 7C model? We are especially interested in the comprehension and conceptualization processes as they have received less attention in the scientific literature than communication and collaboration.

CONCLUSION

This article discusses physicians' usage of a mobile healthcare information system. This was studied through the 7C knowledge management framework. The usage of the system seemed to improve the knowledge work of individual physicians as well as the collective intelligence of work community. The easiest sub-process to support through the system seemed to be collaboration between the physicians. Comprehension and, quite surprisingly, Communication were the most difficult aspects to support. All parts of the case system helped improve the knowledge creation spiral.

These findings go hand in hand with some of the previous findings (e.g. Ebell et al., 1997, Honeybourne et al., 2006) of the usefulness of healthcare information systems, especially in acute medical situations where decisions have to be made swiftly. The findings also hint that the daily use of such a system may indeed over time be of benefit not only for patient safety (Honeybourne et al., 2006) but for the professional skills of the physicians as well.

A limitation of our study is that we were not able to go deeper with studying the differences between experienced and less experienced physicians. Another limitation would be that the picture database was not in use by all of the physicians so the results concerning it are not conclusive. Also one limitation on our study could be that most of the physicians participating in the study had more than 20 years of work experience. It could be argued that the less experience the physician has, the more he has to learn and more he could benefit from the use of a mobile healthcare information system.

In sum, *knowledge management* seems to be a prominent approach for studying healthcare information systems and their impact on physicians' work.

REFERENCES

Abidi, S. (2001). Knowledge management in healthcare: towards "knowledge-driven" decision-support services. *International Journal of Medical Informatics*, *63*(1-2), 2, 5–18. doi:10.1016/S1386-5056(01)00167-8

Adatia, F., & Bedard, P. (2003). Palm reading: 5. Handheld software for physicians. *Canadian Medical Association Journal*, *168*(6), 727–734.

Alavi, M., & Leidner, D. E. (2001). Review: Knowledge management and Knowledge Management Systems: Conceptual Frameworks and Research Issues. *MIS Quarterly*, *25*(1), 107–136. doi:10.2307/3250961

Bose, R. (2003). Knowledge management-enabled health care management systems: capabilities, infrastructure, and decision-support. *Expert Systems with Applications*, *24*, 59–71. doi:10.1016/S0957-4174(02)00083-0

Ebell, M. H., Gaspar, D. L., & Khurana, S. (1997). Family physicians' preference for computerized decision-support hardware and software. *The Journal of Family Practice*, *45*(2), 127–128.

Eddy, D. M. (2005). Evidence-Based Medicine: A Unified Approach. *Health Affairs*, *24*(1), 9–17. doi:10.1377/hlthaff.24.1.9

Embi, P. (2001). Information at hand: Using handheld computers in medicine. *Cleveland Clinic Journal of Medicine*, *68*(10), 840–853. doi:10.3949/ccjm.68.10.840

Engelbart, D. (1992). Toward High-Performance Organizations: A Strategic Role for Groupware. *In proceedings of the GroupWare '92 Conference*, San Jose, CA, August 3-5, 1992, Morgan Kaufmann Publishers.

Evidence-based Medicine Working Group. (1992). Evidence-based Medicine: A New Approach to Teaching the Practice of Medicine. *Journal of the American Medical Association*, *268*(17), 2420–2425. doi:10.1001/jama.268.17.2420

Fayyad, U. M., Shapiro, G. P., Smyth, P., & Uthurusamy, R. (Eds.). (1996). *Advances in knowledge discovery and data mining*. California: AAAi Press.

Fischer, S., Stewart, T., Mehta, S., Wax, R., & Lapinsky, S. E. (2003). Handheld computing in medicine. *Journal of the American Medical Informatics Association*, *10*(2), 139–149. doi:10.1197/jamia.M1180

Grasso, B., & Genest, R. (2001). Clinical computing: Use of a personal digital assistant in reducing medication error rates. *Psychiatric Services (Washington, D.C.)*, *52*(7), 883–886. doi:10.1176/appi.ps.52.7.883

Han, S., Harkke, V., Mustonen, P., Seppänen, M., & Kallio, M. (2004a). Mobilizing medical information and knowledge: some insights from a survey. *Proceedings of the 12th European Conference on Information Systems (ECIS)*, Turku, Finland.

Han, S., Harkke, V., Mustonen, P., Seppänen, M., & Kallio, M. (2005). Understanding physician acceptance of mobile technology: insights from two telephone interviews in Finland. *International Journal of Electronic Healthcare*, *1*(4), 380–395. doi:10.1504/IJEH.2005.006686

Han, S., Mustonen, P., Seppänen, M., & Kallio, M. (2004b). Physicians' behaviour intentions regarding the use of mobile technology: an exploratory study. *Proceedings of the 8th Pacific Asia Conference on Information Systems (PACIS)*, Sanghai, China.

Han, S., Mustonen, P., Seppänen, M., & Kallio, M. (2006). Physician's acceptance of mobile communication technology: an exploratory study. *International Journal of Mobile Communications*, *4*(2), 210–230.

Hasman, A., Albert, A., Wainwright, P., Klar, R., & Sosa, M. (1995). Education and training in health informatics in Europe, State of art, guidelines, applications. In *Studies in Health Technology and Informatics*, IOS Press, Amsterdam, *25*.

Hasman, A., Haux, R., & Albert, A. (1996). A systematic view on medical informatics. *Computer Methods and Programs in Biomedicine*, *51*, 131–139. doi:10.1016/S0169-2607(96)01769-5

Honeybourne, C., Suttont, S., & Ward, L. (2006). Knowledge in the Palm of your hands: PDAs in the clinical setting. *Health Information and Libraries Journal*, *23*, 51–59. doi:10.1111/j.1471-1842.2006.00621.x

Jadad, A. R., Haynes, R. B., Hunt, D., & Browman, G. P. (2000). The Internet and evidence-based decision-making: a needed synergy for efficient knowledge management in health care. *Canadian Medical Association Journal*, *162*(3), 362–365.

Kraft, M. R., Desouza, K. C., & Androwich, I. (2003). Data Mining in Healthcare Information Systems: Case Study of a Veterans' Administration Spinal Cord Injury Population. *Proceedings of the 36th Hawaii International Conference on System Sciences (HICSS'03)*. Jan. 6-9.

Kushniruk, A., Triola, M., Borycki, E., Stein, B., & Kannry, J. (2005). Technology induced error and usability: the relationship between usability problems and prescription errors when using a handheld application. *International Journal of Medical Informatics*, *74*(7-8), 519–526. doi:10.1016/j.ijmedinf.2005.01.003

Lapinsky, S. E., Weshler, J., Mehta, S., Varkul, M., Hallett, D., & Stewart, T. (2001). Handheld computers in critical care. *Critical Care (London, England)*, *5*(4), 227–231. doi:10.1186/cc1028

Nonaka, I., & Takeuchi, H. (1995). *The Knowledge-Creating Company — How Japanese Companies Create the Dynamics of Innovation*. Oxford University Press.

Oinas-Kukkonen, H. (2004). The 7C Model for Organizational Knowledge Sharing, Learning and Management. *Proceedings of the Fifth European Conference on Organizational Knowledge, Learning and Capabilities (OKLC ' 04)*, Innsbruck, Austria, April 2-3.

Oinas-Kukkonen, H. (2005). Towards Evaluating Knowledge Management through the 7C Model. *Proceedings of the European Conference on Information Technology Evaluation, (ECITE '05)*, Turku, Finland, September 29-30.

Raghupathi, W. (1997). Health Care Information Systems. *Communications of the ACM*, *40*(8), 80–82. doi:10.1145/257874.257894

Rothschild, J. M., Lee, T. H., Bae, T., & Bates, D. W. (2002). Clinician use of a palmtop drug reference guide. *Journal of the American Medical Informatics Association*, *9*(3), 223–229. doi:10.1197/jamia.M1001

Sackett, D. L., Rosenberg, W. M. C., Gray, J. A. M., Haynes, B., & Richardson, W. S. (1996). Evidence based medicine: what it is and what it isn't. *British Medical Journal*, *312*(13), 71–72.

Sackett, D. L., & Straus, S. (1998). Finding and applying evidence during clinical rounds: the evidence cart. *Journal of the American Medical Association*, *280*(15), 1336–1338. doi:10.1001/jama.280.15.1336

Siau, K. (2003). Health Care Informatics. *IEEE Transactions on Information Technology in Biomedicine*, *7*(1), 1–6. doi:10.1109/TITB.2002.805449

Sintchenko, V., Iredell, J., Gilbert, G., & Coiera, E. (2005). Handheld Computer-based Decision Support Reduces Patient Length of Stay and Antibiotic Prescribing in Critical Care. *Journal of the American Medical Informatics Association*, *12*(4), 398–402. doi:10.1197/jamia.M1798

Suomi, R. (2001). Streamlining Operations in Health Care with ICT. In T.A. Spil & R.A Stegwee (Eds.), *Strategies for Healthcare Information Systems*, Idea Group Publishing: Hershey, PA, 2001, 31-44.

Teich, J. M., & Wrinn, M. M. (2000). Clinical decision support systems come of age. *M.D. Computing*, *17*(1), 43–46.

APPENDIX A

Demographics

1. Gender Male / Female
2. Experience Less than 1 years / 1-5 years / 5-10 years / 10-20 years / over 20 years
3. Occupation General practitioner / Specialist / Researcher / Management position
4. I use the mobile databases Daily / A few times a week / Once a week / Once a month/ Less than once a month
5. I use the following parts of the system
   EBM guidelines
   Pharmaca Fennica
   ICD-10
   Acute care guide
   Drug interactions
   Picture database
   Connection information
6. I work with hospital management Daily/A few times a week/Once a week/Once a month/Less than once a month/Never
7. I work with physicians Daily/A few times a week/Once a week/Once a month/Less than once a month/Never
8. I work with nurses Daily/A few times a week/Once a week/Once a month/Less than once a month/Never
9. I work with patients Daily/A few times a week/Once a week/Once a month/Less than once a month/Never

The Medical Databases

Please, answer using these criteria:

1 = Completely disagree, 2 = Partially disagree, 3 = I don't know 4 = Partially agree, 5 = Completely agree

10. The mobile medical databases increase the professional capabilities of my work community. 1 2 3 4 5
11. The mobile medical databases help me better comprehend issues relatedto work at hand. 1 2 3 4 5
12. The mobile medical databases help me communicate better. 1 2 3 4 5
13. The mobile medical databases help the working community to reach a consensus in issues related to work at hand. 1 2 3 4 5
14. The mobile medical databases support collaboration. 1 2 3 4 5
15. This mobile service makes me to learn new things. 1 2 3 4 5
16. In my opinion, this is a useful mobile service. 1 2 3 4 5

The Use of Mobile Internet

17. Do you read email with you mobile phone Yes / no
18. Do you use your mobile phone for other internet services. Yes / no

This work was previously published in Mobile Health Solutions for Biomedical Applications , edited by P. Olla; J. Tan , pp. 111-127, copyright 2009 by Medical Information Science Reference (an imprint of IGI Global).

Chapter 3.3

Personal Health Records Systems Go Mobile:
Defining Evaluation Components

Phillip Olla
Madonna University, USA

Joseph Tan
Wayne State University, USA

ABSTRACT

This chapter provides an overview of mobile personal health record (MPHR) systems. A Mobile personal health record is an eclectic application through which patients can access, manage, and share their health information from a mobile device in a private, confidential, and secure environment. Personal health records have evolved over the past three decades from a small card or booklet with immunizations recorded into fully functional mobile accessible portals, and it is the PHR evolution outside of the secure healthcare environment that is causing some concerns regarding privacy. Specifically, the chapter reviews the extant literature on critical evaluative components to be considered when assessing MPHR systems.

DOI: 10.4018/978-1-60566-332-6.ch003

INTRODUCTION

Information technology (IT) is dramatically transforming the delivery of healthcare services. This can be seen through the increased activity in Mobile Health (M-Health) and promotion of the Electronic Health Record (EHR) systems in the healthcare industry and the recent attention and increased activity in the adoption of Personal Health Record (PHR) systems. By distinction, PHR systems have not established a similar height of interest as the EHR (Tang, 2006), but this is changing as more government bodies such as the U.S. Secretary of Health and Human Services, the National Coordinator for Health Information Technology, and the Administrator of the Centres for Medicare and Medicaid Services (CMS) have all identified PHRs as a top priority. In addition to the government organizations involvement, standards organization such as Health Level Seven (HL7) have began the standard definition process to formalize a system model for PHRs.

PHR aims to allow individual health consumers the ability to monitor and manage their personal health information from multiple sources in a single repository. Research shows that maintaining a PHR encourages personal participation in healthcare and cultivates an increased emphasis on communication between the individual and the healthcare provider (Kupchunas, 2007). The use of a PHR provides the opportunity for healthcare providers to monitor and educate patients on health matters and lifestyle changes, and it also acts as a tool for enhancing health literacy. The PHR will eventually improve the decision making capabilities as the patients become more proficient at recording and monitoring vital health information (Lee, Delaney, & Moorhead, 2007). The goal of utilizing personal health records would be to enhance and optimize the healthcare practices while allowing patients to manage their own health care decision-making. For the caregivers, PHR technology can improve efficiency, cost-effectiveness, timeliness, safety, and efficacy of the care processes, whereas for the individual consumers, it can help improve their quality of life. Large organizations and government bodies have recently gained an interest in the PHR phenomenon; for example, Intel, Wal-Mart and BP have formed a consortium, called Dossia, to supply PHRs for their employees; Medicare and Medicaid Services are trialing PHR with Medicare claims; and Google and Microsoft have also entered this market with new products such as Microsoft Health Vault and Google Health. In addition, Verizon Communications in combination with WebMD now offers a password-protected site for PHR (Reese, 2007).

The PHR migration to the mobile platform offers immense benefits such as portability and convenience in the accessing and transmitting of personal health records from a single location, the empowerment of the health consumers to control, verify, and manage their own health information, and the potential enhancement of patient-caregiver relations. Unfortunately these benefits can be overshadowed by the concerns regarding security, privacy, mobile technology choice, and validity of information. This chapter will highlight the important evaluation components that need to be considered when the PHR is modified to support mobility.

The discussion is structured as follows. Following the introduction, the next section describes the history and background of PHRs. Against this backdrop, an overview of the literature and progress being made on PHR research will be highlighted. This will be followed by a discussion on the four categories of PHR systems, namely “individually maintained”, “tethered” to a health plan or employer, “comprehensive” or “Health 2.0”. Once the advantages and disadvantages of the various types of PHR systems have been presented, the discussion will converge on a framework for Mobile PHR systems evaluation, which is then followed by the review of three commercial Mobile PHR systems using components from the framework. The chapter will then conclude with a summary of thoughts on future growth and development in this area.

BACKGROUND AND HISTORY OF PHR

The Personal Heath Record (PHR) is not a completely new phenomenon; accordingly, one of the earliest references to a PHR can be found in an article by Okawa (1973) entitled, “A personal health record for young female students.” Several references to personal health records surfaced prominently as “paper records” up until the mid 1990’s, when the computerized version of the PHR appeared. With the diffusion and general use of computers, individuals became interested in maintaining an electric copy of their personal health information. Sittig (2002) conducted a search of available Internet-based PHR's and came up with 27 identified programs or usable tools; by April of 2003, only 7 of these tools were relevant and still accessible (Sittig, 2002). The demise of these Internet-based companies occurred with the meltdown of the dotcoms, poor business plans, inefficiency, and decreased value to the individual. (Personal Health Working Group, 2005). Even though the early PHR's were ultimately unsuccessful, they provided valuable insight into the next generation of PHR's by supporting the fact that by "adopting EMRs, providers and health care delivery systems can facilitate the development and implementation of PHR tools and PHR's should offer clear benefits to users and critical stakeholders." (Personal Health Working Group)

In summary, PHRs have evolved over the past three decades from a small card or booklet with immunizations recorded on it to a computerized application that stores an individual's personal health information. A report by the Markle Foundation, Connecting for Health (2003), defines PHR's specifically as

"An electric application through which individuals can access, manage and share their health information, and that of others for whom they are authorized, in a private secure, and confidential environment." Page 4

Imperative to the usefulness and functioning of the PHR is the establishment of a common data set. At the very least, it should contain information regarding items such as: allergies and adverse drug reactions, illness and hospitalizations, surgeries and procedures, vaccinations, lab test results, and family history. The National Committee on Vital and Health Statistics (NCVHS) reported in 2005 that it is not possible or even desirable to attempt a unitary definition of a PHR. The NCVHS did however state that it is possible and useful to characterize PHRs by their attributes. Attributes associated with PHRs are elements such as the nature of the PHR's content, the source or sources of information, and the functions that they offer (Sprague, 2006). In retrospect, the consumer and health care provider will be able to maintain this health care information in a way that is assessable to both parties.

More recently, President Bush and Secretary Leavitt brokered a plan that would allow patients and their health care providers the ability to access their personal health records through the use of technology (Gellman, 2008). Having this technological capability ensures that patient and health care provider can access healthcare information at any time when seeking medical care. As a result, in 2001, the National Committee on Vital and Health Statistics identified areas in deliverance of healthcare services that required improvements in systems in order to promote quality patient care services, continuity of care and beneficial treatment modalities. Technological systems were further explored in order to change the way personal health information was maintained by the patient and the health care provider.

The Hurricane Katrina saga in the USA has caused the healthcare industry to recognize the importance of seeking ways to secure personal health records. For years, people had collected, maintained and stored their health information on paper, in memory, and other manual means. During such disaster, all of the information kept by patients and health care providers became inaccessible. But with the advances in technology, consumers are provided with tools and mechanisms to maintain their own health records through the capability of computer-based applications. The consumer then has the ultimate responsibility of keeping track and updating their personal information so that their medical care is effective and efficient. Additional benefits of a PHR include access to health information, data collection, improved health, disease management and tracking, improved communication with health care providers, and although not well documented, it is also believed to lower costs related to chronic disease management and wellness programs (Tang, Ash, Bates, Overhage, & Sands, 2006) According to Kupchunas, "maintaining a PHR encourages increased personal participation in healthcare and fosters a greater emphasis on communication between the individual and the caregivers" (Kupchunas, 2007: pg 185).

PHR Literature Review

PHRs aim to enhance and optimize the healthcare practices while allowing patients to manage their own health care decision-making. On the side of healthcare practices, this would improve efficiency, effectiveness, timeliness, safety; on the side of the patients, it would help them to improve their quality of life. A comprehensive review of the extant literature published on issues related to PHRs using scropus tools (www.scropus.com) is now presented.

Scopus is the largest abstract and citation database of research literature and Web sources. Scropus contains over 33 million abstract and provides access to publications in 15,000 peer-reviewed journals and 200 book series from more than 4,000 publishers. The system also has access to over 1200 Open Access journals, 500 conference proceedings and 600 trade publications. The literature search undertaken not only investigated the bulk of the academic literature but also reviewed data from 386 million scientific Web pages and 22 million patent records from 5 patent offices. Even though our search criteria covered a period of 20 years, we have chosen to present data that are only from the last decade. The search excluded medical health records, electronic health records, and electronic medical records. This essentially directs the review to focus on system functionality of PHRs along with the unique elements associated with a PHR.

PHR FUNCTIONALITY AND COMPONENTS

There have been considerable research and investment into PHRs over the past decade. This is evident in the growing number of publications and patents registered in this area. Based on a review of the extant literature, the main areas of functionality are illustrated in Figure 1.

As shown in Figure 2, the functionality can be broken down into various aspects of consumer functionality (Denton, 2001). Two major aspects, which are considered to be among the most promising uses for PHR system, are the use of PHR for health education and for managing specific patients conditions(Arbogast & Dodrill, 1984; Bent, Bolsin, Creati, Patrick, & Colson, 2002; Bhuyan, 2004). Another aspect is linking the PHR to decision support. This is also a key research component with obvious benefits to the patients choosing and understanding a suitable treatment plan (Abidi & Goh, 2000; Ackerman, 2007). Other important aspects include consumer information (managing clinical and personal data) and the growing use of PHR systems to support and improve administrative support functions.

As issues relating to the area of privacy and security (Agrawal & C. Johnson, 2007; Alban, Feldmar, Gabbay, & Lefor, 2005; Albright, 2007; Alhaqbani & Fidge, 2008; Al-Salqan, Jagannathan, Davis, Zhang, & Reddy, 1995; Anderson, 1996; Armitage et al., 2008; Blobel, Pharow, Spiegel, Engel, & Engelbrecht, 2001) have now become more important than ever given the nature of the new generations of PHR systems, we will examine them separately and more closely in a later section of this chapter.

Although there seems to be a peak in academic research around 2006 (see Figure 1), this has not slowed down the commercial field. There is an increase in Web based activities and patent applications. This shows that as the research matures more commercial offerings are being launched. The industry-based publications are focusing on

Figure 1. Personal health records publications

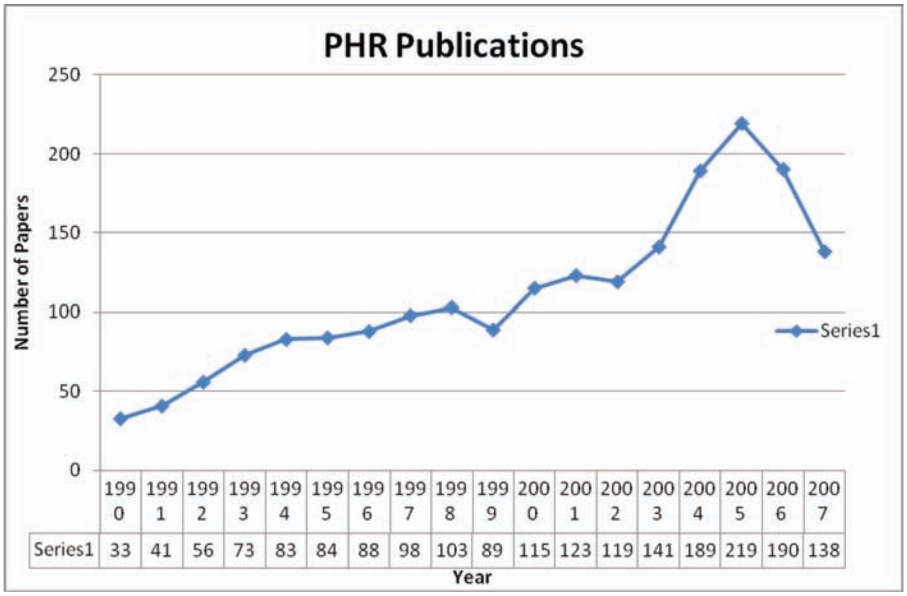
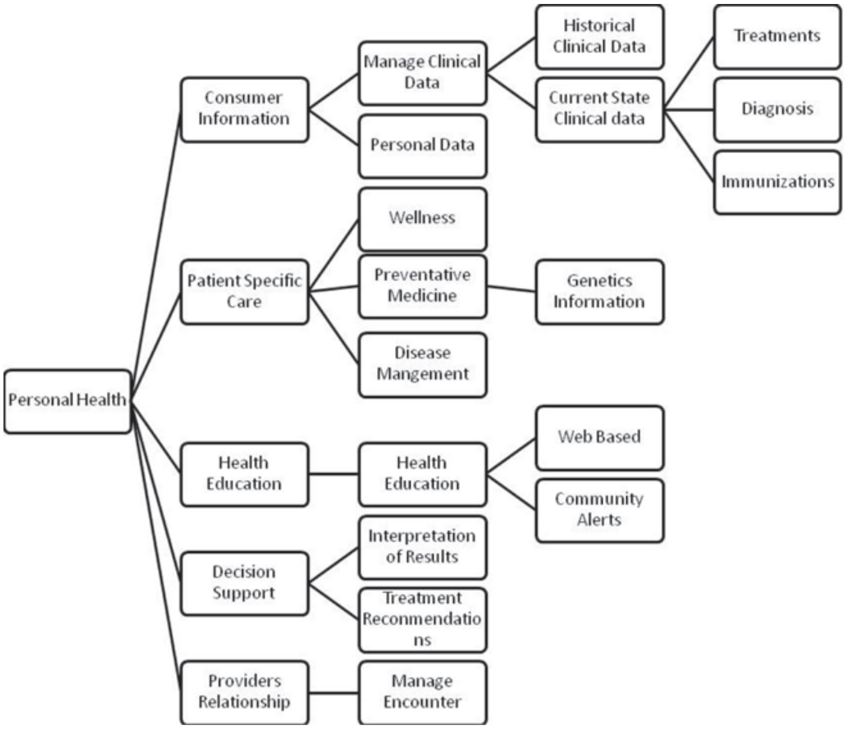


Figure 2. Concept map of personal health records research from literature



issues such as standards, interoperability, security and integration (Ball & Gold, 2006).

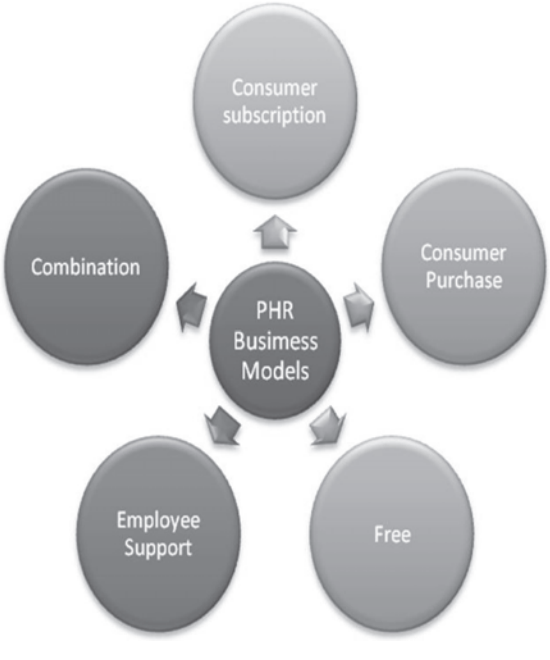
Personal health records are maturing rapidly and several diverse actors' have full-scale implementation of PHR systems - these actors include employer groups such as DOSSIA, and commercial vendors such as Google and Microsoft. The emergence of large organizations such as Google who already hold significant volumes of data about individuals is creating serious concerns. The concept map below provides a snapshot of the current work being undertaken in the field, the research covers a broad spectrum, which highlights the multidisciplinary approach to research in this field.

Business Models

A study by Adler, highlighted the fact that 74.6% of patients surveyed were willing to pay a small annual fee for one or more of the following online services: viewing parts of their medical record, messaging with their physician, medication refills, appointment requests, and billing inquiries (Adler, 2006). A variety of sources, such as healthcare providers, insurers, employer or commercial suppliers offer a wide range of products that are available to help you create your own PHR. Some PHRs include products that have free tools, others offer products for purchase, Figure 3 summarizes the various existing business models.

An array of complex business models exists in the PHR domain. However, from a general marketing perspective, these can be grouped into three commercial types – consumer purchase, consumer subscription, and a combination of the two (Gellman, R. 2008). For the purpose of this review, the business models have been classified into five categories:

Figure 3. Business model for personal health records



1. **Consumer subscription model:** The consumer is responsible for an ongoing service fee to access the data and related systems.
2. **Consumer purchase model:** With this approach the consumer pays a fixed fee to purchase the software that provides the core functionality of the PHR outright. This type is typically a desktop application. The subscriber may also have the option to purchase a support contact.
3. **Free model:** With this model the PHR is free to consumers because the service is supported by advertising.
4. **Employee support model:** With this model, an employer or health plan will contribute part or all the fees to run the service. This is seen as preventative medicine as there is strong evidence that they could save money on health care costs in the long run.
5. **Combination:** There is also the possibility that a combination of these various models could be in effect. For example a PHR service paid for by an employer or health plan may allow advertising.

Although these models may be the obvious source of revenues, there may be other elements in play such as affiliation models with informational Web sites, niche search engines, articles, surveys, software downloads, and a variety of products that are not directly associated with the PHR system.

Prices and formats vary widely, with diverse levels of technical abilities and functionality among the different product lines. From the perspective of Health Insurance Portability and Accountability Act (HIPPA), many of the PHR sites state in their guidelines that they 'comply with', or 'we voluntarily operate within the guidelines', but most mentioned nothing about HIPPA certification. Most sites stated they protect the privacy of personal health information (PHI) and will not share your PHI. A PHR privacy policy study in 2007 conducted by the Department of Health and Human Services (DHHS) stated that "only 3 percent, or one in 30, of PHR privacy policies stated that explicit consumer consent was necessary prior to the vendor sharing any of the data in the PHR" (Gellman, 2008, p. 7). Even though numerous PHRs are free to consumers, a PHR vendor is operating a business, in which revenues are generated primarily through advertising and marketing. Therefore, it is imperative that consumers educate themselves when sharing their information with PHR vendors.

Categorization of PHR Systems based on Ownership

There are many ways to categorize PHR systems, but for the purpose of this chapter, the concept of ownership is used. This approach was taken to highlight the potential issues that arise from transferring ownership. Most of the existing applications fall into three main categories: individually maintained, "tethered" to a health plan or employer, or comprehensive (Sprague, 2006).

A new category, which has also emerged recently and has been added for the purpose of this review, is called health 2.0. It is this new category of PHR applications that is providing serious concerns from a security and ethics perspective.

In order to assist readers attempting to compare and contrast among the different categories, we will also highlight the respective advantages and disadvantages associated with each category.

MOBILE HEALTH 2.0 PHRS

This category refers to the new generation of Web 2.0 healthcare applications that support mobility. Health 2.0 is just as difficult to define as the Web 2.0 concepts. The Health 2.0 conference definition focuses on user-generated aspects of Web2.0 within health care but not directly interacting with the mainstream health care system. The problem with this definition is that it is very difficult to separate the user generated and mainstream healthcare systems without generating duplication and redundancy. Given that there are several definitions, we have decided to share the approach taken by Scott Shreeve from CrossOver Healthcare due to the pragmatic nature of his definition of a Health 2.0 Company:

"Next generation health companies that leverage the principles of openness, standards, and transparency; utilize the technology tools of collaboration, information exchange, and knowledge transfer; and focus on delivering value added services that empower health participants (patients, physicians, providers, and payers) with freedom, choice, and accountability for health outcomes.

There is currently a lot of debate regarding this new concept. Some believe that the these companies are providing a wider movement to reform the entire US health care system, while others believe that these are merely tools and technologies to support the current system. There are considerable concerns when companies that are not within the health care industry take active roles in storing and maintaining personal health data. Most of the companies that operate in this domain are strong advocates for mobility and are keen to integrate mobile technology into their Web portal solutions.

Google is implementing a pilot at Cleveland Clinic hospital in Cleveland as the pilot site for a new personal health records initiative. Between 1,500 and 10,000 patients will partake in the project. Patients will have their current MyChart electronic health records migrated to their Google accounts. Once the PHRs, are shared with Google, patients will have the capability to access them outside of the Cleveland Clinic. Google is not the only technology giant looking to change the healthcare industry. AOL founder, Steve Case, has recently launched a new organization called Revolution Health (http://www.revolutionhealth.com/); InterActiveCorp has also invested in several health-related start-ups (http://www.healthcentral.com/); and Microsoft has been very active with a medical record service called HealthVault.

One of the ways that companies are providing customers with additional benefits is by providing secure access to the health records stored on the portals via a mobile device. At this point, we will highlight the respective advantages and disadvantages associated with the Health 2.0 category.

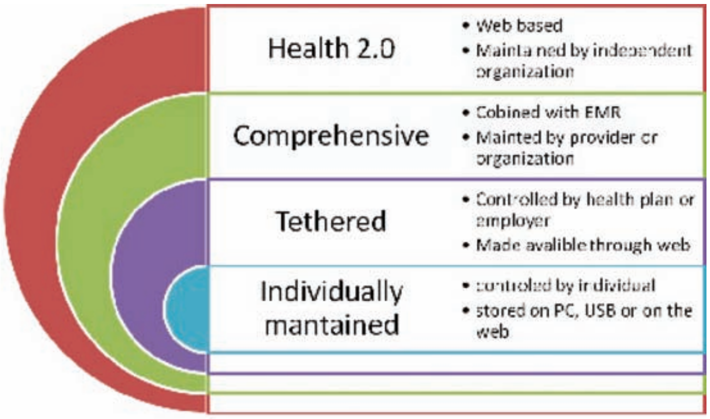
Advantages

- The data is available from anywhere
- Interoperability and the use of open interfaces mean that data can be imported directly from the healthcare provider in some cases.

Disadvantages

- This approach has already raised serious privacy concerns due to the migration of private data into the commercial domain, and critics of such projects have already begun to make themselves heard.
- These third-party PHR systems are not covered by the HIPPA, which has been in effect since 1996 and requires individuals to be notified when a party other than a patient's doctor wants to access confidential medical information.
- There will be some costs associated with the business model.
- Access to the Internet is required to access data via the mobile device.

Figure 4. Personal health records categories



INDIVIDUALLY MAINTAINED PHR

The simplest form of a PHR is one that is maintained by the individual. This sort of PHR is created, updated, and controlled strictly by the individual (Sprague, 2006). Such a PHR allows the individual to organize and retrieve their own health information and it captures the patient's concerns, symptoms, emergency contacts, and other relevant information (Endsley et al., 2006). This type of PHR can be software driven and may reside on a person's computer or be Web-based. The Wed-based format is maintained by a third-party. Other devices such as "smart cards," USB drives, and CDs can also be utilized for this type of PHR (Endsley et al., 2006).

Advantages

The individually maintained PHR has a limited number of advantages, aside from it being controlled by the individual; the security may be the biggest advantage of this type of PHR. The individual PHR provides more control over access to the data contained within the PHR (Tang et al., 2006).

Disadvantages

The question regarding the individual PHR is how often will the individual update their PHR? The individual PHR, as maintained by the individual, may not be updated as often as they should. Another disadvantage is that it may not be considered a trusted conduit for transmission of medical information among clinical offices or health care institutions. Another aspect is the fact that the individual PHR may not have enough back-up systems in place in case of any technical malfunction (Tang et al., 2006). As we discussed the back-up system, we need to also take into consideration the literacy of the individual. How well versed is the individual with regards to medical and technical information? Does the individual understand and comprehend the information and can they relay the information technically (Tang et al., 2006).

"TETHERED" TO A HEALTH PLAN OR EMPLOYER PHR

The "tethered" PHR, populated with claims data and typically available to the consumer through a secure Web portal, is created by a health plan or an employer Web.

Advantages

The main advantage of the "tethered" PHR is the fact that this type of integrated PHR can provide the patient with much more relevant data. It may also provide the patient with a better back-up system, due to the fact that the integrated PHRs have a larger back-up system (Sprague, 2006).

Disadvantages

A major disadvantage to the "tethered" PHR is the lack of portability; for example, the individual who changes jobs or insurance companies may lose access to the personal health information (Sprague et al., 2006). Other disadvantages include security and privacy issues and the question of standardized language (Tang et al., 2006).

COMPREHENSIVE PHR

A more sophisticated PHR is made available through the electronic health record (EHR). A care provider or organization, such as a hospital, physician, or an integrated delivery system, usually maintains the EHR. The EHR is designed to be a repository of clinical information on a patient and to accept information from a variety of sources. The sources of information may include physicians, laboratories, and consumers. The capability of this type of PHR allows the consumer access to some portion of his or her clinical data, under rules set by the provider; it may also allow secure e-mail messaging, access to condition-specific information, appointment scheduling, and many other functions (Sprague, 2006). Different organizations will maintain a range of somewhat differing policies and procedures with respect to availability, accessibility, portability, release and use of personal health information captured in the PHR.

Advantages

The biggest advantage is the access that patients will have to a wide array of credible health information, data, and knowledge (Tang et al., 2006). A secondary but still very important advantage is the potential to lower communication barriers between the patient and health care provider (Tang et al., 2006). Integrated or comprehensive PHRs provide an ongoing connection between patient and physician (Tang et al., 2006).

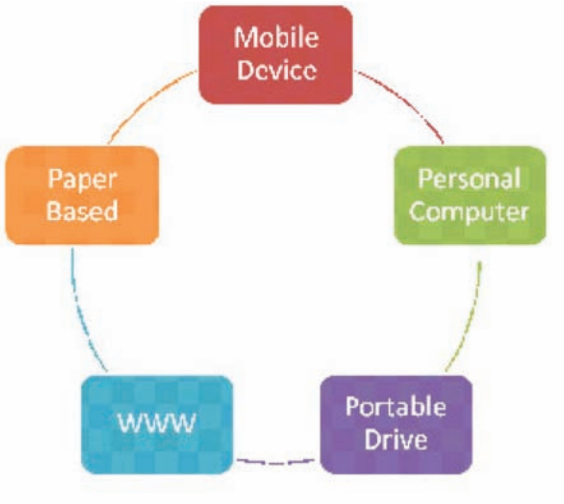
Disadvantages

Many of the disadvantages are the same for the comprehensive as for the "tethered" PHR. The issues of security and privacy and the use of standardized language are being raised with regards to the comprehensive PHR. The World Privacy Forum recently issues a report on why many PHRs can actually threaten security. The next section will discuss some of the important issues surrounding privacy and security of PHR systems

Categorization Based on Storage Medium

There are now organizations that collected, organized, summarized, and then make available electronically copies of all of the medical information. In some cases, the information is provided to user in a wallet or regular CD, or it could be accessed through the Internet. Typically an electronic PHR can be maintained in various formats including paper-based, PC, Internet or portable (flash drive, CDROM, DVD or smart card) or on mobile devices.

Figure 5. Categorization of PHRs based on storage medium



PHR ON THE PERSONAL COMPUTER

PHR products that involved health information residing on one's own computer is one of the most common types of PHR service. . The user typically uses a CD or downloads the PHR template from the Internet to the personal computer. Information about one's health would then be entered and maintained by the user on his or her computer.

PHR ON UNIVERSAL SERIAL BUS (USB) DRIVES

A USB, (Universal Serial Bus), also known as thumb drive or jump drive, is an inexpensive, portable, electronic device used to store information. The USB is a NAND flash device, with memory stored in chips. This architecture allows for low power consumption, fast speed of use, and high density, allowing for storage of large amounts of information (Axelson, 2006). Device memory is "nonvolatile", easily allowing the user to write and erase information. Moreover, these devices are designed to spread the write-erase cycles evenly across the components of the device in order to prolong the device life.

Advantages

Utilization of a USB device for storage of the PHR promotes an important goal, which is, encouraging individuals to become actively involved in their healthcare. With a USB device, the individual manages health information data input and storage (Ball, Smith, & Bakalar, 2007). Once health information is stored on a portable USB device, this information can be quickly accessed anywhere, a factor especially important during emergencies (Shetty, 2007). USB access is a standard feature on all computer systems, and the USB devices allow easy insertion and disconnection without interruption of the system (www.intel.com).

Individuals who advocate for development and utilization of PHRs stress that portability of the PHR is important as individuals move through the healthcare system. A USB would allow individuals to input and integrate data from many different sources, such as electronic health records, laboratories, radiology departments, and pharmacies. With increased consumer awareness of the importance of privacy, confidentiality and information security, a USB device that is individually carried and controlled can be an ideal solution (Ball et al., 2007). One design characteristic of USB devices that makes them desirable for information storage is durability, as the devices have no moving parts with the casing protecting the components (Axelson, 2006). Research of various USB vendors provided information on features available, including continuously increasing storage capacity, overwrite/modification prevention, display of remaining storage capacity, display of owner identity, and ability to perform on-line back up support. Security technology available includes encryption, password protection, requirements for complex passwords, password reset capability, biometric identification verification, and "lost and found" features.

Disadvantages

USB device issues that can be problematic for PHR utilization include potential for device damage and data corruption. In addition, the costs of USB devices increase as the technological and security features become more advanced and complex. Healthcare information is secure on the USB device when in possession of the owner, however, if the device is lost and data on the device is not encrypted or password protected, privacy can become jeopardized (Tang et al., 2006). While the goal of a PHR is to increase an individual's engagement in their own healthcare, those involved in the evaluation and promotion of PHRs question whether consumers are capable and willing to assume the tasks and costs involved in maintaining a stand-alone/USB PHR (National Committee on Vital and Health Statistics, 2006). The ongoing work involved in keeping the USB PHR up to date will most likely be seen as a burden to many consumers. Many providers would not likely see a PHR that contains information stored and maintained solely by individual consumers as a trusted or valid source. Similarly, providers may deem the information stored by consumers as "clinically irrelevant", and if the information were excessive, it would be overwhelming for providers to review (Tang et al., 2006). If providers decide that information contained in the PHR is unimportant, the value of the PHR is adversely affected (Ball et al., 2007). Finally, providers may be concerned with the legal issues involved in the utilization of PHR data, that is, when the treatment decisions they made are based on inaccurate or invalid patient-entered information (Tang et al., 2006).

While utilization of USB devices for PHRs promotes individual's engagement in their healthcare, the ability to interface and integrate healthcare information over time is a priority that an USB/stand-alone record cannot provide as the sole PHR source.

PHR ON THE WORLD WIDE WEB

Personal health records on the Internet are a growing phenomenon. These systems typically consist of a patient's personal health information on the Internet, entered by them and/or possibly by their caregivers. Patients can record their personal information, demographic information, emergency contacts, insurance, medications, allergies, immunizations, tests, hospitalizations, surgeries, advance directive, spiritual affiliation, and even their care plan (Colorafi, 2006). There are several Web sites on the Internet promoting personal health records. In 2001, if you performed a general search on the Internet for personal health records revealed over 19 sites, some of the examples found included Dr. I-Net, HealthCompass, MedicalEdge, MedicalRecord.com, MedicData, Medscape, AboutMyHealth, and many more (Kim, & Johnson, 2001), this number has grown significantly. The Web services begin with a registration process that involves the user choosing a username and password. Through a Web interface, users then complete information about their (or a family member's) health that is stored in a secure server maintained by the PHR company. Users can then access that information (and/or authorize access to others such as emergency contacts, physicians, or ER departments) by logging-in and providing their password.

At this point not too many patients are aware of personal health records. First, many of them are not computer savvy; or since some of the Web sites are subscription based. However, there are some companies that are willing to help out their employees, and are encouraging the use of a PHR. A number of U.S. companies are working together to develop "Dossia", a Web-based framework to assist employees and retirees to create and maintain lifelong personal health records, of themselves and their dependents.

Advantages

There are many advantages to having PHR on the Web for patients, physicians, employers, and pharmaceutical companies. "Technology can allow the use of personal health records that patients themselves can maintain, can allow and promote telehealth systems, and can actually enhance consumer choice" (Colorafi, 2006) Page 3. Several of these sites "allow patients and physicians to share patient-charted information and diagnostic test results. The benefit to the physician and office staff is that it enhances the physician's teaching efficiency and reduces communication bottlenecks when the telephone is the sole communication tool" (Smithline & Christenson, 2001). Another push towards the Internet for physicians is the ease of use with their handheld devices. They are able to research medications, diseases, treatments, as well as patient labs, test results, and even billing, coding, and dictation abilities. Electronic prescribing systems are also on the rise and a great advantage to the physician and patient. These systems increase patient safety and physician efficiency (Smithline & Christenson, 2001). There are many benefits to the use of the Internet and personal health record. "The most important benefit the Internet will bring to health care will be the integration of information" (Smithline & Christenson, 2001).

Disadvantages

1. With all the positive aspects of PHR and the Internet, some major disadvantages includecost and training. In addition, with the increased use of computers and the Internet, there is an increase of technical issues and system downtime.
2. Training staff can be tricky, especially since a large number of health care providers did not grow up with the internet or e-mail.
3. There will be a large cost for training staff in addition to hardware costs, software costs, implementation, maintenance, and productivity improvements (Colorafi, 2006).

PHRS ON MOBILE DEVICES

There is a new trend that is enabling patients to use their mobile devices to access details from their PHR. Patients can use the mobile device for a variety of functions including: maintaining a real-time health diary, and tracking vital health measures such as blood glucose levels, blood pressure, carbohydrate intake, height, weight. This approach can also be used to record and monitor physical activity such as diet, calorie intake or exercise. As people are becoming more reliant on mobile technology to organize and manage day to day routines, accessing and maintaining personal health information on wireless devices is a natural progression.

One approach taken by system developers is to provide functionality that will allow emergency details along with important data such as immunization records, insurance details, and allergy information from a PHR portal to be downloaded to a secure module within a mobile devices operating system. Another approach is to provide access to the PHR via Smartphones / mobile device using the Internet and the mobile network to view and update the records held in the PHR portal. The benefit of the latter approach is the ability to gain access to more detailed information such as clinical records, medical history and interventions.

Advantages

1. Patients can create and maintain comprehensive online PHR accounts via the mobile devices.
2. The mobile devices provide the capability to easily update and manage that PHR at any time, and from any location.
3. Easy and convenient to use for wellness and health monitoring.

Disadvantages

1. If the device is lost and the health data is stored on the mobile device, there could be serious security implications for the patient.
2. The screen for the mobile device may not display all the information clearly due to the size and those users who are not used to mobile displays may find it difficult to navigate and access information.
3. Only limited information can be viewed, while images and notes may be difficult to understand. The mobile version is not a replacement for the Web portal, and the role is to provide an interface to the portal.

Creating a Framework for Mobile PHR Systems Evaluation

The Mobile PHRS framework presented here has been inspired by the Personal Health Record System Functional Model (PHR-S FM), a model proposed by the Health Level Seven (HL7), along with the Evaluation model proposed by (Kim & K. Johnson, 2002). The approach by Kim (2002) provides a comprehensive view of the PHR functions, and identified five prospective functions of PHRs. The model outlined requirements for accurate entry of information and verification of reported test and study results. The criteria also outlined requirements for the provision of different routes of access, links to consumer health care information, functions to process and interpret information, and functions to provide secure communication between patients and providers. This evaluation was constrained by Web based criteria and does not take mobility into consideration. Another important element omitted from the Kim model is the data storage medium.

HL7 is a premier health care information technology standards development organization boasting an extensive national and international representation. The main purpose of the PHR-S FM is to define the set of functions that may be present in PHR systems. The PHR-S also presents a set of guidelines that "facilitate health information exchange among different PHR systems and between PHR and EHR (electronic health records) systems," The HL7 group advocates that "The PHR-S FM can be applied to specific PHR models (stand-alone, Internet-based, provider-based, payer-based, or employer-based models). At the same time, the Functional Model is flexible enough to encourage product innovation." The mobile model presented here also takes into consideration the mobility aspects. The model is currently not an American National Standards Institute (ANSI)-accredited standard. The ANSI accreditation process will take 2 years. This means that the PHR-S FM will become a U.S. standard for PHRs at around 2010. Once the PHR-S FM is finalized by HL7, it will ensure that standards are available to the health care industry and the general public for use in PHR development. There is currently a profusion of PHR systems in existence but there is a lack of a functional standard to which these systems should conform. HL7's PHR-S FM will be the first major industry standard to specify functionality for PHR systems. HL7 proclaims that the development of standardized, interoperable PHRs is a major component in the U.S[1]. DHHS plans, which is to make health information available electronically through a National Health Information Network (NHIN) by the year 2014.

Portability of Records: The HL7 EHR Technical Committee was created in 2005 by the PHR Working Group - the group has members from heathcare providers, consumers, vendors, and payers. The group recently announced that it had entered into a memorandum of understanding (MOU) with America's Health Insurance Plans (AHIP) and the Blue Cross and Blue Shield Association (BCBSA) to create a collaborative process for the maintenance of portability standards for PHRs. AHIP and the BCBSA have already developed an implementation guide (Implementation Guide for the Personal Health Record Data Transfer Between Health Plans) containing technical standards, a data dictionary, and operating rules for the transfer of PHR data elements between health insurance plans. Under the MOU, AHIP and the BCBSA have agreed to turn over the maintenance of the technical standards components of the Implementation Guide to HL7 and ASC X12 to ensure long-term maintenance of the standards.

With considerable research and investment into personal health records over the past decade, and the growing number of publications and patents registered in this areas, our review unveiled that the main areas of PHR functionality or concern can be grouped into four functional areas as illustrated in Figure 6 and Figure 7.

Personal health records are maturing rapidly and several diverse actors' have fullscale implementation of PHRs, - these groups include subscribers, employer groups such as DOSSIA, and commercial vendors such as Google. There are few Web based systems that are fully integrated into ambulatory or hospital-based EMR systems.

There are considerable challenges to implement the ideal PHR system, and there are important lessons that can be learned from the early adopters. A study by Halmaka et al (2008) identified a set of unique implementation issues and concerns from three case studies MyChart at Palo Alto Medical Foundation, PatientSite at Beth Israel Deaconess

Figure 6. Mobile personal health record functional overview

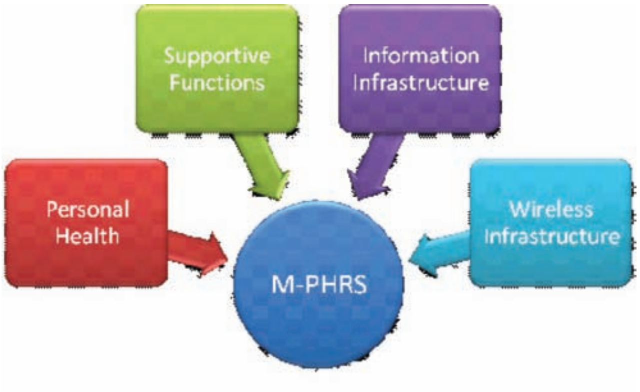
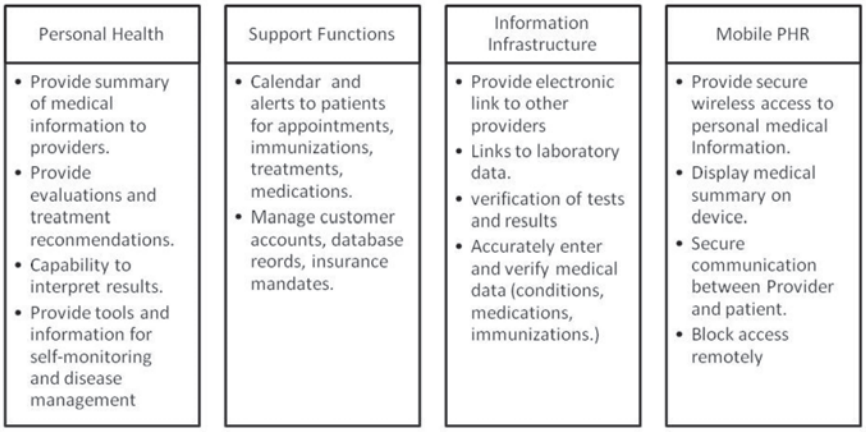


Figure 7. Mobile personal health record functionality



Personal Health	Support Functions	Information Infrastructure	Mobile PHR
• Provide summary of medical information to providers. • Provide evaluations and treatment reconmendations. • Capability to interpret results. • Provide tools and information for self-monitoring and disease management	• Calendar and alerts to patients for appointments, immunizations, treatments, medications. • Manage customer accounts, database reords, insurance mandates.	• Provide electronic link to other providers • Links to laboratory data. • verification of tests and results • Accurately enter and verify medical data (conditions, medications, immunizations.)	• Provide secure wireless access to personal medical Information. • Display medical summary on device. • Secure communication between Provider and patient. • Block access remotely

Medical Center, and Indivo at Children's Hospital Boston. They identified the following implementation challenges from 1999 to 2007, postulating that further challenges are likely to evolve over the next five years.

Current challenging questions facing implemented PHR systems include:

- Should the entire problem list be shared?
- Should the entire medication list and allergy list be shared?
- Should all laboratory and diagnostic test results be shared with the patient?
- Should clinical notes be shared with the patient?
- How should patients be authenticated to access the PHR?
- Should minors be able to have their own private PHR and should patients be able to share access to their PHR via proxies?
- Should PHR include secure clinician/patient messaging?

Future challenging questions that may arise in 2008 and Beyond include:

- PHRs are institution-based and patients will want a single PHR that works with all their sites of care – how can this be achieved?

- Should PHRs support electronic data input from outside institutions?
- How do you allow patients to integrate knowledge sources on the Internet with their PHRs?
- How do you connect patients using social networking tools? Patients with specific diseases may want to connect to communities of others with similar diagnoses
- Patients may wish to participate in clinical trials, post market pharmaceutical vigilance, or public health surveillance via their PHR – how is this possible without compromising security?
- How do you securely incorporate the concept of mobility in a PHR system?

The next section will discuss the wireless and information management element of the evaluation framework, which are important evaluation components of a mobile PHR.

Mobile PHR Information Infrastructure

There are no clear guarantees that the use of any IT applications in healthcare is going to be effective due to the technical complexity of Health IT systems. In the past healthcare software and hardware markets were considered to be less mature than other Industries and for medical technologies (Chiasson & Davidson, 2004). This notion is changing due to the development of new innovative software applications and availability of hardware specifically targeted to the growing healthcare market. The key to the growth in this area has been the launch of software that improves effectiveness by providing functionality to manage the administrative and support functions of healthcare.

It is important that any PHRS system should take into consideration Information Infrastructure from the following Dimensions.

1. **Interoperability:** Interconnectivity among systems is important and managing relationships with various healthcare providers in a seamless and efficient manner along with providing user-friendly processes and interfaces to perform administrative functions are key features that must be considered in the design of a PHR.
2. **Information management:** Question about how the data is to be stored, how often will it be backed up, and what storage medium is in place are key to successful information management.
3. **Record security:** A variety of options may be available such as password protection, biometrics, and encryption, but the challenge is to fit the best mechanism to the purpose and design of the PHRs.
4. **Audit capabilities:** With growing security and privacy concerns, measures must be in place to provide detailed audit of access to the records.

It is vital that any MPHRS is evaluated on the audit capabilities. Clear and comprehensive audit policies must be defined that describe the use of patient medical records within the system. The policies should not only aim to protect the confidentiality and integrity of data but also protect the patient. One of the important features of the new generation of PHR systems is their ability to interconnect electronically using predefined interfaces or XML based interfaces. All sub systems transferring data need to provide secure interconnection capabilities between the host systems and the PHR database. The data must be protected in terms of data integrity and patient privacy.

Security policies for personal health information must be carefully designed in order to limit the number of people, clinical physicians, insurance companies, nurses, and others, that can access the patient record, and to control the operations that may be applied to the record itself (Anderson 2006).

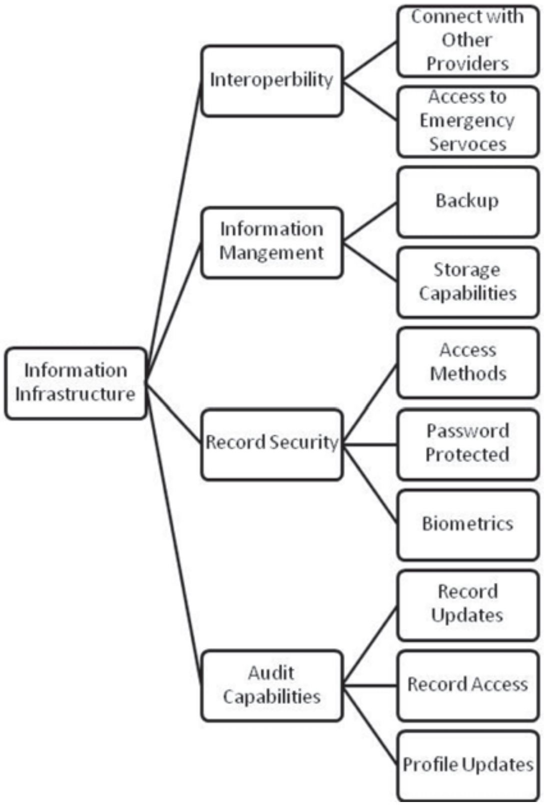
Jelena (2007) defines clear policies that are appropriate for wirless clinical information systems, these policies have been adapted to a PHR. These policies are discussed below as a number of security procedures:

- Each record must have an associated access control list - a list that restrict access to the records other than those individuals and groups identified on the access control list.
- There must be an individual on the access control list that must have administrator privileges and/or rights, i.e., the power to add other users to the access control list. It is critical that the administrator notifies the patient of any changes of names on the access control list to any part of the patient records.
- An audit log of usage activity must be presented to the user. Each time the record is accessed the following information must be presented - the name of the user performing the access, the date and time of access, and the manner of access (including records read, updated, stored, and/or deleted) - and has to be recorded.
- When the patient is incapacitated, the ownership of the records should belong with the legal guardian or another person with the appropriate power of attorney, not the person with the patients' mobile device.

WIRELESS NETWORK COMPONENTS

The adoption of mobile technologies in healthcare is on the increase and technologies such as Wireless Local Area Networks (WLAN) that use different protocols from the standard digital mobile technologies such as 2G, 2.5 and 3G technologies. A summary of these technologies are presented below along with the speeds and range covered.

Figure 8. Information infrastructure components



It is important to understand how the device will connect to the Internet to access private health information as some networks are more secure than others. The ease of access that wireless networks offer is matched by the security and privacy challenges presented by the networks.

One of the key concerns surrounding the implementation of Mobile PHRS is the issue of security. Moving a PHR into the mobile realm compounds these security fears. There are four types of security breaches that can occur.

1. **Data duplication:** PHRs raise the possibility of storing health data in multiple storage locations. For example in the EMR, Hospitals databases, and the PHR. In a mobile scenario this issue is compounded because the data may also exist on the mobile device.

2. **Data transmission issues:** Using open unsecured networks such as wireless local area networks (wifi) to transmit personal health information will leave users open to security vulnerabilities. The system must detect when using an unsecured network and prevent the release of information in that scenario.
3. **Lost devices:** If the device is lost, the data server must prevent that device from accessing medical information from that device. If the functionality is embedded within the SIM card the device must prevent the embedded functionality as well.
4. **Virus and malware:** There is a growing trend of Viruses being targeted at mobile devices due to the proliferation of mobile devices.

MOBILE PHR SYSTEMS REVIEW

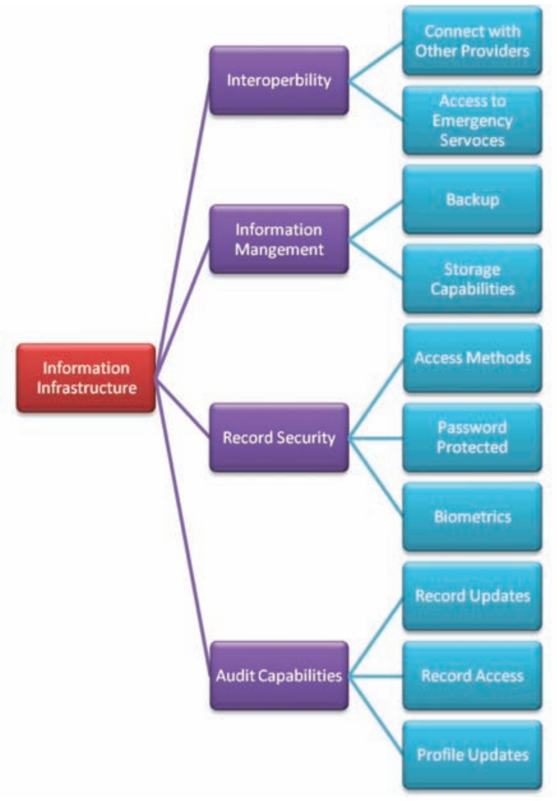
There are a variety of configurations that can be employed for a mobile PHR system. Each of the approaches provides a variety of benefits along with potential security vulnerabilities. The section will use the evaluation framework defined in the previous section to review three commercial PHR systems that support mobile phone access.

System 1: In Case of Emergency (ICE) PHR Mobile

This PHR product is a combination of CapMed products, icePHR and Microsoft HealthVault. The aim here is to make appropriate medical records freely available "In Case of Emergency (ICE)". The user has the capabilities to modify what pieces of their information will be accessible in an emergency situation by using a Web application. The full medical record resides within the HealthVault eco-system and is transferred into the icePHR. The icePHR emergency data are viewed by three methods.

1. displayed through a personalized icePHR Web site,
2. wallet-size emergency card,
3. Mobile client side wallet.

Figure 9. Wireless system components



The Wallet is the client-side portion of the application and resides on the mobile phone or personal computer. The personal health information located externally or privilege information is accessed right to the wallet. The mobile device would need to receive a software installation which can be delivered over-the-air. Vault Server: the Wallet communicates with the MobiSecure Vault Server for data synchronization and management. The role of Server-based software is to securely host, manage and retrieve personal user data from external data sources. The Personal Health record application must be hosted on the server side of the provider of the Vault Server software. The user

Table 1. Wireless networks

Networks	Speed	Range and Coverage	Main Issues for M-Health
2nd Generation GSM	9.6 kilobits per second (KBPS)	World wide coverage, dependent on network operators roaming agreements.	Bandwidth limitation, Interference.
High Speed Circuit Switched Data (HSCSD)	Between 28.8 KBPS and 57.6 KBPS.	Not global, only supported by service providers network.	Not widely available, scarcity of devices.
General Packet Radio Service (GPRS)	171.2 KBPS	Not global, only supported by service providers network.	Not widely available.
EDGE	384 KBPS	Not global, only supported by service providers network.	Not widely available, scarcity of devices
UMTS	144 KBPS - 2 MBPS depending on mobility	When fully implemented should offer interoperability between networks, global coverage.	Device battery life, operational costs.
Wireless Local Area	54 MBPS	30–50 m indoors and 100–500 m outdoors. Must be in the vicinity of hot spot.	Privacy, security.
Personal Area Networks – Bluetooth	400 KBPS symmetrically 150 -700 KBPS asymmetrically	10 – 100m	Privacy, security, low bandwidth.
Personal Area Networks – Zigbee	20 kb/s – 250 KBPS depending on band	30m	Security, privacy, low bandwidth.
WiMAX	Up to 70MBPS	Approx. 40m from base station.	Currently no devices and networks cards.
RFID	100 KBPS	1 m Non line-of-sight and contact less transfer of data between a tag and Reader.	Security, privacy.
Satellite Networks	400 to 512 KBPS new satellites have potential of 155MBPS.	Global coverage.	Data costs, shortage of devices with roaming capabilities. Bandwidth limitations.

has the capability to view, submit or send, via fax, email or SMS, the user's selected data.

IcePHR Mobile is a mobile device accessible software application that provides the capability to store and manage emergency medical information and contact numbers in a mobile phone. This product requires that the user subscribes to icePHR subscription. Mobile devices must meet the requirements of installing and running the custom icePHR Mobile application to allow the data to be stored on the phone negating the need for a data link connection. The application will allow subscribers the editing capability to insert, update and delete medical information directly on the icePHR server when Internet access is available.

The icePHR application is only supported on specified networks and on a number of certified handsets, which includes smartphone, blackberries and standard mobile phone handsets that run java Midlet.

The phones that do not incorporate the technology to install and run the icePHR Mobile™ application can use the WAP to view medical information stored on the server. To use WAP, the handset must have a built in Web browser such as Media Net. Unlike the Java icePHR Mobile application where medical data are stored on the device, using the WAP access method no information is stored on the device nor can the user edit the records over WAP.

Table 2. Evaluating three commercial MPHR Systems

Criteria	System 1	System 2	System 3
System Name	ICE PHR	No More Clipboard	allOne Mobile
System Description	software application that provides the capability to store and manage emergency medical information and contact numbers the a mobile phone.	Mobile Web based patient-controlled personal health record management system designed to consolidate medical information	All*One* Mobile cell phone-based application. to manage personal health information. Patient information
Network	2G or 3G Cellular requires data plan and SMS Plan	Access via mobile Internet browser using WiFi	Access via mobile Internet browser using WiFi
Device - OS	RIM 3.6, J2ME 1.1, Windows mobile for Pocket PC and Smart phone 2003+	Any device with Internet access	Blackberry RIM Java, Windows mobile for Pocket PC and Smart phone 2003+
Devise - Type	Mobile Phone (singular, sprint devices), Smartphone or PC	Any mobile device with Internet capabilities	Any mobile device with Internet capabilities
Information management	Application is downloaded and stored on the device	Application is run from the server. The user accesses the information via navigating to the home page on the mobile device	Application is downloaded and stored on the device
Data Storage	Stored on Device. (There is also an option to store data on server for non supported handsets	All the data is stored on the server	Data is stored on both the server and device
PHR Capabilities	Provided by ICEPHR and Microsoft Health Vault	Provided by Nomoreclipboard.com. Can integrate with Microsoft health vault	Integrates with online PHRs via community of Care (CCR) standards
Business Model	Add on to the ICE PHR subscription	Subscription only	Subscription only
Access technology	Uses WAP for non supported devices	Via mobile browser. Future enhancement will allow cellphone technology to access sever	Via mobile browser.

System 2: No More Clipboard M-PHR

NoMoreClipboard.com is an online, patient-controlled personal health record management system designed to consolidate medical information in one convenient and secure location for easy retrieval and updates. NoMoreClipboard.com provides Web-based solutions to maintain an online personal health record (PHR). The system also provides cell phone integration capabilities. Patients with Internet-enabled Smartphones such as the Palm Treo or Apple iPhone can interact with a PHR if they have an account with NoMoreClipboard. This approach requires the user to be connected to the Internet as no data is downloaded to the device. To gain access to the Web portal from a mobile device the users points their Smartphone browser to the PHR portal address and a version of the PHR application optimized for mobile devices is presented.

Future functionality will include the capability to send reminders, receive appointment alerts, medications reminders, or follow care plan directives. The Patients will also have the capability to capture pain levels or illness symptoms as they occur and insert this information directly into the PHR. Patients will also be able to capture and store images from their phone into their PHR. From a security perspective the site uses Secure Socket Layer (SSL) account security. Although the information is secured behind a firewall, accessing the information over non-secured network can lead to security vulnerabilities. An application under development that uses Binary Runtime Environment for Wireless (BREW) will allow patients with standard Code division multiple access (CDMA) based wireless devices to access their PHRs. A Short Messaging Service (SMS) interface is also being developed to enable communications between patients and the PHR system.

System 3: AllOne Mobile MPHR

All*One* Mobile cell phone-based application was created by the All*One* Health Group Inc. to manage personal health information. Patient information is stored behind a password-protected, encrypted channel using Diversinet wireless security application. All*One* Mobile uses mobile technology to facilitate the exchange of critical health information between individuals, providers, and health plans. This application downloads wirelessly a small application to the mobile device, which accesses the patients PHR stored securely on the Internet. The PHR system allows updates from the mobile device. The application supports all smartphones and the majority of non-business mobile consumer devices. The All*One* Mobile application supports the following features.

- Storage of confidential personal information, including provider and insurance information, allergies, immunizations, and medications
- Synchronize their mobile device with Web based PHR.
- Fax PHR information from a Mobile device
- Control access to receipt of relevant and timely communications on health care–related topics

All*One* Mobile integrates with existing health care information systems and applications, including existing online PHRs.

CONCLUSION

The goal of the MPHR system is to provide secure and controlled access to personal health informationat anytime via a mobile device to improve health outcomes. Mobile PHRs can provide patients with a variety of functions including: maintaining a real-time health diary, and tracking of vital health measures such as blood glucose levels, blood pressure, carbohydrate intake, height, weight.

This chapter presented a framework adapted from the HL7 PHR functional model and PHR literature.The purpose of the framework is to define the set of functions that may be present in Mobile PHR systems and to highlight important components that must be taken into consideration when evaluating Mobile PHR systems.

The growing number of large technology organizations entering the PHR landscape will eventually help the industry by driving standards forward, developing open interfaces and generating awareness of the products and implementing solutions that incorporate mobility on the one hand, and satisfying standards requirements and regulatory policies such as HIPAA privacy and security rulings on the other hand.

The key challenge that is likely to evolve from the influx of non healthcare organization delivering PHR systems runs parallel with Electronic Medical Records (EMR) and EHRs prior to HIPPA rules and regulations, enacted by the USA congress in 1996. These problems included the denial of health care coverage to individuals with chronic and genetic predispositions to diseases and the release of personal health information. Ultimately consumers must exercise extreme caution when utilizing and implementing a mobile or Web based PHR.

REFERENCES

Abidi, S., & Goh, A. (2000). A personalised Healthcare Information Delivery System: pushing customised healthcare information over the WWW. *Studies in health technology and informatics*, 77, 663-667.

Ackerman, M. (2007). The personal health record. *The Journal of medical practice management: MPM*, 23(2), 84-85.

Adler, K. (2006). Web portals in primary care: An evaluation of patient readiness and willingness to pay for online services. *Journal of Medical Internet Research*, *8*(4). doi:10.2196/jmir.8.4.e26

Agrawal, R., & Johnson, C. (2007). Securing electronic health records without impeding the flow of information. *International Journal of Medical Informatics, 76*(5-6), 471-479.

Al-Salqan, Y. Y., Jagannathan, V., Davis, T., Zhang, N., & Reddy, Y. (1995). Security and confidentiality in health care informatics. In *Proceedings of the ACM Workshop on Role-Based Access Control* (pp. 47-51).

Alban, R., Feldmar, D., Gabbay, J., & Lefor, A. (2005). Internet security and privacy protection for the health care professional. *Current Surgery, 62*(1), 106-110.

Albright, B. (2007). Prepping for PHRs. The growing trend of consumer empowerment includes the speedy rise of personal health records. *Healthcare informatics: the business magazine for information and communication systems, 24*(2).

Alhaqbani, B., & Fidge, C. (2008). *Access control requirements for processing electronic health records, 4928*, 371-382.

Anderson, R. J. (1996). Security policy model for clinical information systems. In *Proceedings of the IEEE Computer Society Symposium on Research in Security and Privacy* (pp. 30-43).

Arbogast, J., & Dodrill, W. (1984). Health maintenance and the personal computer. *Journal of Family Practice, 18*(6), 947-950.

Armitage, J., Souhami, R., Friedman, L., Hilbrich, L., Holland, J., Muhlbaier, L., et al. (2008). The impact of privacy and confidentiality laws on the conduct of clinical trials. *Clinical Trials, 5*(1), 70-74.

Ball, M., & Gold, J. (2006). Banking on health: Personal records and information exchange. *Journal of healthcare information management: JHIM, 20*(2), 71-83.

Bent, P., Bolsin, S., Creati, B., Patrick, A., & Colson, M. (2002). Professional monitoring and critical incident reporting using personal digital assistants. *Medical Journal of Australia, 177*(9), 496-499.

Bhuyan, K. (2004). Health promotion through self-care and community participation: Elements of a proposed programme in the developing countries. *BMC Public Health*, *4*, 11–31. doi:10.1186/1471-2458-4-11

Blobel, B., Pharow, P., Spiegel, V., Engel, K., & Engelbrecht, R. (2001). Securing interoperability between chip card based medical information systems and health networks. *International Journal of Medical Informatics, 64*(2-3), 401-415.

Chiasson, M. W., & Davidson, E. (2004). Pushing the contextual envelope: developing and diffusing IS theory for health information systems research. *Information and Organization, 14*(3), 155-188.

Denton, I. (2001). Will patients use electronic personal health records? Responses from a real-life experience. *Journal of healthcare information management: JHIM, 15*(3), 251-259.

Gellman, R. (2008). Personal Health Records and Personal Health Record Systems. *The World Privacy Forum*.

Halamka, J., Mandl, K., & Tang, C. (2007). Early Experiences with Personal Health Records . *Journal of the American Medical Informatics Association*, *15*(1), 1–7. doi:10.1197/jamia.M2562

Jelena, M., & Vojislav, B. M. (2007). Implementation of security policy for clinical information systems over wireless sensor networks . *Ad Hoc Networks*, *5*, 134–144. doi:10.1016/j.adhoc.2006.05.008

Kim, M., & Johnson, K. (2002). Personal health records: Evaluation of functionality and utility. *Journal of the American Medical Informatics Association, 9*(2), 171-180.

Kupchunas, W. (2007). Personal health record: New opportunity for patient education. *Orthopaedic Nursing, 26*(3), 185-191.

Lee, M., Delaney, C., & Moorhead, S. (2007). Building a personal health record from a nursing perspective. *International Journal of Medical Informatics, 76*(SUPPL. 2).

NoMoreClipboard.com. (2008). PHR Launches Cell Phone Integration. *Business Wire.* Oct 29, 2007.

Okawa, T. (1973). A personal health record for young female students. *The Japanese Journal for Midwife*, *27*(11), 36–40.

Sittig, D. (2002). Personal health records on the internet: A snapshot of the pioneers at the end of the 20th Century. *International Journal of Medical Informatics*, *65*(1), 1–6. doi:10.1016/S1386-5056(01)00215-5

Sprague, L. (2006). Personal health records: the people's choice? *NHPF issue brief / National Health Policy Forum, George Washington University*, (820), 1-13.

Tang, P., Ash, J., Bates, D., Overhage, J., & Sands, D. (2006). Personal health records: Definitions, benefits, and strategies for overcoming barriers to adoption. *Journal of the American Medical Informatics Association, 13*(2), 121-126.

Thielst, C. B. (2007). The New Frontier of Electronic, Personal, and Virtual Health Records. *Journal of Healthcare Management*, *52*(2), 75–78.

ENDNOTE

[1] www.hl7.org/ehr.

This work was previously published in Mobile Health Solutions for Biomedical Applications, edited by P. Olla; J. Tan pp. 45-70, copyright 2009 by Medical Information Science Reference (an imprint of IGI Global).

Chapter 3.4

Adoption of Mobile Technology by Public Healthcare Doctors:

A Developing Country Perspective

Nesaar Banderker
University of Cape Town, South Africa

Jean-Paul Van Belle
University of Cape Town, South Africa

ABSTRACT

South African doctors working in the public healthcare sector are faced with the unique resource constraints prevalent in a developing country. Mobile information and communication technologies (ICTs) hold the promise of improving the quality of healthcare, but this potential can only be unlocked if individuals decide to adopt the new technologies. Understanding the factors that influence the doctor's adoption of a technology is therefore vital. This article reports on an investigation into the factors influencing the adoption of mobile devices by doctors in the public healthcare sector in the Western Cape, South Africa. The research methodology was shaped by qualitative enquiry and described through thematic analysis. The authors confirmed the key adoption factors identified in prior research: job relevance, usefulness, perceived user resources and device characteristics. However, some additional adoption factors were uncovered in this research, namely patient influence, support structures from national government and hospital administration, and unease in respect of malpractice legal suits.

BACKGROUND

Healthcare in South Africa

Healthcare is a key component of South African society, socially and economically (Chiasson et al., 2004). Total healthcare spending in South Africa is 8.7% of GDP which is substantially above the norm of 5% recommended for developing countries by the WHO (Chetty, 2007). The *public* healthcare budget alone totalled R47.8 billion (approximately US$ 6.7 billion) in 2006, representing 4.27% of GDP. This represents a substantial growth compared with 1995 when it stood at only 1.84% of GDP. However, despite these efforts by the new democratically elected government, huge inequalities remain. The budget of the private sector, which services less than 8 million people, exceeds that of the public sector servicing 38 million (Chetty, 2007). Much of this remains a legacy of the pre-1994 apartheid era inequalities institutionalised through labour laws and highly unequal provision of services for different racial groups (Department of Health, 2004). There is still a movement of skilled resources from areas of poverty and low socio-economic development to more wealthy areas. Doctors who have recently qualified and completed their compulsory two years working for the public healthcare sector are either moving into private practice or leaving South Africa to work in other countries (Padarath et al., 2003). This results in a scarcity of skilled clinical resources in the public healthcare sector.

Although doctors working in the public healthcare sector are highly skilled, their available time is preciously sliced to try and diagnose and care for as many patients in a day as is possible. 80 to 85% of the South African population has access to public healthcare facilities only (Chetty, 2007). A doctor in the public day hospital environment is expected to diagnose, treat and manage about 40 patients during an 8–hour shift. This means that the doctor spends an average of only 12 minutes with each patient. Doctors in public healthcare also have to work extremely long shifts of sometimes more than 30 hours. Due to this extreme pressure, doctors can easily make an incorrect diagnosis or prescribe the incorrect patient management routine. Patients attending these public hospitals have to wait in long queues to be seen by the doctor. When they finally see the doctor, the visit is rushed. A full examination of the patient is not always possible and this could result in inadequate care of the patient.

ICTs offer tremendous potential in supporting the public healthcare function in the South African society. Although administrative healthcare information systems have been implemented, the shift to systems that support the clinical work performed by healthcare professionals directly has been slow to take off (Andersen, 1997). Better ICT support would, in turn, enable doctors to facilitate the provision of high quality, better informed and cost-effective public healthcare to all the citizens of South Africa.

Mobile Technologies in Healthcare

Mobile technologies can bring immense benefits to the healthcare environment (Varshney, 2006), because it is so information intensive (Li, Chang, Hung & Fu 2005). Doctors do most of their work at the point of care, which is the patient. This means that they move around between wards, outpatient clinics, diagnostic and therapeutic departments and operating theatres. This movement, together with the fact that most South African public hospitals usually only have one central computer terminal per ward, makes it extremely difficult to service all the needs of the doctor. The use of ICTs in support of this point of care activity of the doctor is what is relevant to this research. Mobile device technologies are quite suitable for supporting the doctor at the point of care. They are small, lightweight, can be carried around with the doctor and usually come with some form of networking protocol built into the device (Porn & Patrick, 2002). Mobile devices are also becoming more affordable and offer more processing power and storage capabilities (Varshney, 2006). Mobile technology ranges from cellular telephones, pagers and PDAs, to very sophisticated tablet computers. Key benefits, as summarized from a large number of studies, include a reduction in medical errors, time savings, better quality care and higher productivity (Lu, Xiao, Sears & Jacko, 2005).

A number of studies have looked at adoption of mobile computing devices. An excellent, systematic analysis of surveys of healthcare providers' PDA adoption is given by Garritty & Emam (2006) who found adoption rates in developed countries to vary between 45% and 85%. For instance, in a longitudinal study of mobile technology 33% of Canadian doctors reported use of a mobile device in their clinical practice in 2003, up from 19% in 2001 and 28% 2002 (Martin, 2003). By contrast, a similar study at selected healthcare institutions in Florida revealed that as many as 95% of the respondents to the survey owned a mobile computing device (Joy & Benrubi, 2004). The study also showed a pattern of perceived benefit for using the devices to maintain procedural statistic logs, pharmacology reference manuals and personal clinical protocols; but respondents did not perceive a massive time saving. Both studies also show quite a sharp increase in mobile device technology adoption by doctors.

Porn and Patrick (2002) and Hameed (2003) identify a number of healthcare applications that could be run successfully on a mobile device:

E-Prescription

This allows doctors to access basic patient information and check formulary compliance before writing the prescription. Potentially harmful drug interactions can be determined and often a patient's personal medication history is available. Prescriptions can be printed or transmitted directly to a pharmacy. The main benefits are a reduction in medication errors and less calls from pharmacies due to illegible handwriting (Berkowitz, 2002).

Charge Capture

This application allows a doctor to view schedules, capture patient charges and access or update patient information all at the point of care.

Order Entry

Applications to order certain tests could be scheduled, delivered to a central processing unit and acted upon. This will reduce errors due to misplacement of application forms.

Test Result Reporting

The results of the tests can be delivered directly to the mobile device. This will free doctors from having to refer to a specific PC workstation to retrieve test results.

Medical Information

Access to the latest medication formulary, disease description, symptoms and treatment as well as access to clinical procedures can be provided on a mobile device.

More technical descriptions of how mobile technologies can work in healthcare sector can be found in numerous sources, e.g. (Varshney, 2006)

Adoption Models and Healthcare

In order to realise the full potential and promise of healthcare information systems, technologies and applications, a better understanding of the organisational context as well as people and social issues is required. The adoption of mobile technologies in the healthcare sector involves both an organisational and an individual aspect. The organisational context or motivational factors that drive mobile ICT adoption is a relatively under-researched field; refer to Khoumbati & Themistocleous (2006) for an overview of relevant research and a comprehensive framework. The focus in this research is on the *individual factors* that drive mobile technology adoption in healthcare, with particularly focus on the doctors.

Because explaining human behaviour in all its complexity is quite a daunting task, a variety of models have been developed to explain and predict user behaviours and intentions. The most widely used of these models are the diffusion of innovation (DOI) theory published by Rogers (1995), the theory of reasoned action (TRA) (Ajzen & Fishbein, 1980), the theory of planned behaviour (TPB) (Ajzen, 1991) and the technology acceptance model (TAM) (Davis, 1989). These models have been well tested, validated and proven to be reliable when used in the evaluation of user acceptance in studies of business organisations, corporations and even students. However, there is less research evaluating technology adoption using TPB, TRA, DOI within a healthcare context.

In validating TAM and its extensions, researchers have determined some key factors that are of significance for use in general technology adoption models. These include perceived ease of use, perceived usefulness, perceived user resources, voluntariness, experience, subjective norm, image and computer self-efficacy. However, doctors are professionals who are particularly highly skilled, knowledgeable, autonomous and pragmatic decision makers. This impacts on the applicability of a number of constructs and causes some of the models not to behave in the way determined by prior research in other contexts. For instance, Hu & Chau & Tam (1999) found that the original TAM did not correlate well with doctor's intentions to use a new technology. When reviewing literature on the adoption of healthcare technologies by medical professionals the majority of the studies found apply to general healthcare systems such as telemedicine, internet health and clinical systems (Chau & Hu 2002, Chismar & Patton, 2003, Horan et al., 2004) while some studies were found that applied specifically to mobile healthcare (Wu, Wang, & Lin, 2005, Harkke, 2005; Li et al., 2005; Lu et al., 2005; Varshney, 2006; Wu, Wang & Lin, 2007).

Overall, however, researchers find the TAM-inspired models to be a successful approach to explaining the adoption of mobile technologies in the healthcare sector, with Wu et al., (2007) purporting to be able to explain up to 70% of the variance in behavioural intention to use mobile healthcare systems. These studies found the following factors to be of relevance when researching adoption in a healthcare setting:

- **Perceived usefulness/Job relevance:** A new technology needs to be useful to its user. Usefulness is defined as causing an increase in the doctor's productivity by being relevant to the doctor.
- **Perceived user resources:** The extent to which an individual believes that they have the personal and organisational support to use the device. This was validated by Horan et al. (2004) and Lu et al. (2005) whose research discovered that workplace compatibility played a more important role in predicting user intentions than the current TAM construct of perceived ease of use.
- **Subjective norm:** People who are close to the doctor could influence the doctor by their opinions of whether the device should be used or not.
- **Image:** Doctors will perceive the use of a mobile technology device as enhancing their status within their working environment. This was validated by Succi and Walter (1999) who state that doctors will more likely be influenced by the impact of the use of the new technology on their professional status. Further research has contested the idea that social processes of subjective norm and image would influence the decision to adopt. This is seen to be a result of the pragmatic nature of doctors in decision making, as well as a reliance on their own assessment rather than that of others. However, in the context of South Africa where being a medical doctor is often seen as a status symbol the two factors of subjective norm and image will

be retained to ascertain whether they would play a positively influencing role.

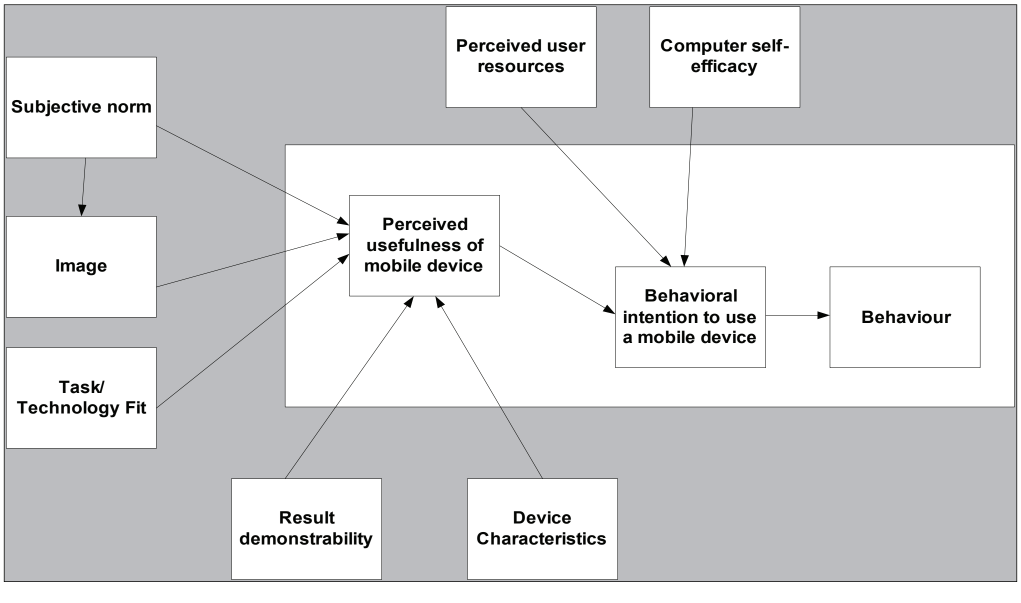
- **Task/technology fit:** A study by Chau & Hu (2002), added this factor – defined as alignment with current work practices – to TAM. It was thought that doctors would more likely adopt a new technology if it aligned closely with their current work practices.
- **Result demonstrability:** The technology should visibly improve the doctor's quality of care provided and enhance his effectiveness thus improving the quality of the doctor's work

Furthermore, in the evaluation of TAM2 (Venkatesh & Davis, 2000) by Chismar and Patton (2003), it was found that the construct of perceived ease of use showed an insignificant effect when used to predict intention of doctors. It has also been found that for technologies that are not mandated for use by the healthcare institutions, the construct of voluntariness can be removed from the model. In studies of a new technology the construct of experience can also be removed, since it was intended to measure the adoption of existing technologies. Due to the high intellectual and cognitive capacity of doctors, they appear to understand new technologies quicker. Doctors are therefore individuals with a high level of self-efficacy. This makes a good argument for the removal of the computer self-efficacy construct from the model. However, due to mobile technologies being relatively new to the South African market and not being widely diffused this factor will be included in the model developed.

The above research reduces the significant factors in the context of doctors' intention to use a mobile technology device to subjective norm, image, task/technology fit, result demonstrability, perceived user resources, computer self-efficacy and the technology device characteristics. These factors are summarized graphically in Figure 1.

The factors listed above formed the starting point for the research interviews.

Figure 1. Significant influencing factors



RESEARCH OBJECTIVE

Despite the purported advantages of mobile technology there is a distinct lack of adoption of this technology in the public healthcare sector in developing countries in general, and South Africa in particular. The public healthcare sector is recognized as having lagged behind other South African industries, such as the financial sector, in the use and adoption of new information technologies (Bower, 2005). ICTs encompass a wide range of technologies.

This research hopes to provide a better view as to *what* the significant factors influencing the adoption of innovative mobile technology solutions by public healthcare doctors to support them in their daily clinical activity are. More specifically, the objective of this research is to identify key factors that hinder or assist doctors' adoption of mobile technologies in healthcare.

Identifying these significant factors of influence will hopefully also provide an *insight* into how ICT solutions for healthcare should be developed, marketed, implemented and who the key stakeholders in the adoption process are. This research is particularly relevant because it cannot be assumed that research conducted in developed world contexts is applicable to developing countries.

RESEARCH METHODOLOGY

The factors identified in the literature (see figure 1) forms the basis for the framework that could be tested against public healthcare doctors. This section addresses the problems of *who* to test the framework against and *how* it will be tested.

Strategy

This research follows an exploratory qualitative research design strategy. It is exploratory since it is not directly involved with hypothesis testing and theory evaluation. It is more directly involved with laying a basic descriptive foundation to explain and understand the possible factors influencing adoption of a mobile technology device by doctors. A qualitative study was chosen over a quantitative one since the former allows for a better understanding of the people, and the social and cultural context in which the technology adoption can occur. Also, richer data sets from which factors influencing the possible adoption of mobile technologies can be obtained by discourse between people instead of having them complete a questionnaire. We believe that our specific qualitative approach complements the quantitative approach adopted by (Wu et al., 2007) who summarized a large number of quantitative adoption studies, and the evidence/opinion-based qualitative approach of (Lu et al., 2005) into adoption factors.

Site Selection and Sampling

The study was conducted in the two largest public healthcare facilities in Cape Town, namely the Groote Schuur Hospital (widely known because of the first heart transplant) and Tygerberg Hospital. These hospital are directly associated with the University of Cape Town and the University of Stellenbosch respectively. They are of similar size, offer very similar services, have similar administrative processes and are analogous to the rest of South Africa's academic public hospitals.

Due to time, resource and financial constraints as well as the limited time availability of doctors, a convenience sampling method was used. Possible doctors were identified by two doctors acting as the researcher's contacts in the hospitals and were selected based on their willingness to take part in the research since all participation was voluntary. Although a convenience sample allowed the researcher to skirt many of the resource issues mentioned, this did come at the expense of possibly compromising the generalisability and representativeness (Pare, 2004). In total, twelve doctors were interviewed. The interview sample was made up of doctors from each of the South African racial profiles.

Data Collection

Participant interviews were used as the primary source of gathering data. The interviews were semi-structured, with set questions as well as open-ended questions. Basic demographic data was also collected from the doctors. Key questions were developed around all the significant factors of influence identified during the literature review (Figure 1 above) with additional questions being derived from Chismar and Patton (2003). Questions were not necessarily asked in the order they were set out since the conversation dictated which question would be asked next. The complete list of the questions is available from the authors. A checklist was kept during the interview to ensure that all questions were asked. Interaction and discussion usually led to further follow-up questions of both explanatory and exploratory nature (Ritchie & Lewis, 2003).

The interview was recorded on an audio recording device, freeing up the interviewer to more closely observe the interviewee and possibly gain some further insight from the visual clues provided by the interviewee. A protocol for conducting the interview was established. This ensured that each interview process was consistent. It also helped ensure that standard items like obtaining consent, providing the interviewee with basic information about the research and informing them that the interview would be recorded, would not be forgotten.

As a departure point for starting the discussion, pictures of other mobile technology devices were shown to the interviewees. In addition, the interviewees were also shown a physical Nokia 9300 with a demonstration of some of the medical software obtained for the device, namely a drug formulary program, a fracture analysis program and a nutrition analysis program.

Data Analysis

There are many methods of analysis suggested for the interpretation of the data collected. These include Hermeneutics (Klein & Myers, 1999), Grounded Theory (Sarker & Wells, 2003), Semiotics – which includes content analysis, conversation analysis and discourse analysis – and thematic analysis (Ritchie & Lewis, 2003). However, these modes of analysis work to develop theory in most cases and fit closely with the interpretive paradigm (Fitzgerald & Howcroft, 1998). A thematic analysis of the textual data was performed, as recommended by Ritchie and Lewis (2003).

The analysis process that was followed can be described as follows:

- The recorded data from the interviews was listened to. While listening to the recording, reflective remarks about the interview and the data from the interview were made. This allowed for the visualization of the researcher's perceptions and ideas (Miles & Huberman, 1994).
- A coding scheme that is consistent with the theoretical propositions identified during the literature review was then developed (Hammersley & Atkinson, 1983). Additional codes were created for ideas presented by the interviewee that did not fit into the original coding scheme.
- The coding scheme was used to allow the segmentation of the data into units that are easily mapped to the theoretical propositions identified during the literature review. The scheme also allows for easier organization and retrieval of the data.
- These codes were then grouped together in logical units which formed higher order categories.
- For these categories a response from each interviewee was mapped. This formed the basis of a thematic chart. The visual nature of a thematic chart helped in discovering

connections between coded segments (Miles & Huberman, 1994).
- From this thematic chart, themes were developed by checking the occurrence of a certain idea and the language used by the interviewee.
- These themes were then used to answer the objectives of the study.

An important consideration in qualitative research is the reliability of the findings. Although a "mere count" of quotations or mentions is not necessarily an appropriate measure, a strong and consistent pattern across respondents does contribute towards a stronger confidence in the results. It was found that there was indeed a surprising degree of agreement between the various respondents and thus the table with the occurrence frequencies for the various factors has been included (Table 2 in the Appendix).

FINDINGS AND DISCUSSION

The results obtained by the analysis of the interview data as well as a discussion of these results are presented together in order to maintain a logical flow of information. Since the data analysis was done using a thematic analysis, the findings will be presented in the themes identified. These themes can also be referred to as the adoption factors identified.

Postulated Themes

Perceived Usefulness of a Mobile Device

The doctors agreed unanimously that the mobile technology device would be very useful and relevant to them. Two of the older doctors, however, could only conceptualise the device being useful by providing information to them. Even so, the information that they thought the device would be able to provide was of enough importance to warrant them stating that it would help in providing better medical care to their patients. "*I know I would be able to obtain electronic versions of certain reference manuals for such a device and I could use this as a source of information."*

This use as an information providing tool was confirmed when a doctor emphatically stated that he *"currently carr[ies] 2 to 3 management reference books around with me. I know that there is an electronic version of all 3 books available for the iPaq."*

The younger doctors could conceptualise many other exciting uses for the device. A few of the solutions that really excited the doctors are:

- Making paper records of patients obsolete: *Such a device could make the need for paper records obsolete. All patient information could be stored electronically and accessed from this device and not from the only PC assigned to an entire ward. This will make missing folders and folders not containing up-to-date patient information a thing of the past.*
- Not having to struggle with reading illegible notes and other information: *Doctors handwriting is generally quite poor and illegible. This device could make incorrect prescriptions due to bad writing a thing of the past.*
- Mobility: *Patient information could be delivered to such a device when you walk into the ward. This would alleviate the need to consult the slow, outdated PC assigned to the floor.*
- As a decision support tool: *I will have the latest available patient management information and with this can ensure that the patient is treated correctly.*

However the doctors did strongly indicate that the device would never be able to replace their skill and training and actually make the decision for them.

Most of the imagined uses envisaged by the doctors are a reality in more developed countries. Examples of mobile electronic patient record systems exist (Turisco & Case, 2001). E-prescriptions systems which make the "illegible" handwriting problem of doctors obsolete also exist (Berkowitz 2002). The transmission of real-time patient information using mobile devices and telecommunication infrastructure has been implemented in Sweden and the Netherlands (Wu, Wang, & Lin, 2005). There are also examples of medical reference material on mobile devices being useful in certain situations (Harkke, 2005).

Social Influences

A strong statement *against* the effect of social influences guiding a doctor's decision to use a mobile technology device was made. One of the older doctors hesitated when answering the questions regarding status. When clarifying her hesitation she stated: "*Indian doctors, especially the older ones, were usually recommended by their parents to become a doctor.*" This was usually for the prestige that came with being able to say that one's child is a doctor as well as the desire to have their children "be better off than the parents". This image of the medical profession being one of status was hard to totally avoid for an Indian doctor. The remainder of the doctors did not agree with the statement that status, image or peer influence will have some bearing on their decision to use the device. "*I would not at all be influenced to use this device by my peers nor would I think of it as increasing my status.*"

There was one softly conflicting statement of "*...as more doctors start using these devices you will become the odd one out for not using one…*" but when explored further it developed into the fact that doctors would only use the device when found to be useful and relevant to their daily clinical activity: "*If I see a colleague using such a device and he is able to provide better care to his patients I would most definitely be influenced to get one.*"

Perceived User Resources

When asking the interviewees questions around perceived user resources, they were quite emphatic that they did not believe they would obtain support for the use of a mobile technology device from within the public healthcare environment. There was a feeling of hopelessness when talking about the public hospitals IT support structures. One aspect of the lack of support related to the level of skills: "*I believe that the hospital IT department is not highly skilled and would take some time to adjust to support a more innovative device like this Nokia 9300.*" It was also felt that the hospital IT department was under-resourced and would not be able to cope with the added support required for the mobile technology device:

They barely cope with just running the daily activities of the hospital. How will they cope with the added support required for this device?

Even though doctors felt that public hospitals did not have the resources to support the use of such a device, they would not be negatively influenced by this:

The hospital might not support the device but that still will not stop me from using it.

The doctors also felt they had the necessary personal resources and skill to use the device.

The University [...] needed an online MMed program for family medicine. The university provided a very basic infrastructure to do this and the doctors lecturing in the department did all of the rest to provide this online program."

Computer Self-Efficacy

All the doctors interviewed considered themselves to be highly skilled professionals who had daily interaction with computers. "*I have an interaction with computers throughout my working day.*" The fact that 10 of the 12 doctors did not have much prior experience with mobile technology devices did not scare them away from using the device: "*As a highly skilled professional I think I am capable of learning to use a new technology from a user manual.*"

Device Characteristics

Ten doctors expressed an initial concern that the limited screen size of the handheld devices might make it less useful: "*Perhaps the screen on this device would not be able display information very legibly*" and "*I don't think a web page will display very nice on such a small screen*". However, some were quite surprised at the amount of information displayed with the drug formulary program on the Nokia 9300: "*That displays information in a very comprehensive manner and with one click of page down you can see the rest of the information.*"

There was a surprising request that the device be able to withstand small liquid chemical spills from the pathology doctors. This was due to the fact that they work with chemicals for most of their day and would probably leave the device lying around near chemicals. *"Would the device be able to withstand a chemical spill?"* The fact that it could not withstand substantial liquid spills and therefore liquid chemical spills even less did not detract from their eagerness to use the device. *"Ok, so it can't. I don't think that this will stop me using it"*

Both loss and theft of the device was also a major consideration for the doctors. "*I think such a device would easily be able to get feet.*" However, the two doctors who were high adopters of a mobile technology device said that doctors would have to learn to take care of the device in a similar manner in which they care for their stethoscopes.

The software demonstrated to the doctors was accepted with great enthusiasm. "*That could most definitely help me as a look up when I don't know what the drug does*" and "*You could look up side effects to make certain there will be no complications for the patient.*" The doctors were enthusiastic that the technology would be able to help them deliver better quality care. This is supported by the uses they conceptualised for the device. One of the doctors working in an emergency trauma unit, where rapid diagnosis and accurate patient management are essential, was sure that a mobile device could further ensure that patient management was in line with the diagnosis as well as being the most effective one and aiding in the fight for the patient's life.

Emerging Themes

A number of additional themes were identified during the analysis of the interview data. They do not form part of the original significant factors of influence identified during the literature review and appear to be specific to the healthcare environment.

Patient Influence

An addition to the social influences theme that was not part of the original significant factors was the patients' perceptions of the doctor if they should see the doctor using a mobile technology device. When talking about a patient's perception of the doctor if the patient should see the doctor using a mobile technology device to reference information from, there was a majority consensus that the patient's perception would *not* negatively influence their decision to use the device. This was conveyed strongly through statements like: "*It will help me improve the care and management provided to the patient and result in a much* *improved patient outcome*"; "*I will not mind at all to use the device to look up information in front of a patient*" or "*Patients should understand or be educated that having the latest information available as a reference tool will be of great benefit to them at the end of the day*".

However, two doctors did say that they would be hesitant to use the device while sitting with the patient: "*The patients might question my competence if they see me looking up information in front of them with this device. The same goes for looking up information from a book.*" However, that would not stop them from using the mobile device to look up information, just that they would not do it while the patient was sitting with them. "*I would most definitely use it when not in front of a patient*" or "*If I needed to look up information then and there I would go to another room and then come back.*"

By contrast, it was also mentioned by one of them that patients are starting to move away from the idea that a doctor should know everything. They are generally starting to ask more questions about the conditions they are diagnosed with. He did say that a mobile device might be useful in explaining conditions graphically to patients, as they would more readily be able to understand a picture than a wordy explanation. "*When patients ask questions about their medical condition, we could perhaps provide a clearer explanation to patients using such a device to display information graphically.*"

Malpractice Legal Suit

Another social influence factor was identified by the pattern of doctors wanting to use the mobile technology device as an information and decision support tool, reflecting the growing unease amongst the doctors of the increasing trend of malpractice legal suits being brought against doctors. This device could help doctors prevent such a situation from arising: "*This will help in action that could be taken against the doctor for incorrect treatment and management.*" If such a device could keep a history of the patient and all decisions made regarding diagnosis and treatment, it could help defend the doctor's decisions: "*An audit of patient information and history, patient management and drugs prescribed could be kept.*"

This unease of legal action being brought against the doctor was also discovered during the discussion on patient influence. So long as the patient knew that the device was being used to make 100% certain that the correct diagnosis and management of the patient takes place, doctors would use the device in front of a patient.

Management and Government Support

Even though these two factors of hospital administration and government help could form part of perceived user resources on a micro-scale it is the macro-scale that was being referred to by the doctors. They were referring to national government and healthcare management and the fact that healthcare could not escape the political reality it found itself in. This is why these two factors are regarded as separate from the de facto definition of perceived user resources.

Support from the managerial structures of the hospital evoked responses tainted with a lot of emotion: "*The people in hospital management have completely forgotten what it is like to be a doctor. They seem to be fighting for some of the wrong things.*" There was a unanimous agreement between all doctors interviewed that absolutely no support would be garnered from the management of public hospitals for the purchase of mobile technology devices: "*Even if we proved to them how useful such a device would be and how it would increase my productivity and improve patient outcomes, I really don't think they would spend money on it.*"

However, this stance is understandable in the context of South Africa as a developing country with more than 70% of working age adults being unemployed, 53% of the population living below the poverty line and 20% of the population being HIV positive (Department of Health, 2004). There are too many needs for the already thinly sliced portion of resources cake provided to the public healthcare sector by the South African government with problems of HIV, TB and inadequate resources deemed to receive more share of the healthcare budget: "*In a developing country like ours we have too many other health concerns to warrant healthcare budgetary expense on such a device*"; "*TB, HIV, infant mortality and cost of health services to the general public all take priority on already scarce financial resources*" and "*Our hospitals are overcrowded and you cannot spend money on a nice-to-have while you do not have beds for patients or doctors to service the patients.*"

When asked whether an external party would not be able to perhaps put some pressure on the hospital management to incorporate a mobile technology device into use in the public hospitals, there was mostly exasperation in the voices of the interviewees. It was said that no such external party exists. Not even the provincial or local government would be able to do this. They set out the budgets for each hospital and stipulate at a very high level what the money should be spent on:*"Government allocates the hospital budget for the year and they stipulate at a very high level where the money should be spent."*

Even then, these stipulations are guidelines and it is up to the hospital management to decide how this money is spent: *"It is up to the hospital management using the government guidelines to spend the money allocated to the hospital"* and *"They would not be able to say exactly on what the money should be spent. They will say that so and so an amount is allocated to information technology. It is up to the hospital management to decide what specific IT to spend the money on."*

This relative freedom to spend the money allocated results in a lot of political battles within the hospital management. This means that sometimes scarce resources are not properly allocated by the hospital management: *"They seem to be fighting for the wrong things"* or *"The management cannot collectively decide what the money should be spent on. This results in this one wanting this and that one wanting that."*

This results in poor administration of the hospital, as well as poor outdated equipment being used. This also results in poor working conditions for doctors, of which the patient has ultimately to bear the consequences.

These findings show that there is a clear statement being made by the doctors that no support would be given to them by the hospitals in the use of a mobile technology device. However, this lack of support for the adoption of a mobile technology device by the environment doctors find themselves in will not detract from there willingness to use the device. In fact 10 of the 12 said that they would purchase the device from their private funds as they could see many potential uses for the device: "*So long as it does not cost too much and the benefit it will add is quite visible, I will not mind paying for it*"; "*I don't think I would mind paying for such a device out of my own pocket if one can be found for about R3500*" (≈ US$500).

It was mentioned that if the use of the device was privately funded, hospital management would grab the opportunity to use the device in the hospital. "*If a company like HP came and privately funded such a device they would jump at the opportunity.*"

Patient-Doctor Relationship

Two of the doctors mentioned that they rarely worked directly with patients: *"I don't work directly with patients. I perform tests on blood samples from the patient."*

These doctors did therefore mention that they would not be influenced negatively in the use of a mobile technology device by patients' perception of them. They were also less worried about malpractice legal suits than their colleagues who worked directly with patients: *"Because I don't work with patients, I would be less worried about these legal suits. I would still worry but far less than my other colleagues."*

Another factor that distinguished these doctors from the ones that worked directly with patients was their perception of what the mobile device could offer them. They were less interested in using the device as an information or decision support tool and more interested in having the device act as a workstation for them. They wanted the device to be integrated into the hospital systems they used so that they were not tied down to a desk: *"If we could have the test results delivered directly to this device so I can report on it, it would help me greatly and I would not be tied down to my desk or my outdated computer."*

They did not however fully understand the intricacies of integrating such a device directly into the hospital systems even though they showed some understanding of security concerns that might be raised by this integration: *"I know that with such a device it will have to be very secure since we are dealing with confidential patient information."*

They did however understand that having the device fully integrated into all the hospital systems would be beneficial to them and make them more productive: *"They upgraded our result reporting application this year but to me it is more of a downgrade. This new application is not integrated into anything else. You cannot even export data to Excel and this makes life exceptionally difficult for us."*

SUMMARY AND CONCLUSION

The data analysis revealed that the factors of job relevance, usefulness, task/technology fit, result demonstrability, computer self-efficacy and device characteristics were in agreement with the findings of previous research on ICT adoption in healthcare. The more technically competent doctors are, the more likely their intention to use a mobile technology device. Where doctors found the device relevant and useful to their daily clinical activities, they would use the device. The better the device and its software could support them, the greater would be their intention to use such a device. Table 1 lists the adoption factors identified as significant during this research.

Could these factors form part of a generalised technology acceptance model for innovative technology in the South African public healthcare sector, along the same lines as (Wu, Wang & Lin, 2007)? We suggest that the hospitals from which participants were obtained are comparable to the rest of the South African public hospitals: doctors working in these hospitals face similar working conditions, challenges, administrative tasks and resource shortages. Their opinions could therefore be seen to be fairly representative for the South African public healthcare sector. This would mean that the factors identified could form a revised TAM for South African public hospitals; this could be researched using quantitative means.

In conclusion, the research shows that South African public healthcare doctors are eagerly looking for ways to support themselves in their daily clinical activities. They can conceptualise many uses for a mobile technology device, many of which are already a practical reality in countries like the USA, UK and many countries in Europe. Using the device as an information and decision support tool can be made a reality for public healthcare doctors in South Africa. This will not only provide much needed support to overworked doctors, it will also help improve healthcare outcomes for the majority of the South African public. The key stakeholders involved in the public healthcare function, the government, healthcare management and ICT industry, can help push the adoption of these devices. The ICT industry could get involved by developing strategic partnerships with the public healthcare sector. These partnerships can be used firstly for the showcasing the

Table 1. Adoption factors identified by the research

Factors	**Supports the literature?**	**Comments**
Perceived usefulness of a mobile device	Yes	In general a very positive perception of mobile technology devices by doctors was evident even though half of them had never come into contact with one before. They perceived the device being able to provide them with relevant information either via the internet or software for the device. They perceived the device as a reference tool, patient information tool and even contemplated its use as a decision support tool that could help in diagnosis and medication prescription.
Social influences	**No**	Doctors in public healthcare in the Western Cape display a professional maturity that does not allow factors like image or subjective norm to influence them.
Perceived user resources	**No**	Lack of resources to support their use of these devices by the hospitals did not negatively influence their intention to adopt. This could be attributed to the social circumstances South African doctors find themselves in, where they have learnt to cope with limited resources on a daily basis. Despite their extremely pressurised work environments, and poor hospital management and administration, patient care is uppermost in their minds.
Computer self-efficacy	Yes	Concurred with previous research (Chismar & Patton 2003), that due to the high self-efficacy beliefs of doctors this factor can be ignored even when researching an innovative technology in a South African context.
Device characteristics	Yes	Doctors would be negatively influenced by characteristics they regarded as being important for them.
Task/technology fit	Yes	The medical profession is a very information intensive one (Harkke 2005) and doctors realised that this device would be able to help keep abreast of the latest information.
Result demonstrability	Yes	Doctors believed that the technology would be able to help them deliver better quality care to their patients.
Patient influence	New	Doctors did not feel intimidated by possible patient perceptions on their doctor's use of the device. Most doctors did however expect that the patient perception would be positive anyway.
Fear of legal action	New	Underlying doctors' perceptions of the device as an information tool was an unease in respect of malpractice legal suits. It was thought that the technology could aid the decisions made. This could help reduce the possibility of incorrect diagnosis and treatment and perhaps legal action against the doctor.
Management and government support	New	Negative sentiments were expressed about the lack of national healthcare structures and government support for the use of such a device. Nevertheless this did not appear to influence their personal intention to adopt mobile technology. It was however felt that these structures should be providing more impetus for the use of these devices.
Doctor-patient relationship	New	Where doctors do not interact with patients, a number of the above factors are not applicable. Thus this can be seen as a moderating variable or factor on the other factors, especially patient influence and fear of legal action.

potential of mobile devices to the public healthcare sector. Once an interest is shown the partnerships can be used for the development of standards, infrastructure and solutions. Government can involve themselves through e-government initiatives and push the concept of mobile technology and healthcare. Hospital management can become involved by starting to support initiatives to help doctors provide better quality care to patients by using these devices as they have envisaged in this research, as a reference-, decision support- and record keeping tool.

The interpretation of the research results should take into account a number of limitations. Firstly, the sample was quite small and, to an extent, self-selected. Also, other stakeholders, especially hospital management and patients, were not interviewed. Finally, the perceptions of mobile technology are influenced by potential and actual use thus many responses could have been based on incorrect or incomplete conceptualisations of potential mobile technology application(s).

ACKNOWLEDGMENT

This article is a revised and updated version of a paper initially presented at the European Conference on Information Systems and later expanded into a chapter in the Handbook of Research on Advances in Health Informatics and Electronic Healthcare Applications. The feedback of the anonymous reviewers is hereby gratefully acknowledged.

REFERENCES

Ajzen, I. (1991). The theory of planned behaviour. *Organizational Behaviour and Human Decision Processes*, *50*, 179-211.

Ajzen, I., & Fishbein, M. (1980). *Understanding Attitudes and Predicting Social Behaviour*. Eaglewood Cliffs, NJ: Prentice-Hall.

Andersen, J.G. (1997). Clearing the way for physicians' use of clinical information systems. *Communications of the ACM*, *40*(*8*), 83-90.

Berkowitz, L.L. (2002). Clinical informatics tools in physician practice. *Healthcare Informatics*, *19*(*4*), 41-44.

Bower, A.G. (2005). *The diffusion and value of healthcare information technology*. Santa-Monica, CA: Rand Publishing.

Chau, P.Y.K., & Hu, P.J. (2002). Examining a model of information technology acceptance by individual professionals: An exploratory study. *Management Information Systems*, *18*(*4*), 191-229.

Chetty, K.S. (2007). *Equity Promoting Health Care Policies in South Africa*. Report to the Health Systems Knowledge Network. Retrieved Jan 10, 2008 from: http://www.wits.ac.za/chp/kn/Chetty%202007%20Equity.pdf

Chiasson, M., Davidson, E., Kaplan, B., Lau, F., & Reddy, M. (2004, September). *Interdisciplinary windows for studying information systems in healthcare: Challenges and opportunities*. Paper presented at IT in healthcare: Socio-technical Approaches Second International Conference, Oregon, USA.

Chismar, W.G., & Patton, S.W. (2003). Does the extended technology acceptance model apply to physicians? *36th Hawaii International Conference on System Sciences*, Hawaii.

Davis, F.D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly*, *13*(*3*), 319-340.

Department of Health (2004). *National HIV and Syphillis Antenatal Seroprevalence Survey in South Africa 2003*. Retrieved January 10, 2008, from http://www.doh.gov.za/docs/2003hiv-f.html.

Fitzgerald, B., & Howcroft, D. (1998, December). Competing dichotomies in IS research and possible strategies for resolution. *AIS International Conference on Information Systems*, Helsinki, Finland.

Garritty, C., & Emam, K. E. (2006). Who's Using PDAs? Estimates of PDA Use by Health Care Providers: A Systematic Review of Surveys. *Journal of Medical Internet Research*, *8*(2), e7.

Hameed, K. (2003). The application of mobile computing and technology to health care services. *Telematics and Informatics*, *20*, 99-106.

Hammersley, M., & Atkinson, P. (1983). *Ethnography: Principles in Practice*. London: Tavistock.

Harkke, V. (2005). Physicians' usage experiences of a mobile information system. *38th Hawaii International Conference on System Sciences*, Hawaii.

Horan, T.A., Tulu, B., Hilton, B., & Burton, J. (2004). Use of online systems in clinical medical assessments: An analysis of physician acceptance of online disability evaluation systems. *37th Hawaii International Conference on System Sciences*, Hawaii.

Hu, P., Chau, P., & Tam, K. (1999). Examining the technology acceptance model using physician acceptance of telemedicine technology. *Journal of Management Information Systems*, *16*(*2*), 91-112

Joy, S., & Benrubi, G. (2004). Personal digital assistant use in Florida in obstetrics and gynaecology residency programs. *Southern Medical Journal*, *97*(*5*), 430-433.

Khoumbati, K., & Themistocleous, M. (2006). Integrating the IT Infrastructures in Healthcare Organisations: a Proposition of Influential Factors. *The Electronic Journal of e-Government, 4*(*1*), 27-36.

Klein, H.K., & Myers, M.D. (1999). A set of principles for conducting and evaluating interpretive field studies in information systems. *MIS Quarterly*, *23*(1), 67-94.

Li, Y.C., Chang, I.C., Hung, W.F., & Fu, H.K. (2005). The critical factors affecting hospital adoption of mobile nursing technologies in Taiwan. *Proceedings of the 38th Hawaii International Conference on System Sciences*, Hawaii, USA.

Lu, Y.C., Xiao, Y., Sears, A., & Jacko, J.A. (2005). A review and a framework of handheld computer adoption in healthcare. *International Journal of Medical Informatics, 74*(*5*), 409-422.

Martin, S. (2003). More than half of MDs under age 35 now using PDAs. *Canadian Medical Association Journal, 16*(*2*), 952-952.

Miles, M. B., & Huberman, A. M. (1994). *Qualitative Data Analysis: An Expanded Sourcebook*. Beverly Hills, CA: Sage.

Padarath, A., Chamberlain, C., McCoy, D., Ntuli, A., Rowson, M., & Loewenson, R. (2003). Health personnel in Southern Africa: Confronting maldistribution and brain drain. *Equinet discussion paper no. 4*. Health Systems Trust, South Africa.

Pare, G. (2004). Investigating information systems with positivist case study research. *Communications of the Association for Information Systems*, *13*, 233-264.

Porn, L.N., & Patrick, K. (2002). Mobile computing acceptance grows as applications evolve. *Healthcare Financial Management*, *56*, 66-70.

Ritchie, J., & Lewis, J. (2003). *Qualitative Research Practice: A Guide for Social Science Students and Researchers*. London: Sage Publications.

Sarker, S., & Wells, J.D. (2003). Understanding mobile handheld device use and adoption. *Communications of the ACM*, *46*(*12*), 35-40.

Turisco, F., & Case, J. (2001). *Wireless and Mobile Computing*. Health Reports, California Healthcare Foundation.

Varshney, U. (2006). Using wireless technologies in healthcare. *International Journal of Mobile Communications*, *4*(*3*), 354-368.

Venkatesh, V., & Davis, F.D. (2000). A theoretical extension of the technology acceptance model: Four longitudinal field studies. *Management Science*, *46*(*2*), 186-204.

Wu, J.H.,Wang, S.C., & Lin, L.M. (2005). *What drives mobile healthcare? An empirical evaluation of technology acceptance. 38th Hawaii International Conference on System Sciences*, Hawaii.

Wu, J.H.,Wang, S.C., & Lin, L.M. (2007). Mobile computing acceptance factors in the healthcare industry: A structural equation model. *International Journal of Medical Informatics, 76*(*1*), 66-77.

APPENDIX: OVERVIEW OF RELATIVE SUPPORT FOR VARIOUS FACTORS

The following table summarizes the relative support for positively influencing factors (✓ = support, ✓✓ = strong support) or inhibiting factors (×). Blank cells indicate a lack of influence under current conditions.

Table 2. Consistency of support for influencing factors between respondents.

Influencing Factor	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12
Device usefulness	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓
Job relevance	✓	✓✓	✓✓	✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓
Status			✓✓									
Image												
Subjective norm				✓								
Perceived user resources												
Computer Literate	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓
User Efficacy	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓
Size of screen	×	×	×	×	×			×	×	×	×	×
Theft	×	×	×	×	×			×	×	×	×	×
Task/technology fit		✓✓	✓✓		✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓
Patient Perception		×	×									
Fear of legal suit			✓✓		✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓
Management support												
Government support												

As can be gleaned from the table, there generally seems to be a high degree of correspondence or agreement between doctors. This is therefore a fairly strong indication of the reliability of the research findings, despite the small sample.

This work was previously published in the International Journal of Healthcare Delivery Reform Initiatives, Vol. 1, Issue 3, edited by M. Guah, pp. 38-54, copyright 2009 by IGI Publishing (an imprint of IGI Global).

Chapter 3.5

Wireless for Managing Health Care:

The Wirhe Framework

Esko Alasaarela
University of Oulu, Finland

Ravi Nemana
University of California - Berkeley, USA

Steven DeMello
Health Technology Center, USA

Nick S. Oliver
Imperial College, UK

Masako Miyazaki
University of Alberta, Canada

ABSTRACT

The Wirhe project is an international collaborative study that focused on the future of healthcare needs, technology requirements and solutions for effective use of wireless technologies for health care delivery. This paper presents results of a Wirhe survey of 85 experts and individual interviews with 35 experts. Key findings include: 1) both notable quality improvements and process enhancements can be expected from effectively utilizing wireless technologies and mobile solutions, 2) integration of personal health monitoring and professional health management is a key issue to be addressed and 3) health promotion and illness prevention efforts can grow by utilizing mobile solutions. We propose a framework that can be used in developing wireless health care solutions for managing diseases and related health problems. This framework can also be used to structure and stratify the needs of technologies and solutions, and to estimate their market potential.

INTRODUCTION

Healthcare is a large industry that spends globally USD 6 trillion per year (in 2008). The US alone spent USD 2.3 trillion on health care in 2007, and spending is growing at a rate of 8 percent annually (Kalorama, 2007). An aging population, changes in environment such as global warming and industrial pollution, and infectious diseases that are non-responsive to treatment set major challenges to manage in human health and health care.

Many leading information technology companies like IBM, Intel, Microsoft, Google, HP and Cisco have started to focus on health care technology solutions. Online health record systems offer people the opportunity to input their health data including diagnostic and care history into forms, which they can share with their peers, nurses or doctors through the Internet. Kalorama's market study (2007) also shows rapid growth in IT; in particular, wireless technologies are seen to have big potential. They are expected to: improve patient care; reduce costs; streamline processes; help with regulatory compliance; and provide many other benefits. Healthcare professionals need real-time access to data at the point of care for improving their decision making and enhancing processes. Remote patient monitoring, e-prescription, asset management and tracking are also potential application areas of wireless technologies in health care.

The total market for wireless technologies in US health care in 2005 was USD 1.8 billion, expected to grow 33 percent annually until 2010, reaching a total market size of USD 7.3 billion.

Microsoft Health Vault is the first trial for a major generic commercial Personal Health Record (PHR). The dominance of Microsoft in personal computing makes this trial especially interesting. One big challenge is the connectivity throughout the health ecosystem and how users can browse their personal information in a wide range of health and wellness IT applications. Google emphasizes the continuity even more. They speak of a Continuity of Care Record (CCR). The health record system has to communicate both with people and machines, and simultaneously maintain the high privacy and security of people's health data.

An IBM research team (Adams et al., 2006) summarizes the challenges of the world's health care this way: "Change must be made; the choices left to the stakeholders of today's health care systems are when and how. If they wait too long to act or do not act decisively enough, their systems could 'hit the wall' – in other words, be unable to continue on the current path – and then, require immediate and major forced restructuring."

Among IBM's recommendations are that: health care providers enhance management of chronic diseases and prevention of illness; consumers take personal responsibility for their health and maximize the value they get from the health care system; societies make better decisions regarding lifestyle expectations; and governments provide the leadership and political will power needed for innovative, sustainable solutions. Three methods to improve health care systems are proposed: 1) transforming value, 2) transforming consumer responsibility and 3) transforming care delivery.

The same IBM research team also describes the major changes needed in typical successful U.S. health plans in 2015; one of them is that business processes should be greatly improved and enhanced with IT-related capabilities (Adams et al., 2007).

Intel's research team (Intel Health, 2007) proposes rethinking the disease management process, emphasizing development of IT solutions for chronic diseases. Patients with chronic conditions account for 83 % of US health care spending; 81 % of inpatient stays; 91 % of prescriptions; 76 % of physician visits; and 98 % of home health care visits (Anderson, 2004). New technical solutions could strengthen patients' long-term engagement in their care. Healthcare providers could get accurate, relevant and timely information from their patients. Patients could have intuitive, enjoyable and educational communication channels to their care team and their families. In addition to periodic mailings and phone calls, communication could occur by e-mail, videoconferences, SMS messages and other mobile services. Touch screen and other user-friendly technologies should serve people with little or no IT experience.

A UK report on wireless based disease management (Wireless Healthcare, 2007) argues that wireless technologies play a key role within disease monitoring and modeling applications for AIDS, diabetes and influenza which are, especially in developed countries, diseases that significantly impact health care providers and pharmaceutical companies.

The California Healthcare Foundation (CHCF) (Adler, 2007) categorizes wireless applications of health care in two ways: 1) Monitoring applications for cardiac, diabetic etc. functions which can use portable, wearable or implantable sensors and work automatically and 2) Patient communication and supporting applications which can provide patients with information and feedback directly, and encourage them to take an active role in managing their health.

Many applications have been developed, for example, for cardiac monitoring (http://medical-connectivity.com/), glucose monitoring (http://healthpia.us/, GlucoPhone, developed by HealthPia, South Korea), multiple vital signs monitoring (portable and wearable), and even implantable monitoring integrated in pacemakers (http://www.biotronik.de/, Cyclos DR-T, developed by Biotronik, Germany). There are also applications for appointment reminders, health education and promotion, public health alerts, compliance monitoring and other treatment support and engagement. BeWell's Asthma Assistant (http://www.bewellmobile.com/) is an example.

CHFC defines issues of adoption of wireless technology. The health industry issues are uncertainty in reimbursement; unproven benefits; incompatibility of the health system for wireless applications; and privacy and security issues. The technical issues are potential information overload; lack of standards; market issues; incomplete coverage; network fragmentation; and the mismatch between the vivid cell phone market and the slow health care market.

The Continua Health Alliance (http://www.continuaalliance.org/) promotes a promising cooperative strategy to achieve continuity in care from the developer point of view (Carroll et al., 2007). There are 177 members who develop architecture, create use cases and define standards for better integrated health care services (CHA, 2009). The three target areas are: 1) disease management - managing a chronic disease outside of a clinical setting, 2) aging independently - using technology and services to live in one's own home longer, and 3) health and fitness - expanding personal health and wellness to where people live and play.

Alberta Health Service's Capital Health (Rowe, 2008) is a good example of applying continuum of care with evidence based practice. The challenge is to cover even the most complex patients in the vast rural areas of Canada with 2700 beds in 13 hospitals and 29 000 staff members including 2400 physicians serving 1.7 million people. The operation serves 10 000 home care clients monthly and 635 000 calls for health advice. Annually they have 956 000 patient days in hospitals, 1.3 million ambulatory visits, 436 000 emergency visits, 93 000 surgical procedures, 13 900 births. The Canada Health Act outlines the rules that provinces and territories must follow to receive federal funding for health care; these are 1) public administration; 2) comprehensiveness; 3) universality; 4) portability; and 5) accessibility. In these conditions it is inevitable to focus on a technology supported continuum of care. (http://www.parl.gc.ca/information/library/PRBpubs/944-e.htm)

On the hospital side there are many indications that wireless technologies can support improved outcomes. Solovy (2007) lists ten lessons for hospitals and health systems to improve their outcome and quality including: 1) improve patient flow, 2) improve workflow, 3) improve whole processes,

4) measure results and 5) manage medication to drive quality to the bedside, 6) use smart alerts to improve care, 7) provide ubiquitous access to digital images, 8) do not forget the operating room, 9) plan for the worst and 10) remember that infrastructure is the key to the future.

There is much research and development work proceeding worldwide to save health care from financial crisis, including process reengineering, new service solutions development and new technology development. Wireless technologies offer interesting potential, but also face many challenges.

PRESENT STATUS OF WIRELESS IN HEALTH CARE

This analysis is based on an international survey and interviews which were carried out during the first half of 2008 in America, Asia and Europe as a part of the Wirhe project, where an international strategy and roadmap plan for cooperative development of wireless technologies and solutions for health care was planned (Alasaarela, 2008).

The Wirhe strategy and roadmap plan was seen as important for several reasons: to increase understanding of the changes needed in the health care industry worldwide and how wireless and mobile solutions can be applied to enhance and improve it; to draw a roadmap with essential milestones; to plan a set of activities and efforts needed to reach the goals; to raise awareness of big challenges; and to define gaps in the process where wireless technologies can provide the solution. The Wirhe strategy and roadmap was funded and published by Tekes (a public technology and innovation fund in Finland) in October 2008 (Alasaarela, 2008).

University of Oulu was chosen as the responsible operator for the Wirhe project. To get a wide scope of understanding for the Wirhe project we collaborated first with the University of California Berkeley in Berkeley, CA, and the Health Technology Center (HealthTech) in San Francisco, CA. Imperial College in London joined the project team to develop the idea of our wireless framework, especially for wireless management of diabetes (Alasaarela & Oliver, 2009). The University of Alberta, Canada, joined to work on defining wireless solutions in rehabilitation[1].

In the first part of the Wirhe project we collected information and expert opinions about drivers and challenges in developing and adopting wireless solutions in health care (Alasaarela, Nemana & DeMello, 2009). This study was carried out during HIMSS conference 2008, in Orlando, Florida, by interviewing 70 participants who are experts on hospital information management. The main findings show that on average the most attractive and credible application is wireless alarming and calling for help. The second and third are mobile access to patient health records and vital signs monitoring. The results also showed that process change challenges are remarkably more difficult than technical challenges. The process change from the doctors' point of view is particularly severe. Among technical challenges usability of the mobile user interface is seen as the most difficult. Also according to this study, security of patient data is no longer among the most severe challenges.

In the second part of the Wirhe project we interviewed 85 experts from 15 countries through an Internet survey. A ZEF analysis method (http://zefsolutions.com/en/) was used to collect opinions and comments and to produce a report of bases, needs, vision, challenges, risks etc. with 699 comments, ideas and proposals of experts. We also interviewed 35 experts face-to-face (15 of them were participants of the ZEF survey) to deepen the scope. In addition, we collected a Wireless in Healthcare database including 160 products or solutions, 193 concurrent scientific and technical articles, 149 news articles during 2007-2008 and 41 conferences and exhibitions during 2008-2009.

The ZEF Survey and Interviews

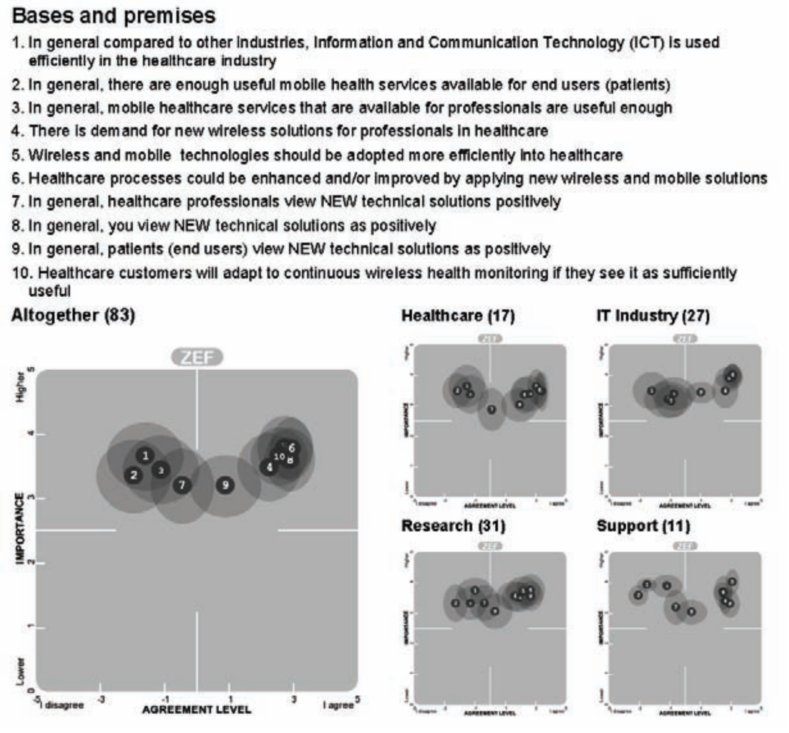
ZEF analysis is a two-dimensional graphical survey tool capable of z-score processing and is available on the Internet (http://zefsolutions.com/en). Examples of ZEF-charts can be seen in Figures 1-4. The respondents get an equivalent graphical survey form and work by pointing their evaluations on the answering field whose coordinates have been defined and indicated on the field axes.

The reports are calculated in the ZEF server as ZEF charts indicating the average points and deviation ellipses around them. The position of the numbers 1 to 10 on the charts in Figure 1, for example, reports averages and the height and width of the ellipses around the numbers are proportional to the deviation in the respective direction.

An absolute or z-scored method can be used in report processing. In the absolute process the original answers are used when processing the averages and deviations. In the z-scored process a normalization (z-scoring) method is used twice: first on each chart for each respondent's answers and second after averaging to the whole data chart by chart. The ZEF method gives full resolution to each respondent and also more accurate results than absolute processed charts. However, the normalized process can be used effectively only when finding comparative differences: better / worse, more / less attractive etc.

The ZEF survey content was planned by a small expert group[1] starting from the contents of our

Figure 1. Bases and premises according to 83 experts' answers to the 10 claims. Numbered spots are on their average points and the ellipses around are proportional to their standard deviations. Four small charts describe opinions of the same experts divided into groups that they represent. The ZEF method is a registered trademark of ZEF Solutions (http://zefsolutions.com/en)



Bases and premises

1. In general compared to other industries, Information and Communication Technology (ICT) is used efficiently in the healthcare industry
2. In general, there are enough useful mobile health services available for end users (patients)
3. In general, mobile healthcare services that are available for professionals are useful enough
4. There is demand for new wireless solutions for professionals in healthcare
5. Wireless and mobile technologies should be adopted more efficiently into healthcare
6. Healthcare processes could be enhanced and/or improved by applying new wireless and mobile solutions
7. In general, healthcare professionals view NEW technical solutions positively
8. In general, you view NEW technical solutions as positively
9. In general, patients (end users) view NEW technical solutions as positively
10. Healthcare customers will adapt to continuous wireless health monitoring if they see it as sufficiently useful

previous wireless strategy projects (Alasaarela, 2009). The question groups with the used dimensions (horizontal / vertical) are: A) Background questions (choice questions only); B) Bases and premises (Agreement level / Importance); C) Needs for development for inpatient use (Need 2012-14 / Need 2008-09); D) Needs for development for outpatient use (Need 2012-14/ Need 2008-09); E) Components of vision for 2014 (Attractiveness / Credibility); F) Threats and risks (Seriousness / Probability); G) Technical challenges (Degree of difficulty); H) Process development challenges (Degree of difficulty); I) Your message to the strategy team (Free text). In each question group there is at least one text box for writing free text comments and ideas.

The experts were invited via email and motivated by a raffle of a Nokia N95 8GB smart phone. They answered by clicking a link in their invitation mail to open their graphical ZEF survey form. Altogether 85 (46 %) experts of 187 invited responded to our ZEF survey. A total of 39 ZEF survey respondents represented USA; 20 Finland; 7 South Korea; 6 UK; and 13 other countries (including Canada, Spain, Belgium, Sweden, Norway, Estonia, Hungary, Japan, the Netherlands, Germany and Switzerland). The respondents represented all-important expert groups: 1) health care services (19), 2) IT industry (27), 3) research (32) and 4) supporting (11).

The number of respondents varies in the reported question groups since the ZEF system gave access to each respondent according to their expert areas that they had selected in the background questions.

Background Questions

In the background questions of the Wirhe study the experts were asked to define their primary responsibilities in their jobs. They were allowed to select one or more responsibilities. 31.8% selected "Management/coordination," 47.1% "Technical research & development," 16.5% "Technology planning, acquiring and/or maintenance," 10.6% "Marketing/sales," 12.9% "Medical diagnosis and care," 2.4% "Nursing/nursing science" and 22.4% "Something else".

Experts were also asked to rate their familiarity with IT technology. The agreement percentages were: 97.6% in "I use mobile phone daily," 89.4% "I use wireless network (WLAN, WiFi) when needed," 76.5% "I use Bluetooth links when needed," 51.8% "I use 3G services when needed," 69.5% "I use GPS navigation when needed," 63.5% "I know ZigBee technology," 51.8% "I know UWB technology," 45.9% "I use PDA device daily and 21.2% "I use wireless network to browse patient records".

Bases and Premises

In general the experts believe that "ICT is not used efficiently in the health care industry" and "there are not enough useful mobile solutions available for end users" (numbers 1 and 2 in Figure 1). In addition the "mobile health care services available for professionals are not useful enough" (3). All groups, people from health care services, IT industry, research and supporting agree on these negative statements. An example comment: "I have not seen an integrated total solution. There are lots of solutions tackling various different problems taking baby steps."

The same people agree that "there is demand for wireless solutions" (4) for professionals, "wireless and mobile solutions should be adopted more efficiently" (5) into health care, and they would "enhance and/or improve health care processes" (6). In addition the same experts believe that "customers would adapt even continuous wireless health monitoring" (10) if they saw it as sufficiently useful. It is interesting to note that the error bars for the responses to the bases and premises section of the ZEF questionnaire are the smallest of all the sections. This indicates that there is significant overall agreement on general principles between experts in wireless health care, regardless of background. The spread of responses and the size of the error bars increase for more specific sections of the ZEF survey, though it should be noted that the number of experts polled differs between sections.

Some of the experts are concerned about the health care processes themselves, which would require major changes. They would not like to grant technology too big a role. The majority of comments were positive, like this one: “Mobile solutions supported by privacy and security checks will be accepted as they will contribute to better, safer and more efficient care.”

Needs of Wireless for In-Hospital Use

The experts believe that in the short term the highest need is for “alarm buttons and systems” (number 11 in Figure 2). The highest needs both in the short and long term are “need for wireless networks” (1) themselves and “need for wireless access to an electronic patient record system” (4), “to an electronic prescription system” (5) and “to medical information” (6). In the long term “wireless sensor belts and wristbands” (10) are also needed.

The experts coming from health care services also stated a “need for wireless terminals” (2), and research experts estimate that the need with the greatest evolution over the forthcoming 5 years will be for “implantable sensors and care actuators” (9).

Patients would love to have services and information access through mobile and wireless devices.

Figure 2. Short and long term needs of wireless for in-hospital use according to 48 experts. The charts have been calculated by using a normalizing (z-scoring) method.

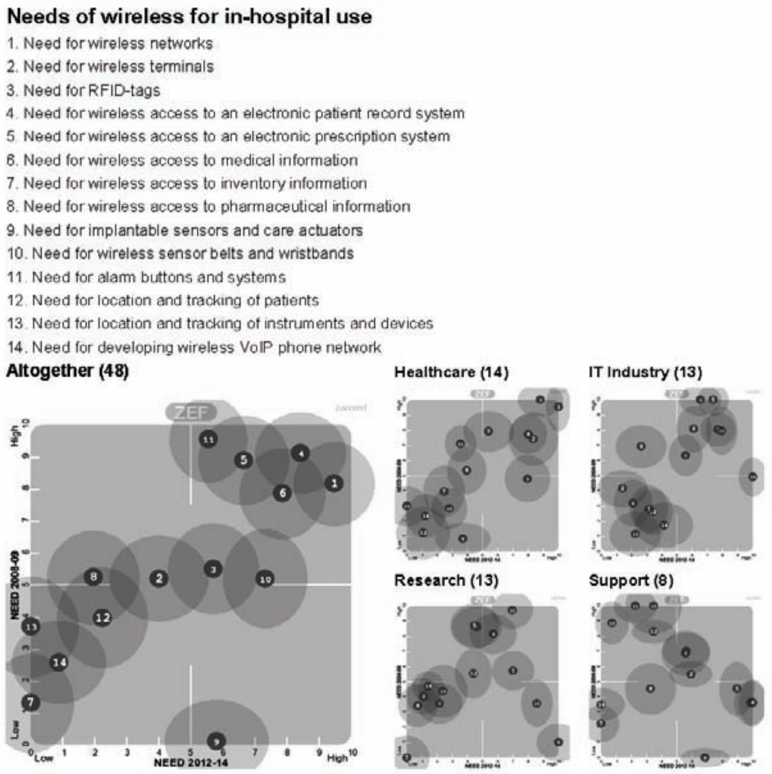
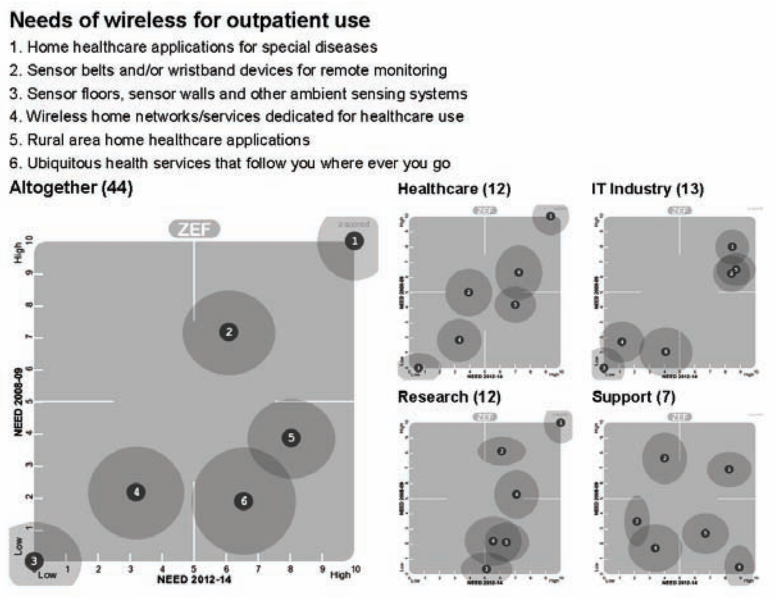


Figure 3. Short and long term needs of wireless for outpatient use according to 44 experts. The charts have been calculated by using a normalizing (z-scoring) method.



Needs of Wireless for Outpatient Use

One candidate is clearly higher than any other in our list of outpatient wireless needs, both short and long range: "home health care applications for special diseases" (1). The second is "sensor belts and/or wristband devices for remote monitoring" (2), especially, in the short term. Only experts from health care services raise "ubiquitous health services" (6) and "rural area home health care applications" (5) as more important long range. IT industry experts do not see ubiquitous health services as important as the three other mentioned above.

On the other hand these experts do not see any special "need for sensor floors, sensor walls or other ambient sensing systems" (3) which are usually seen as important in ubiquitous technology.

The text comments of the experts support the results above: "Near future: remote monitoring and tele-assistance. Far future: sensor implants, implants improving body functions (for example vision, pain relief), artificial limbs connected to neural system."

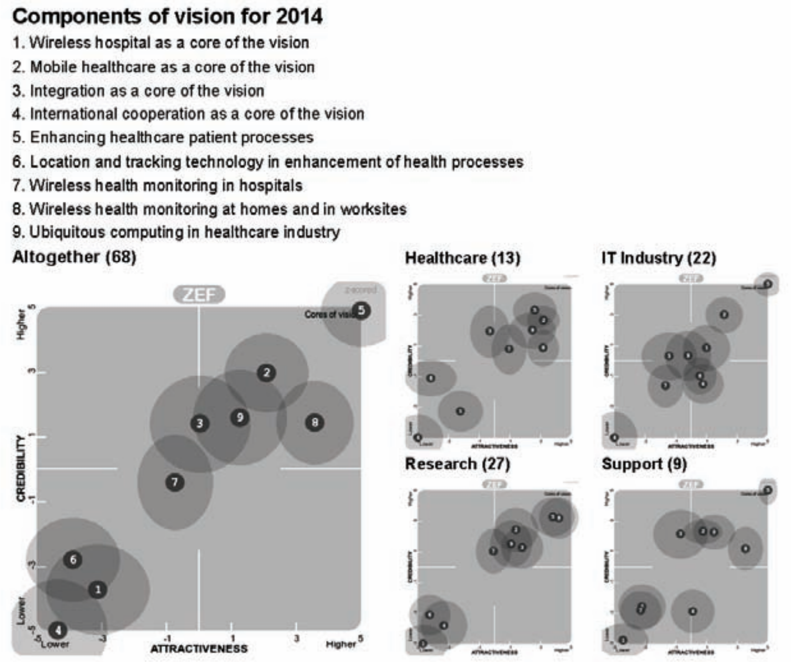
FUTURE OF WIRELESS IN HEALTHCARE

Vision and Goals for Future Development

In defining future vision and goals we used ZEF analysis to rate the attractiveness and credibility of questions or matters listed on a ZEF table. The thoroughly planned list of the asked choices for cores and components of vision can be seen in Figure 4. In the survey form each of them was described in greater detail.

In addition we asked the experts to write their comments and ideas about vision like: "Which objectives would be the most important to take into account?" and "Try to formulate your vision

Figure 4. The main summary of the ZEF analysis of the vision components calculated by using z-scoring to get relative results



for wireless solutions in health care. What are the key issues? What are the key technologies? What are the expected benefits?"

The result of the ZEF analysis can be seen in Figure 4. After numerous discussions with experts the results were as follows. "Enhancing health care patient processes" (5) is the most credible and attractive component of the vision. The second is "mobile health care as a core of the vision" (2). The next two are "wireless monitoring at homes and in worksites" (8) and "ubiquitous computing in health care industry" (9). Two more: "integration as a core of the vision" (3) and "wireless health monitoring in hospitals" (7) are highly credible and attractive, especially, according to experts from health care services and research.

Although most of the original average points (calculated without z-scoring) are situated in the upper right corner (representing attractive and credible elements), numbers 1, 4 and 6 are clearly lower both in attractiveness and credibility than the other. Thus the wireless hospital and wireless location and tracking cannot be core elements on average in the future according to these experts.

The "international cooperation" (4) is an interesting detail in this study. It is the least attractive and least credible component of vision. Why? Perhaps the health care systems are so national by their inherent character that the experts can foresee such severe national challenges that they cannot credit any possibility of international co-operation. This analysis reveals that we have an especially hard challenge to obtain international cooperation.

The two text questions generated 92 answers which strengthen and detail the interpretation. Here are two samples:

An informed and empowered consumer is more compliant. Wireless technology facilitates monitoring at home and work. Key issues relate to *privacy, security and reimbursement. The RFID, cell phones and ubiquitous technologies will continue to develop. This will produce significant cost savings to society as a result of better outcomes and fewer medical errors.*

Key issues: The application of wireless technologies in health care lags behind other areas. It is important to come up with a platform that can be easily integrated with the existing devices. An open platform will allow researchers to test and implement their technologies. Key technologies: PDA or smart phones enabled with wireless technology. Developing robust sensing technology. Software to provide patients and clinicians with feedback. Expected benefits: Tremendous reduction in health care costs. Increase in efficiency of clinicians. Convenience to patients.

Defined Vision 2014

According to the above studies and tens of face-to-face interviews of experts the vision 2014 was formulated as (Alasaarela, 2008):

Towards 2014 health care will become more mobilized and integrated – close to ubiquitous. The patient processes will be enhanced and supported by wireless monitoring and care services at homes and worksites as well as in hospitals. Wireless technologies and mobile solutions will be applied systematically to different disease groups according to a unified framework based on international development and standardization work.

The first part of the vision comes directly from the study results above. The second part –systematic application of wireless to different diseases - comes from discussions with experts. An estimation of prevalence and annual costs of some diseases in the USA can be seen in Table 1.

Major diseases compounded by aging and obesity problems form one of the biggest health care costs in the USA and even globally. Our hypothesis is that by utilizing wireless solutions we can manage these costs more effectively. The main aim of this study is to offer a framework that will reveal the exact points in the health service continuum where mobile solutions will bring the most significant outcomes and improve the quality of care. The unified framework can be used to manage planning of wireless solutions for each health problem systematically.

Table 1. The most expensive diseases in America (Herper, 2005)

Disease	*Annual costs*	**Patients in USA**
Heart conditions	$68 billion	20 million
Trauma	$58 billion	36 million
Mental Illness	$48 billion	31 million
Cancer	$48 billion	11 million
Respiratory Ailments	$45 billion	50 million
Hypertension	$33 billion	37 million
Arthritis and Joint Disorders	$32 billion	23 million
Diabetes	$28 billion	14 million
Back problems	$23 billion	18 million
Total	$383 billion	

Integration of Personal and Institutional Health Care

The future of wireless in health care can be viewed in four ways: 1) From the health professionals' point of view, how can health care processes be enhanced and improved by adopting wireless and mobile solutions? 2) From the patients' and citizens' point of view, how can disease and health management be enhanced, improved and better adapted to their daily lives? 3) From the providers' and governments' point of view, how can the whole health care industry be improved and made more efficient by promoting new wireless and mobile solutions? 4) From the engineers' technology point of view, how can modern wireless and mobile communication technologies be applied to solve problems in the health care industry?

In order to optimize the management of health care we need to combine the professionals' process-based thinking, the citizens' wellbeing, patients' disease-based thinking and the government and institutional return on investment (ROI) based thinking. This means integration of health care in a novel and fundamental way. Technologies are only tools to realize the solutions needed.

A health care process can be considered to be a chain of successive activities which health care professionals perform for the patient in a hospital or in the community. Broadly speaking, activities of the patient's own before coming to health services and after returning back home can also be considered to belong to this health care process. Therefore, wireless supported health care processes involve most of the same activities, which the patients receive in their wireless supported disease management programs.

The disease management concept is an entity, which comprises methods, systems, services, devices and products for diagnosing, caring for and monitoring a patient with a specific disease during the course of that disease. Mostly the term of disease management is attached to chronic illnesses, but now we broaden it to acute illness episodes as well. Perhaps, it would be better to speak of "health management concepts" or "healing support concepts".

Development of wireless supported disease management concepts requires a great deal of medical and nursing knowledge - much more than developing the devices and systems which are needed in only one phase of a health care process. This arises from a more holistic way of considering health processes.

By combining the three viewing angles we can formulate concepts to manage diseases with a wireless-supported continuum of care from preventive health management to care and rehabilitation services. This would lead to efficient, high quality care, financial savings and improved clinical outcomes which would not be possible without wireless and mobile solutions.

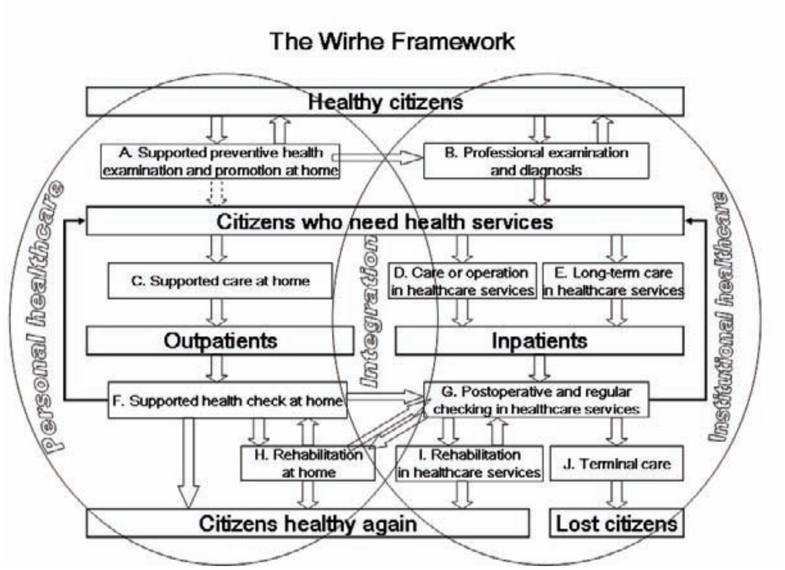
THE WIRHE FRAMEWORK FOR WIRELESS MANAGEMENT OF DISEASES

Each disease and health problem needs a specific diagnosing, caring and monitoring concept, comprising all-important phases starting from the first indicators of pathology and ending with no symptoms or indicators, demonstrating health. Disease prevention is also needed for specific risk groups (people with genetic or environmental risks).

Wireless support offers not only opportunities to manage diseases in a novel way, but also the opportunity to tailor the disease management concept individually for each patient, taking into account unique needs, wishes and lifestyles. The overall goal is that all patients continue their normal daily life despite their disease status and that wireless health care provides no additional burden to the patient.

Public, private and self-care can be seen as building blocks. They can be re-engineered to form a systematic framework (Figure 5) for developing the wireless supported health care. The

Figure 5. The Wirhe framework shows how the patient-driven disease management (left) and the professionals-driven health care processes (right) are integrated to form a unified service chain with many different paths for customers. Each text block refers to needs and solutions, both available and lacking. For example, supported care at home for a heart condition (arrhythmia) needs heart monitoring and requires a wireless ECG sensor with a means to transmit an alert and ECG sample to a professional health service unit as soon as abnormalities emerge in the data.



existing wireless and mobile solutions can now be placed on the Wirhe framework.

Wireless support may be very different for different diseases. It might also be tailored to meet individual patient's needs, particularly if the patient has two or more chronic diseases.

Important blocks in the Wirhe Framework are:

A. Supported preventive health examination and promotion at home
B. Professional examination and diagnosis
C. Supported care at home
D. Care or operation in health care services
E. Long-term care in health care services
F. Supported health check at home
G. Postoperative health check and regular (continuous or sampled) health monitoring in health care services
H. Rehabilitation at home
I. Rehabilitation in health care services
J. Terminal care

Wireless networks and access points are needed in hospitals, clinics, and health centers as well as at home. Therefore, they are needed in most of the blocks. Cisco (http://www.cisco.com/) and Philips (http://www.philips.com) are well known global providers of wireless networks solutions with access points, controllers, etc.

Aruba Wireless Networks (http://www.arubanetworks.com/) provides user-centric wireless networks to integrate adaptive wireless LANs, identity-based security, and application continuity services for health care campuses, clinics, physician and home-offices.

Flo Healthcare (http://www.flohealth care.com/) markets mobile clinical workstations, wireless access points and accessories specifically for the health care industry. Wireless connection to information helps clinicians stay better connected with their patients.

Cardinal Health (http://www.cardinal.com/) markets their Alaris solution including system manager and gateway units, a safety net module and a connectivity program for facilitating data flow between key technologies. Their customers are located on five continents and include hospitals, medical centers, retail and mail order pharmacies, clinics, physicians, pharmacists and other health care providers.

Nortel Networks (http://www.nortel.com/) provides affordable, scalable IP voice and wireless mobility solutions and other IP based clinical applications including asset tracking and management systems.

Motorola Remote Patient Monitoring Solutions (http://www.motorola.com/, earlier known as Symbol Technologies) combine WLAN enabled mobile computers, voice over WLAN, leading clinical IT and medical device applications to help improve the speed and quality of medical treatment.

Next we describe briefly each block and give examples of the kind of needs and wireless solutions there might be in each block. Some of the blocks are not needed in all of the diseases. For example, diabetes is a life-long disease. Therefore, rehabilitation is seldom needed for diabetes itself; it is more often needed due to its co-morbidities. In addition, diabetes itself is not fatal, although it may lead to fatal complications (Alasaarela & Oliver, 2009).

A. Supported Preventive Health Examination and Promotion at Home

Preventive care and health promotion are some of the most important needs in the future. Many changes in human life-style, working environment, eating habits, environmental pollution etc. set new challenges to our health. We need new solutions to measure and monitor our health to diagnose coming health problems as early as possible. We also need solutions to collect the right information at the right time about the right problem. In the future genetic information will become increasingly important.

In fact, if we are able to assess our genetic risks, follow daily what we eat and drink, monitor the gamut of our physical and mental exercise and measure regularly our bio signals, we will have a clearer risk assessment of what diseases and other health problems we should be concerned about. Is it possible to develop wireless solutions to offer these services? What are the most important means to start from?

There are already many technologies and platforms available for these needs. Heart rate monitors are well known; for example Polar Electro's products (http://www.polar.fi), who have also developed analysis software for fitness and weight monitoring. Firstbeat Technologies (http://www.firstbeat.fi) has developed an HRV (Heart rate variability) analyzing method and software which utilizes heart rate data to find latent diseases.

Cell phone networks working on the 3G level are effective platforms for preventive health solutions. Many mobile services for managing fitness, weigh, nutrition and lifestyle are under development. Wireless devices for monitoring vital signs and specific physiological parameters can also be used by healthy people, especially if they belong to a high-risk group. The monitoring could also be linked to health providers and call centers.

B. Professional Examination and Diagnosis

The professional examination happens mostly within health services (in health centers, hospitals or clinics). Therefore, some of the wireless technologies which are available for care are available also for examination.

As an example, LifeWatch Corp. (http://www.lifewatchinc.com/) offer wireless blood pressure meters, oxygen saturation monitors, weigh scales, PDA monitors with Bluetooth connection and services for integrated monitoring and analysis.

Medixine Ltd. (http://www.medixine.com/) offers an integrated monitor system via a Bluetooth connection for measuring devices such as blood pressure meters, scales and glucometers. The data are forwarded to the Medixine server either via a mobile phone or a Bluetooth hub.

C. Supported Care at Home

Home health care is a rapidly proliferating market. At Medica 2008 (http://www.medica.de/) visitors could see many comprehensive solutions for managing chronic patients at home. Wireless technology is important both for patient's freedom to move at home and for continuous connection and support from care providers.

Among the most utilized products in the home health care market are the Honeywell HomMed solutions. HomMed is one of the leaders in telehealth and remote patient monitoring solutions (http://www.hommed.com/) and over half a million patients are served by HomMed solutions. They are dedicated to improving the quality of patients' lives and reducing the cost of health care by providing integrated solutions for home care. The products of HomMed are the Centry and Genesis telehealth monitors with a wide variety of peripherals, medication reminders and a central station. The solutions can be used to collect heart rate, blood pressure, oxygen saturation and other vital signs data and to process and display it for diagnostic and care development use.

Philips Electronics (http://www.medical.philips.com/) offers among other products a TeleStation hub for the transmission of vital signs data collected from the wireless measurement devices at a patient's home. It is also a medium for interactive communication between care providers and patients at home. They also offer Intellivue Telemetry Systems for SpO2, ECG and improved tachycardia assessment, which uses so-called smart-hopping technology to maintain seamless connections between the central station and telemetry devices. Their Classic Pendant Personal help button gives patients at home access to fast assistance by a simple alert touch. Philips offers also many wireless products for hospital and other institutional use.

MedApps is an emerging company (http://www.medapps.net) which offers portable devices and a web-based monitoring application to deliver an end-to-end mobile, wireless, health monitoring system.

University of Alberta (a team lead by Dr. Masako Miyazaki) has developed a comprehensive home care solution, WWPM for chronic elderly patients (Miyazaki, 2008). The system was tested by a third party research team for a healthy population and clients' population in Capital Health. The system was spun off from the University of Alberta and is now available through Redengine Health (http:// www.redenginehealth.com).

eHIT Ltd (http://www.ehit.fi/) specializes in eHealth and eWellness solutions where end users actively participate in the maintenance of their own health. Their solutions include self-care, home care, and occupational health.

BeWell Mobile (http://www.bewellmobile.com/) is offered to advance engagement of conditions such as asthma and diabetes patients in three ways: via Web Portal, eDiaries by cell phones and Reminders by SMS.

ExmoCare (http://www.exmocare.com/) develops, produces and markets wireless health care, wellness and biosensor products. Its operations are focused around its line of wireless biosensor wristwatches and recurring monthly service plans for remote chronic care, weight management and eventually diabetes care.

BodyTel Scientific (http://www.bodytel.com/) specializes in telemedical monitoring and management systems for chronic diseases, particularly diabetes.

Visual Telecommunications Network (http://www.vitelnet.com/) offers ViTel Net solutions for home health monitoring, referral, consultation and emergency telemedicine.

Confidant (http://www.confidantinc.com/) has developed mobile phone solutions helping people suffering from chronic diseases manage their health easily while maintaining an active lifestyle.

D. Care or Operation in Health Care Services

Wireless networks are already in daily use in most of the hospitals in the western countries. For example, when physicians and nurses go on their rounds they have their laptops or tablet PCs to maintain access to patient record and medical information systems. In addition, there are many technologies available to apply WLAN, Bluetooth, RFID or other wireless connections.

Alien Technology (http://www.alientechnology.com/) provides RFID tags, RFID readers and related services.

InnerWireless (http://www.innerwireless.com/health care.asp) is a provider of comprehensive in-building wireless distribution systems, as well as wireless tracking and location solutions.

Medanets Oy (http://www.medanets.com/) offers a solution where the measurement data are transferred into the information system via a wireless network, either automatically or with one entry. The information is immediately available to all system users.

Allscripts (http://www.allscripts.com/) offers mobile TouchChart solutions for physicians to quickly prescribe, check for drug interactions, access medical histories and review drug reference information. Providers can connect directly to the pharmacy via electronic fax and electronically exchange prescription data.

CardioNet (http://www.cardionet.com/) offers a solution for arrhythmia patients. They wear three chest leads with a small sensor that detects heart rhythm and wirelessly transmits to the monitor. LifeWatch Corp. (http://www.lifewatchinc.com/) has a similar arrhythmia solution LifeStar, with a single lead ECG.

Audio Riders' (http://www.audioriders.fi/) Carerider collects information from wireless sensors placed in beds and nursing chairs, which is then integrated with the intelligent job control of the service.

CRF Inc (http://www.crfhealth.com/) is the leading global provider of eDiaries and wireless data collection solutions for the biopharmaceutical industry.

Emfit (http://www.emfit.com/) is specialized in developing and manufacturing networked, IP-based nurse call systems with assistive non-body-contact vitals and movements monitoring, fall and wander alarms, and epileptic seizure alarms.

Incode (http://www.incode.fi/) offers wireless technology for nurse calls etc.

Medictes (http://www.medictes.fi/) is focused on health care data systems by offering communication tools, applications and solutions. Their MobiiliSanelu allows clinicians to dictate ubiquitously by a web application or cell phone. The saved dictations are available for listening and unpacking in real-time.

A wireless, battery-free, fetal vital signs sensor which monitors baby's vital signs day and night has been developed in the National Children's Hospital. RF System Laboratory is in charge of product development. They have also been working with NASA to support astronauts during space flight (http://www.rfnokko.com/nokkop2.html)

E. Long-Term Care in Health Care Services

The applications of long-term care differ from basic hospital care. Their aim is to help patients to live with minimal intrusion while being monitored frequently enough to detect changes in health status. Many long-term patients have several chronic conditions and wear monitoring devices for years, increasing technology costs. However, in present care models, these patients use the vast majority of health care resources. Therefore, the expected savings of implementing wireless solutions are higher.

Televital (http://www.televital.com/) offers VitalWare VMS integrated Electronic Patient Medical Record and real-time telemedicine software modules with auto-recognition and configuration architecture that enables plug-and-play for a wide variety of medical devices from different manufacturers.

Sensitron (http://www.sensitron.net/) has developed careTrends solution, which is an enterprise software and wireless vital signs collection and dissemination system, to improve patient quality of care and decrease health care costs.

IST International Security Technology (http://www.istsec.fi/) offers automatic personal security systems monitoring and analyzing users´ activity levels. Their Vivago wristtop monitor consists of sensors and algorithms that allow body signals to be monitored and analyzed automatically and continuously.

Medtronic (http://www.medtronic.com/) is a manufacturer of medical technology solutions for people with chronic disease. Each year, 6 million patients utilize Medtronic's technology, used to treat conditions such as diabetes, heart disease, neurological disorders, and vascular illnesses. Their Minimed Paradigm system integrates an insulin pump with real-time continuous glucose monitoring and sends blood sugar test results wirelessly to an insulin pump – making integration of glucose and insulin data easier.

Toumaz Technology (http://www.toumaz.com/) is a specialist in ultra low power sensing technology. Their Sensium is a sensor interface and transceiver platform for a wide range of applications in health care, not only for chronic diseases but also for lifestyle management. The device includes a reconfigurable sensor interface, digital block with 8051 processor and an RF transceiver block.

F. Supported Health Check at Home

Patients may acquire some home devices and services to monitor their important health parameters, blood pressure, blood glucose, weight, temperature etc. An example of a chronic disease with a need for regular self-checking is diabetes. Most diabetics should measure their blood glucose several times per day using portable glucometers. Some of these glucometers have wireless capability to transmit data to personal computers for later review.

ProWellness (http://www.prowellness.com/indexEN.html) has developed a mobile system for diabetics to monitor their health at home. Similar solutions are available from eHIT, Medapps etc.

G. Postoperative and Continuous Checking in Health Care Services

Many patient monitors are available with wireless connections. When intensive monitoring is not needed it is better to have a light minimally invasive or non-invasive patient monitor and move the patient into an area where costs are lower. Light patient monitors are available from many companies.

For example, Welch Allyn (http://www.welchallyn.com/) offers Spot Vital Signs Lxi monitors which use a barcode scanner, and a wireless radio to capture and transfer patient vital signs quickly thus bringing wireless vital signs transmission capability from the bedside.

H. Rehabilitation at Home

There are wide range of technologies that have been used to provide remote delivery of rehabilitation by Occupational Therapists, Physical Therapists, Speech Pathologist and Audiologists The most widely used modalities, as of 2008, are webcams, videophones, and websites containing health information. There are telecommunication infrastructure challenges depending on where you reside. If your clients are living in a remote community in Canada, your access to high speed Internet would provide TV type broadcasting for patients with chronic illness and provide education just in time. The majority of rehabilitation services can be augmented if therapists and clients can access necessary equipment. For example, Occupational Therapists at the Glenrose Hospital, Edmonton incorporates the Wii fit (NINTENDO) game for head injury patients' balance, cognitive and endurance building. Providing readily commercially available wireless games enhances patients' recoveries. Many aspects of rehabilitation practice can be enhanced with objective measurement tools such as 3D motion analysis for Occupational Therapy and Physical Therapy, instead of goniometry and manual muscle testing which are susceptible to error in measurement.

Two important areas of telerehabilitation research are (1) demonstrating equivalence of assessment and therapy to in-person assessment and therapy, and (2) building new data collection systems to digitize information that a therapist can use in practice. Groundbreaking research in telehaptics (the sense of touch) and virtual reality may broaden the scope of telerehabilitation practice, in the future. (http://en.wikipedia.org/wiki/Telerehabilitation)

I. Rehabilitation in Health Care Services

It is obvious that health care and being healthy do not have any clear boundaries. It is a continuum of care throughout our life inside and outside of institutions. One way to look at this is the level of care you need or level of productivity you have accomplished. You may need a small device to help you to get back to work or need a wheelchair to get around. Institutional rehabilitation service can be augmented by having a secure wireless LAN so that health care providers can access clients' data at the point of care. There is a serious need to evaluate all the wireless products which are used in an institution so that industries can provide the equipment clients' needs without interfering with other wireless medical devices.

J. Terminal Care

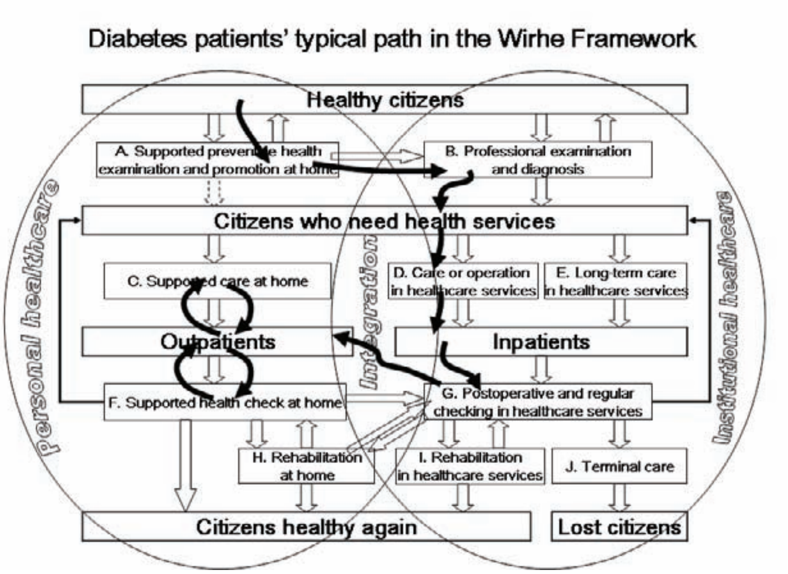
In terminal care there are only few wireless solutions available. If the patient is immobile, wires are not disruptive and the advantages of wireless data are reduced. However, terminal care should be planned for future utilization of wireless technologies due to potential improvements in cost efficiency.

Hoana Medical (http://www.hoana.com/) markets a special bed solution (LifeBed™ System) which could work in terminal care. Patient vigilance system provides a solution for continuous observation of patient conditions. Unlike conventional monitoring systems no physical contact or connections are needed. Wireless solutions for palliation of symptoms in the dying patient might include pain monitoring, consciousness monitoring and analgesic or hypnotic drug delivery.

PATHS OF PATIENTS IN THE WIRHE FRAMEWORK

In Figure 6 we can see an example of a path followed by a patient in the Wirhe framework. The individual with no symptoms of diabetes uses only preventive services. However, if the process of home monitoring and preventive care reveals signs of diabetes he/she goes on to professional examination. If diabetes is not diagnosed he/she returns back to use only preventive services. If the diagnosis is made, he/she progresses through the framework to care in a clinic. After a satisfactory review in the hospital he/she returns home to use supported care services with supported health monitoring at home. This loop continues until there is a need to go to a professional health

Figure 6. A typical path of diabetes patients when they proceed in health care services from healthy citizens to outpatient loop (Alasaarela & Oliver, 2009)



check, at which stage he/she can access inpatient or outpatient hospital care and his/her care will describe an alternative loop in the Framework until resolution.

If the patient can use the same mobile user interface to access the service systems at home, in the workplace and in health care organizations, he/she will not need to carry different devices with him/her. Suitable devices are smart phones, PDA devices and mini-PCs. One interface system means a big advantage to the patient user. The same would be useful to doctors and nurses as well, although not so remarkable as for patients. In many cases the professionals benefits more from a big screen interface when they work in or close to their office and a mobile device when they go into the field.

Integration can be built on electronic health record (EHR) systems. Mobility means wireless access to patients' health records when and where needed and automatic (sometimes manual but mobile) wireless collection of health information from patients. If all products and services (mobile or fixed) are built around the EHR system, the integration comes through the operating system of the EHR. Therefore, it would be ideal if all EHR systems were to use the same architecture and interface policies (such as HL7 – Health Level Seven). Standardization is a key factor in both national and international integration.

The Continua Health Alliance (CHA) is developing health standards, protocols and practices. Integration between health institutions and systems is a severe problem not only in diabetes but widely in global health systems. Healthcare IT systems have been developed mostly by companies who compete against each other to maintain their customers. Alliances like CHA help companies to cooperate rather than compete.

DISCUSSION AND CONCLUSION

Wireless technology is a cost-efficient way to respond to the challenges for public health care systems posed by inevitable structural changes. Due to demographic changes, the amount of patients will increase in upcoming years, while the relative amount of health care professionals is going to decrease. Despite these financial challenges, high quality treatment and organizational integrity must be maintained. An inevitable structural change is happening already.

The public health care systems are challenged to operate according to business requirements. The business baselines in developing health care systems are cost efficiency, patient-orientation, high quality at all operational levels and accessibility of services.

All these baselines can be improved by bringing real-time functions into health care systems accessed by wireless technologies. As human resources are decreased, a leading strategy is to develop technological solutions and preventive health care. Wireless technology is a relatively small, but strategically vitally important part of required IT solutions.

In the Wirhe Framework the viewpoints of health care professionals, citizens and government have been integrated to form a mutual fight against diseases and health problems. Now the wireless technologies and mobile solutions can be applied, in practice, according to the Wirhe framework. This allows a cost-efficient use of existing technologies; therefore, the focus can be shifted towards the development of unavailable products and services and unmet needs.

Wireless technologies can play a critical role in maintaining the independence of our elderly population, through support of safety monitoring (both within the home as well as tracking via GPS); assessment of gait (to predict the likelihood of falls); monitoring and transmission of vital signs and specific biological parameters (such as glucose levels); and the capability of triggering emergency alerts.

Alzheimer's patients would benefit from a wireless "safety net" that constantly tracks their location, assesses their level of cognitive awareness and capacity, and notifies family members and caregivers of behaviors or events.

Wireless support of food intake monitoring, tracking of dietary patterns, timely education and alerts, and even data support for meal services (using body chemistry and eating history to determine and order prepared meals) are all valuable applications to support those with obesity problems.

Even a small productivity increase in service processes will pay wireless technology investments back rapidly. For example, in diabetes alone, a USD 3 billion savings could be achieved if only 10% of patients adopt wireless treatment process, according to the Wirhe framework, resulting in a 20 % resource savings. The very reasonable payback time for investments is only 2 years (Alasaarela & Oliver, 2009).

Real-time, wireless health care will benefit patients in numerous ways. Also the motivation and efficiency of health care professionals will improve markedly, as they can focus on care giving instead of bureaucracy. The main benefit will be faster, better and more efficient treatment processes, which will be of higher quality. Accordingly, waiting lists for treatment will shorten. In the future, wireless technology will improve productivity in health monitoring, outpatient activities and hospital activities.

In fact, wireless technology can be an important enabler of the structural change of public health care worldwide.

ACKNOWLEDGMENT

The authors would like to thank Riku Mäkelä, Tekes, Finland, for his great contribution in planning and practical implementation of the Wirhe project. In addition, they send their warmest thanks to the 105 experts, who gave their valuable contributions by participating in interviews and queries.

REFERENCES

Adams, J., Archbold, B., Mounib, E. L., & New, D. (2007). Healthcare 2015 and U.S. health plans. New roles, new competencies. IBM Institute for Business Value, IBM Corporation.

Adams, J., Mounib, E., Pai, A., Stuart, N., Thomas, R., & Tomaszewicz, P. (2006). Healthcare 2015: Win-win or lose-lose? A portrait and a path to successful transformation. IBM Institute for Business Value, IBM Corporation.

Adler, R. (2007). Health Care Unplugged: The Evolving Role of Wireless Technology. California HealthCare Foundation.

Alasaarela, E., & Oliver, N. S. (2009). Wireless solutions for managing diabetes. Unpublished manuscript, University of Oulu, Oulu and Imperial College, London.

Alasaarela, E. (2008). Wirhe – Wireless Solutions in Healthcare. International strategy and roadmap towards 2014. Tekes, Helsinki, 17 p.

Alasaarela, E. (2009). National Perspectives on the Future of Wireless in Health Care in Finland. University of Oulu, unpublished manuscript, 15 p.

Alasaarela, E., Nemana, R., & DeMello, R. (2009, February). Drivers and challenges of wireless solutions in future health care. Paper accepted in eTELEMED09 Conference in Cancun, Mexico.

Anderson, G. (2004). Chronic Conditions: Making the Case for Ongoing Care. Partnership for Solutions, Sept. 2004. Available at http://www.partnershipforsolutions.org/ DMS/files/chronicbook2004.pdf, last accessed on 12 January 2009.

Carroll, R., Cnossen, R., Schnell, M., & Simons, D.(2007). Continua: An Interoperable Personal Healthcare Ecosystem. IEEE Pervasive Computing, 6(4).

CHA (2009). The Next Generation of Personal Telehealth is Here. Continua Overview Presentation. Continua Health Alliance. Available at http://www.continuaalliance. org/about/, last accessed on 12 January 2009.

Herper, M. (2005). The most expensive diseases. Forbes. Available at http://www.forbes.com/2005/04/14/cx_mh0414healthcosts.html, last accessed on 12 January 2009.

Intel Health (2007). Reconceiving Disease Management: A Technology Perspective. Whitepaper of Intel Health. Available at http://www.intel.com/pressroom/kits/healthcare/ DiseaseMgmt_whitepaper.pdf, last accessed on 12 January 2009.

Kalorama (2007). Wireless Opportunities in Healthcare. Kalorama Information.

Miyazaki, M., Rowe, M., Ohyanagi, T., Liu, L., Clark, C., Cook, A., & Duguay, R. (2008, April). Bidirectional wireless physiological monitoring of homecare clients. Presented in13th Annual International Meeting of the American Telemedicine Association, Seattle, Washington.

Rowe, M. (2008). V-P Capital Health. Alberta Health Services.

Solovy, A. (2007). Ten Lessons from the Top 100. Healthcare's Most Wired, H&HN Hospitals and Health Networks.

Wireless Healthcare (2007). Wireless Based Disease Management. Wireless Healthcare, Steinkrug Publications.

ENDNOTES

[1] Dr. Masako Miyazaki is the principal investigator of the "E-Health Edmonton Program-Development and Integration of Wireless Wearable Physiological Monitors" at the University of Alberta, Canada.

[2] Participating persons: Steven DeMello and Ateret Haselkorn from Health Technology Center, Ravi Nemana from UC Berkeley, Riku Mäkelä, Kalevi Virta and Anne Turula from Tekes and Esko Alasaarela from the University of Oulu.

This work was previously published in the International Journal of Healthcare Delivery Reform Initiatives, Vol. 1, Issue 2, edited by M. Guah, pp. 52-73, copyright 2009 by IGI Publishing (an imprint of IGI Global).

Chapter 3.6

Confirmatory Factor Analysis to Establish Determinants of Wireless Technology in the Indian Healthcare

Raj Gururajan
University of Southern Queensland, Australia

Tiana Gurney
University of Southern Queensland, Australia

Abdul Hafeez-Baig
University of Southern Queensland, Australia

ABSTRACT

This study reports the determinants of wireless technology in the Indian healthcare validated by a second order regression model. In order to assert the determinants, a qualitative study was conducted with 30 physicians using interviews to arrive at a set of barriers and drivers. Further analysis of the qualitative data indicated that there is a third component emerging, namely, clinical influence. The interview data was used to develop a survey instrument and this was administered on the Indian clinicians with 200 completed surveys. This data was used to establish the sub-components of the three major determinants as identified in the qualitative study. This is reported in this article.

INTRODUCTION

In the last few years, high expectations, technological developments, and effective and efficient services have been shown to be prerequisites for improvements in the healthcare domain (Rogoski, 2005; Versel, 2008). Latest trends in the healthcare sector include the design of more flexible and efficient service provider frameworks aimed at providing health services to all stakeholders. In order to implement such frameworks, wireless technology is increasingly being used in the healthcare sector. A decrease in the cost of wireless devices and improved awareness of the benefits by using related wireless applications are two of the contributing factors towards the increased use of wireless technology in this sector (Gururajan, Quaddus, Fink, Vuori, & Soar, 2005; R. Gururajan, Hafeez-Baig, & Gururjan, 2008). Even though the future of this technology and its usability is promising, its adoption is still in its infancy, which is attributed to the complex and critical nature of the healthcare environment. In the current competitive and complex business environment, technology developments have played a critical role in delivering high quality of care (Reinecke, 2004). However, there is limited knowledge and empirical research on the effectiveness and adoption of wireless technology in general, and in the Indian healthcare system in particular.

Recent research has established that investment in emerging Information Technology (IT), including Information Systems (IS), can lead to productivity gains only if they are accepted and effectively used by respective stakeholders. Consequently, acceptance and utilization of IT/IS in the healthcare environment have been central themes in the information systems literature. Therefore, the fundamental focus of this research is to investigate and examine the influence of internal and external determinants on the usefulness of wireless technology. Further, this research also assesses how its acceptance contributes to the adoption of wireless technology. We believe that this research is the first of its kind attempted in the Indian healthcare domain and it employs empirical evidence to explore the impact of wireless technology and its usefulness in the Indian healthcare system. The Indian healthcare domain is at the forefront in adopting the latest medical technologies and applications, as evidenced by media reports and, as such, it constitutes an excellent context for validating existing adoption theories and extending them.

The main contribution of this research includes the identification of a set of drivers and barriers to using wireless technology in a given Indian healthcare setting. In addition to this, for the first time, a set of clinical factors influencing the adoption of wireless technology has been identified and validated using a second order regression model.

LITERATURE REVIEW

The concept of wireless technology in healthcare is discussed in many studies (Dyer, 2003; Hu, Chau, & Sheng, 2002; Sausser, 2003; Simpson, 2003; Siracuse, Pharm, & Sowell, 2008; Versel, 2008; Wisnicki, 2002; Wu & Wu, 2007; Zhang, 2007). For example, Wisnicki (2002) provides details of how broadband technology, an essential component of wireless technology, can be used in healthcare. While prior studies agree that wireless applications have the potential to address the endemic problems of healthcare, very limited information can be found about the determinants of such applications (Gururajan, Toleman, & Soar, 2004; Gururajan, Moloney, & Kerr, 2005). In general, the majority of the works reviewed are descriptive about the benefits of wireless handheld devices in healthcare in general, and medicine in particular. There are only a small number of studies that provide evidence-based information concerning these devices in healthcare (Fischer et al., 2003; Sax et al., 2005)(Hafeez-Baig, 2007). Furthermore, five major studies in the area of healthcare (evaluated by (Spil & Schuring, 2006) testing the Technology Acceptance Model (TAM) produced findings which were inconsistent with the body of knowledge in non-healthcare settings. With 'Perceived Ease of Use' and 'Perceived Usefulness' as the major TAM attributes, these studies found that in the health environment, 'Perceived Usefulness' is an important attribute in technology adoption, while 'Perceived Ease of Use' was found to have no effect (Spil & Schuring, 2006). This is different to findings reported in non-health IS studies, where both attributes were found to be reliable technology adoption predictors. Therefore, further empirical investigation is required to explain the reasons why this variation exists in healthcare. In addition, there is a need to explore if further attributes exist which may influence the adoption of wireless applications in the healthcare environment.

TECHNOLOGY ADOPTION IN HEALTHCARE CONTEXT

In healthcare literature, the discussion on wireless technology falls into three periods. For example, studies prior to and including 2000 discussed the status of wireless technology and the possible role the technology can play in healthcare. Studies between 2000 and 2003 discussed how wireless technology can be deployed in healthcare and the potential benefits the technology can bring to healthcare. It should be noted that these studies were only 'discussion' type studies. Majority of these studies did not provide any empirical evidence as to the use or acceptance of wireless technology in healthcare domains. Studies from 2004 till current date have collected data to establish the usefulness of wireless technology in healthcare. These studies, to some extent have focussed on the PDAs as these devices have been found to be useful in nursing domain for clinical data management.

The studies between 2000 and 2003 discussed a number of potentials of wireless technology in clinical domains. For example, how broadband technology can be used in healthcare was discussed by (Wisnicki, 2002), ability to address prevailing healthcare staff crisis by adopting intelligent solutions using agent and wireless technology that can identify the need and match the need with available resources in a timely and efficient manner was outlined by (Davis, 2002), better compliance with the rigorous regulatory framework was highlighted by (Wisnicki, 2002), reduction in medication errors and hence the benefits that can be realised was discussed by (Turisco, 2000), provision for greater flexibility and mobility of healthcare workers in performing their work was portrayed by (Athey & Stern, 2002), effective management of the increasingly complex information challenges and improved access to those information from anywhere at anytime was discussed by (Stuart & Bawany, 2001). Our review clearly identified that all these studies were only implying the potential of wireless technology and did not provide any empirical evidence.

While prior studies agreed that wireless applications have the potential to address the endemic problems of healthcare, very limited information can be found about the determinants of such wireless applications in order to establish the adoption of technology in a given healthcare context (Gururajan et al., 2004; Gururajan et al., 2005). During the period of 2004 – 2006, studies emerged in the area of technology acceptance, specifically focussing on the acceptance of wireless technology in healthcare domains. These studies were empirical in nature and were testing the available models of technology acceptance or a variation in order to ascertain whether previous models hold good for a new technology in a specific domain . These studies were reported in a book titled 'E-Health Systems Diffusion and Use', published by Idea Group Publishing in 2006 (Spil & Schuring, 2006). These studies are summarised below:

Predicting Internet Use: Applying the Extended Technology Acceptance Model to the Healthcare Environment (Chismar & Wiley-Patton, 2006) – This study empirically established that only perceived usefulness is significant and ease of use was not significant.

The dynamics of IT adoption in a major change process in health delivery (Lapointe, Lamothe, & Fortin, 2006) – This study established that TAM as devised by (Davies, Bagozzi, & Warshaw, 1989) is not adequate for health systems because adoption/resistance factors may be group related as opposed to the fundamental basis of TAM which is individualistic, influence of intra and inter organisational factors, linkages to cultures, environmental factors as well as the complexity of the environment.

Introducing electronic patient records to hospitals: Innovation adoption paths (Suomi, 2006) – This study found that relative advantage, strong network externalities available, rich availability of information through different communication channels are key factors for innovation and adoption. It should be noted that these are not discussed in the TAM models.

User acceptance and diffusion of innovations summarised (Spil & Schuring, 2006) – This summary established that perceived usefulness is a predictor of technology acceptance in healthcare. Ease of use was not found to be significant.

Understanding physicians' use of online systems: an empirical assessment of an electronic disability evaluation system (Horan, Tule, & Hilton, 2006) – This study found that in order to diffuse technology in an organisation, it is important to ascertain physicians' behaviour, their workflow practices and their perceptions regarding the value of specific information systems.

In essence, the recent studies appear to be indicating that the current models of technology acceptance or its derivatives are not suitable to predict the adoption factors of wireless technology in healthcare environment. Strong support can also be derived from three specific studies that have tested TAM models in healthcare. The first study conducted by (Jayasuriya, 1998) established that ease of use was not significant in a clinical domain. The second study by (Chau & Hu, 2002) echoed similar sentiments. The third study by Hu et al. (Hu, Chau, & Tam, 1999) also found similar findings.

Further, recent studies conducted by (Howard, Gururajan, Hafeez-Baig, & Howard, 2006) also established that ease of use was not significant while determining factors of adoption in a clinical domain in regard to wireless technology. Further, (Ivers & Gururajan, 2006) also found that there are other factors beyond the TAM models influencing the acceptance of technology (Versel, 2008).

Interviews conducted with Queensland nursing staff members in Australia (Gururajan, Moloney, & D. Kerr, 2005) revealed that clinical usefulness of wireless technology is far more significant than ease of use factor as established in TAM. Another focus group discussion with the Western Australian senior health managers (R. Gururajan, M. Quaddus et al., 2005) also indicated that aspects of clinical usefulness such as integration of clinical data may be a significant factor than the ease of use factor. (Howard et al., 2006) also identified clinical usefulness is far more influencing than the ease of use factor while determining factors of adoption of wireless technology in the Indian healthcare domain.

However, the recent findings that the ease of use factor not showing strong significance in healthcare domain while determining wireless technology adoption warrants explanation as this is different to many other reported studies in the generic IS domain where both attributes (ease of use and perceived usefulness) were reported to be reliable predictors.

This variation requires further empirical investigation in order to explain the reason behind this variation specific to healthcare. Therefore, there is a need to identify attributes that assist in the adoption of wireless applications in healthcare environment. We argue that the initial validity of many technology acceptance models was predominantly established by testing the model with students as surrogates in a generic software application domain. This environment is very different to the healthcare environment, where the skills are at different levels. Further, the healthcare environment is complex, sensitive and time critical. These could be some of the reasons why TAM did not perform as expected in healthcare settings.

In addition, in the recent variant of technology acceptance, namely, UTAUT, (Venkatesh, Morris, Davis, & Davis, 2003) reviewed eight prominent models of user acceptance and managed to create a unified view. The unified model comprised of seven constructs. The first four – performance expectancy, effort expectancy, social influence and facilitating conditions – were theorised to be direct determinants. The last three – attitude towards technology, self efficacy and anxiety – were theorised to be indirect. All the seven constructs were found to be significant determinants of technology usage by Venkatesh et al ((Venkatesh et al., 2003).

In terms of attitude, Venkatesh et al. (Venkatesh et al., 2003) defined it as an individual's overall affective reaction to using a system. The model depicts four constructs relating to this determinant – attitude towards behaviour, intrinsic motivation, affect towards use and affect. (Spil & Schuring, 2006) verified that in three cases the relation between attitude and behavioural intention is significant. Therefore, this determinant cannot be indirect. If there is significance between attitude and behaviour intention, then there is a direct relationship.

Therefore, there appears to be a basis to identify factors that contribute to the adoption of technologies in healthcare settings. Given that wireless technologies have started making in-roads in healthcare, the overarching purpose of the research is to identify the factors that influence the adoption of wireless technology in the Indian healthcare system. The rationale of the purpose is justified by the fact that India is a leader in software technologies, especially medical applications. Further, India is emerging as 'health tourism', due to the advancement in medical technology and reduction in cost in offering high quality health services—as highlighted by various print media. However, our initial review of available literature indicated that this area is under-researched. Collectively, these aspects led to the following research question:

- What are the determinants for the adoption of wireless technology by physicians in the Indian healthcare system?

The first stage of this study is focused on answering the research question qualitatively and the second stage on answering the research question quantitatively. Details as to how the research question was answered are provided in the research methodology section below.

METHODOLOGY

An examination of existing IS studies indicated that there is a necessity for a suitable research method. Most of the reviewed studies follow a quantitative approach which involves an instrument being administered onto a domain with perhaps a lesser understanding of the domain issues. For this study it was felt that if technology issues are to be studied with respect to a specific domain, then user involvement with the technology issues forms a major part in establishing the adoption (or inhibiting) factors. By necessity, this would occur prior to administering quantitative instruments (e.g. survey). This, in turn, requires an understanding of research philosophy, values of inquiry that would guide the study, and the choice of relevant research techniques required to conduct the investigation in order to answer the research questions.

Further, there appears to be limited information available in the Indian IS domain to guide the principles of this study. This study is relatively new and, hence, requires a rigorous justification as to the choice of research methods employed. We also believe that due to aspects associated with various regulatory issues impacting the Indian health system, unique factors of technology acceptance, as well as usefulness, may emerge. Our initial meetings with Indian physicians also suggested that there is a divide in terms of technology usage between private and public hospitals, where private hospitals are rich in technology use and public hospitals are not. On the other hand, in many traditional studies in IS, either quantitative or, to some lesser extent, qualitative methods are used—but not both. In recent years this has been cited as a weakness (see (Mingers, 2001) for a detailed argument on this). Taking this into account, this study investigates the suitability of both approaches in order to answer the research question.

We recognise that the foundation for any research will be grounded on the researcher's fundamental philosophical view of the world (Myers, 1997). The choice of tools, including research techniques, instruments, and methods such as qualitative and quantitative, are not inherently linked to a particular philosophical position, as these positions are generic in nature. It is the contextual framework within which they are applied that provides consistency to an inquiry. While the choice of tools and methods are not linked to the philosophical view, the articulation—which is commonly the process of explaining choices of research methods and its related choice of research instruments—helps determine the philosophical disposition. This is usually achieved by asking questions on the beliefs, perceptions, experiences, advantages and disadvantages in order to determine this disposition. This may even include a researcher's personal experience within that domain, or their expertise in explicating the information using any approach that may be suitable to that domain. This has prompted us to follow a qualitative approach as the first phase of the study. We argue that this approach facilitates direction to the second phase of the study where quantitative evidence can be collected to establish causality between the dependent and the independent variables.

The research question dictates the need for quantitative research methods, while the behavioural component of the same investigation dictates qualitative research methods. The rationale for this approach is based on the notion that behavioural components require a thorough understanding of how users apply wireless technology in a given setting in order to understand behavioural issues. To extract 'tacit' aspects, this is best accomplished by applying a qualitative approach. A quantitative instrument can then be developed to extract the quantitative aspects, such as the opinion scores.

Health professionals view the term 'wireless technology' in different ways, either as a product or a process. The combined domain of wireless technology and healthcare is relatively new in the Indian IS domain. While IS studies have discussed the impact of Information & Communication Technology (ICT) tools and associated behavioural intentions on healthcare users, limited information can be found as to how the combination of wireless technology and healthcare settings would influence users who are already conversant with novel and advanced medical technologies (Spil & Schuring, 2006). The workplace or organizational factors that influence such combinations are yet to be explored in detail. Such an exploration has close association with the choice of research method as these methods pave the way for proper inquiry into the factors that determine technology acceptance in a given setting. On this basis, the suitability of one research method over another has to be carefully weighed. Consequently, this study identified an exploratory approach to be suitable for the initial investigation. This approach is particularly favourable in confirming the direction of the study, variables chosen for the study, and in helping refine the literature. The exploratory study can also possibly eliminate some variables, while providing opportunities for including emerging variables.

Qualitative Data Collection

As argued, for the first stage of this research the investigators used a qualitative approach to collect initial sets of themes for the adoption of wireless technology in the Indian healthcare system. For this purpose, 30 physicians operating in Indian healthcare were identified randomly. These physicians were interviewed by an independent member (external to the team) who identified the attributes for the adoption of wireless technology by physicians in the Indian healthcare system. This approach was deliberate to address criticisms of 'bias' in the interview process. Further, due to linguistic issues, we required a person with proficiency in both Indian language and English. The interview questions were derived from existing literature. The first stage of the data collection concentrated on Indian hospitals with some form of wireless technology already in use. The physicians were also chosen based on their wireless technology awareness or working experience. They were drawn from both private and government hospitals. The interviews were conducted over a 45-60 minute period and recorded using a digital recorder. Once they were recorded, the interviews were transcribed.

Quantitative Data Collection

This study developed a survey instrument from the interview data. The main reason for this digressed attitude was that previously tested instruments in the technology domain were not relevant to healthcare setting and were found to be inadequate in answering the research question. The data from the interviews were used to develop specific ranges of questions to gather a more detailed view from the wider population. This survey instrument was pilot tested to capture the information reflecting the perceptions and practice of those adopting the wireless technology in the Indian healthcare system. Particularly, it focussed on what internal and external environmental factors affect the adoption of wireless technology and the extent of this influence. The survey was then distributed to over 300 physicians randomly chosen from the telephone book and a total of 200 responses were received. The survey responses were then entered into a spreadsheet file. A Visual Basic interface was written to generate numerical codes for various elements of the survey for data analysis using SPSS. The coded spreadsheet file was then copied onto a SPSS file format.

DATA ANALYSIS

Qualitative data was analysed using the NVivo (version 7) application, which helped identify the initial themes from the interviews. Quantitative data were analysed using SPSS, which helped identify the factors and their correlation for the adoption of wireless technology in the Indian healthcare setting.

Qualitative Data Analysis

Qualitative data was manually coded to extract themes that had an impact on wireless technology acceptance as stated by the physicians. In total, 63 themes were extracted from the interviews. The initial themes include awareness, cost factors,

Table 1. The factors driving and inhibiting wireless technology adoption in healthcare

Drivers	Barriers
Save-time Improve-clinical-workflow Efficiency-in-communication Delivery-of-high-qual-info Better-quality-of-service Save-effort Improve-clinical-performance More-contact-time-with-patients Improved-delivery-of-information Reduce-overall-cost Positive-impact-on-patient-safety Reduce-inaccuracies Improve-public-image Reduce-medical-errors Easy-access-to-data Attract-more-practitioners Reduce-workload	Legal barriers Administrative purpose Communication with physicians Patient education Communication with colleagues Obtain lab results Note taking Electronic medical records Device usage barrier Benefit evaluation barrier Resource barrier Electronic prescribing

advantages and disadvantages, medical errors, information sharing, current state of technology, usefulness and role of wireless technology, and technology awareness. On the basis of the interviews and the literature review, the themes were classified into drivers and inhibitors as shown in the following table. This list of drivers and inhibitors was expected to provide a direction for the development of the survey instrument for the collection of quantitative data to capture the wider community views and to generalize the outcome of the research. This grouping is presented in Table 1.

The content of the Table 1 is consistent with findings of previous studies conducted by Gururajan et al. (2004; 2005). This prompted conducting a quantitative study in order to establish causality among dependent and independent variables, as well as external validity and generalisability.

Quantitative Data Analyses

In order to ensure statistical reliability, suitable tests were run on the entire instrument, as well as selected group of variables. For example, the reliability test returned a Cronbach alpha value of 0.965 for the instrument indicating high reliability (Zikmund, 1994). We ran this test because the instrument was generated from the interview data and, hence, it was necessary to establish statistical reliability. In addition, reliability tests were also run for three factor groupings, namely, drivers, inhibitors of adoption and other technology factors. The reliability tests returned values of 0.941,

Table 2. The factors driving and inhibiting wireless technology adoption in healthcare from data analysis of survey result

Drivers	Loading values	Barriers	Loading values
Improve-clinical-workflow	.798	Poor technology barrier	.605
Tech-support	.764	Time for training barrier	.572
Delivery-of-high-qual-info	.760	Tech expertise barrier	.554
Save-time	.757	Benefit evaluation barrier	.503
Better-quality-of-service	.749	Legal barriers	.465
Save-effort	.743	Solutions barrier	.444
Improved-delivery-of-information	.732	System migration barrier	.442
Efficiency-in-communication	.730	Technical support barrier	.436
More-contact-time-with-patients	.725	Lack of support barrier	.352
Improve-clinical-performance	.702	Device access barrier	.316
More-training	.699	Device comfort barrier	.248
Improve-public-image	.695	Funding barrier	-.225
Easy-access-to-data	.692	Security as barrier	.224
Positive-impact-on-patient-safety	.679	Device usage barrier	.208
Reduce-inaccuracies	.659		
Reduce-workload	.657		
Reduce-medical-errors	.650		
Reduce-overall-cost	.634		
Attract-more-practitioners	.600		
Org-culture	.464		

0.447 and 0.536, respectively, indicating that the data were suitable for factor analysis testing.

As a second step, survey data were analysed for factor analysis using SPSS. It is evident from the table below that two factor component matrix identified drivers and the barriers for the adoption of wireless technology in the Indian healthcare setting. This finding is consistent and aligned with the findings of the qualitative data collection stage (i.e. first stage) of this research.

The drivers were further tested for factor groupings. The analysis resulted in Table 3.

The driving factors of adoption yielded three categories of factors, namely, 'organisational', 'management' and 'clinical'. The organisational components include wireless technology drivers that can generate specific benefits for organisations. The management components represent the benefits that healthcare managers can realise using wireless technology. The clinical components encompass clinical drivers of using wireless technology.

A similar factor model was generated for the inhibitors. The model resulted in Table 4.

Similar to the drivers, the inhibitors also resulted in three specific categories. The 'technology' category includes technology factors that inhibit wireless adoption in the Indian healthcare. The 'resource' category encompasses resource barriers that are currently being encountered in the healthcare setting. Finally the 'usage' category is comprised of inhibiting factors, which are associated with usage issues.

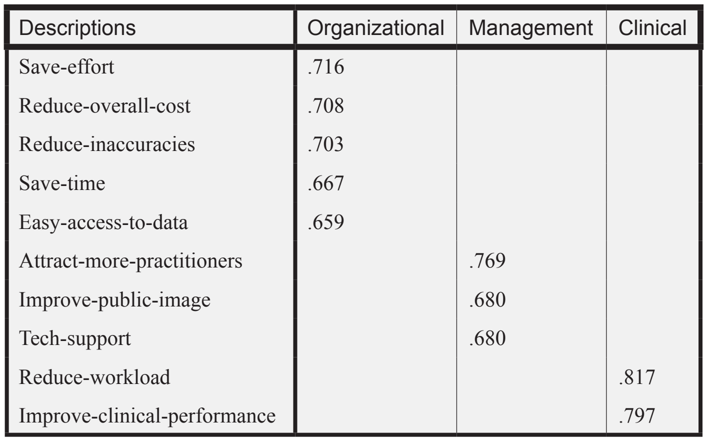
In addition to the two factor groups, namely drivers and inhibitors, we also identified a third. We named this 'clinical usefulness' and its components are shown in Table 5 below.

This factor group yielded three components. The first component deals with the general communication aspects facilitated by wireless technology in healthcare settings. The second component refers to clinical communication using wireless technology. The third component is specific to records management. In summary, the data analyses yielded three specific categories of factors which can affect the adoption of wireless technologies in the healthcare setting. These comprise adoption drivers, inhibitors, and clinical usefulness.

Hypotheses Formulation and Testing

Based on the evidence collected, the three sets of factors, namely, drivers, barriers and clinical usefulness, contribute to the acceptance of wireless technology in healthcare. We hypothesise that the drivers positively impact clinical usefulness,

Table 3. The factors driving wireless technology adoption in healthcare from data analysis of survey result



Descriptions	Organizational	Management	Clinical
Save-effort	.716		
Reduce-overall-cost	.708		
Reduce-inaccuracies	.703		
Save-time	.667		
Easy-access-to-data	.659		
Attract-more-practitioners		.769	
Improve-public-image		.680	
Tech-support		.680	
Reduce-workload			.817
Improve-clinical-performance			.797

Table 4. The factors inhibiting wireless technology adoption in healthcare from data analysis of survey result

Descriptions	Technology	Resource	Usage
Poor technology barrier	.625		
Time for training barrier	.582		
Solutions barrier	.575		
Benefit evaluation barrier	.528		
Tech expertise barrier	.527		
System migration barrier	.511		
Funding barrier		-.749	
Resource barrier		-.690	
Technical support barrier			.542
Device usage barrier			.519

Table 5. The factors 'clinical usefulness' of wireless technology adoption in healthcare from data analysis of survey result

Descriptions	General Communication	Clinical Communication	Records Management
Obtain lab results	.837		
Administrative purpose	.770		
Electronic prescribing	.670		
Medical database referral	.632		
Patient education		.727	
Communication with colleagues		.707	
Communication with patients		.676	
Drug administration		.596	
Communication with physicians		.548	
Electronic Medical Records			.764
Generating exception list			.738
Note taking			.617
Disease state management			.563

whereas the barriers have a negative impact on it. While the drivers and barriers include factors beyond the technology aspects, their respective influences are restricted to the clinical domain as this is where the usefulness of wireless technology can be experienced. Therefore, the following two hypotheses were generated for testing:

H1: *Drivers of wireless technology positively impact clinical usefulness.*

H2: *Barriers to wireless technology negatively impact clinical usefulness.*

A "Structural Equaction Modeling (SEM) model was developed in order to test the hypotheses. The rationale for using SEM includes: SEM is used for confirmatory factor analysis (CFA); the pattern of loadings of items on the latent constructs is explicit; SEM provides strong convergent and discriminant validity; p-value of t-value is significant (over 0.50

level) for constructs; and measurement items load highly on theoretically assigned factors and not highly on other factors.

SEM MODEL DEVELOPMENT

In order to develop the SEM model, an AMOS version 16 was used. Initially, the individual drivers, barriers and clinical usefulness were tested for CFA (Confirmatory Factor Analysis) scores and these were found to be reliable. When the CFA was found to be satisfactory, a model was built with clinical influences as dependent variable on drivers and barriers. The final outcome is shown in figure below.

Figure 8 shows that the factor loading (the number on the path: for example, for the construct Drivers, has 0.16, 0.21, and .48). The drivers and clinical usefulness load highly (over 0.8 for most of the items), indicating a high reliability. Further, all variables have a t-value of over 2.0 to indicate high convergent validity.

Upon construct validation, a simple SEM (consolidated) model was developed to test the hypotheses. The model consists of clinical usefulness as the dependent variable, and drivers ("Organizational" (O), "Clinical" (C), and "Management" (M)) and barriers ("Usage" (U), "Technology" (T), and "Resources" (R)" (M) as independent variables. The model was run with AMOS Graph program and the screenshot shown in Figure 2 displays the values along the link from Drivers to Clinical Usefulness, and Barriers to Clinical Usefulness.

According to (Holmes-Smith, 2000) to analyse a model for the data fit, the following five measurements need to be analysed carefully:

- Chi-square (X^2 acceptable fit: $p > 0.05$)
- Normed Chi-square (X^2/df acceptable fit $1 < X^2/df < 2$)
- Goodness-of-fit index (GFI- acceptable fit value, $0.95<GFI<1$, reasonable fit value would be $0.90<GFI<0.95$)
- Tucker-Lewis Index (TLI- acceptable value; $TLI>0.95$; reasonable value of fit $0.9<TLI<0.95$ and lack of model parsimony would be $TLI>1$)
- RootMean-Square Error of Approximation (RMSEA- acceptable fit value: $RMSEA<0.05$; reasonable level of: $0.05<RMSEA<0.08$)

Above criteria was used to analyse the data fit for each of the construct before computing the composite variables. Figures below show the values of each variable separately for initial model and the improved acceptable model for each of the composite model.

Data Reduction and Technique for Compatibility Variable

Diagram 1, 2 and 3 above shows the data fit for the improve model. This was achieved by ap-

Figure 1. Initial model

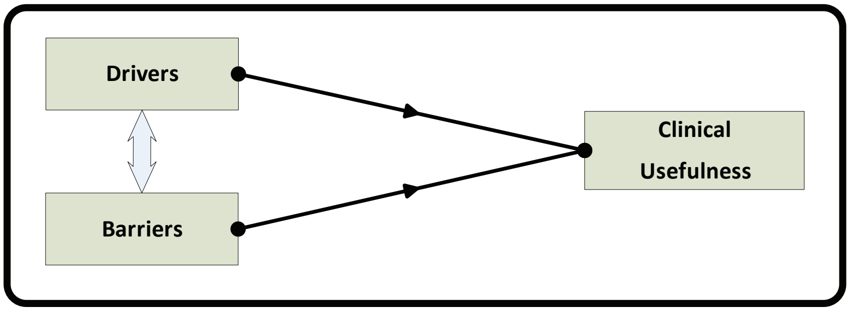


Table 6. Description of items used in building the SEM model and their reliability

Variables	Initial	Descriptions	Reliability
Drivers	D1	Reduce-workload	0.885
	D2	Improve-public-image	
	D3	Improve-clinical-performance	
	D4	Attract-more-practitioners	
	D5	Save-time	
	D6	Save-effort	
	D7	Tech-support	
	D8	Reduce-overall-cost	
	D9	Easy-access-to-data	
Barriers	B1	Funding barrier	0.539
	B2	Resource barrier	
	B3	Solutions barrier	
	B4	System migration barrier	
	B5	Benefit evaluation barrier	
	B6	Time for training barrier	
	B7	Poor technology barrier	
	B8	Tech expertise barrier	
	B9	Technical support barrier	
	B10	Device usage barrier	
Clinical Influences	CI 1	Electronic medical records	0.850
	CI 2	Medical database referral	
	CI 3	Electronic prescribing	
	CI 4	Obtain lab results	
	CI 5	Disease state management	
	CI 6	Adminstrative purpose	
	CI 7	Generating exception list	
	CI 8	Patient education	
	CI 9	Note taking	
	CI 10	Drug administration	
	CI 11	Communiation with physicians	
	CI 12	Communication with colleagues	

propriate after the analysis of the suggestions provided "Modification Indies" provided by SEM along with the analysis of the adequate theoretical support. Objective was to achieve the improved measure of data fit for the empirical data while keeping integrity of the theoretical support. Results shows that changes in the model has resulted all the five indicator showed that empirical data fitted the improve measurement model.

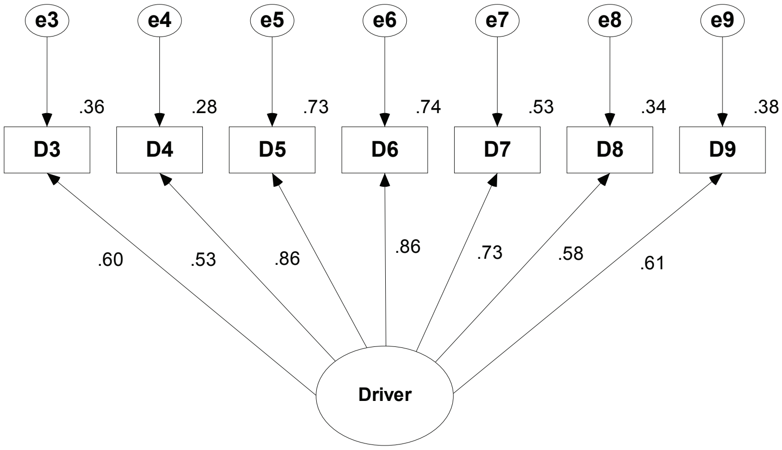
Once the data reduction techniques was used to individual variables and data was found to fit as per (Holmes-Smith, 2000) incies, we draw the initial SEM model with Barriers (B) and Drivers (D) as an independent variables and "clinical Usefulness (CU) as dependent variable in the model.

As can been seen from the above Figure 4 above five of the popular measured provided by (Holmes-Smith, 2000) is provided under the diagram. First two values (Chi-square, and Normed Chi-square) were not at acceptable level, however values of other three (Goodness-of-fit index, Tucker-Lewis Index, and RootMean-Square Error of Approximation) were not at acceptable level. It was concluded that the data did not adequately fit the model.

Diagram 5 above shows the data fit for the improve model. This was achieved by appropriate after the analysis of the suggestions provided "Modification Indies" provided by SEM along with the analysis of the adequate theoretical support. Objective was to achieve the improved measure of data fit for the empirical data while keeping integrity of the theoretical support. Results shows that changes in the model has resulted all the five indicator showed that empirical data fitted the improve measurement model.

The diagram in the above figure provide the visual results of aggregating the items of the measurement model of stage two of the process, which provided the evidence for the data fit the model for the empirical data. As a result we produced a composite variable for "Drivers", "Barriers", and

Figure 2. Drivers: $X^2 = 27.5$, $df = 14$, $p = 0.017$, $X^2/df = 1.964$, *GFI = 0.961, TLI = .963*



RMSEA = 0.070 (Data fit the improved model)

Figure 3. Drivers: $X^2 = 37.3$, $df = 25$, $p = 0.054$, $X^2/df = 1.492$, *GFI = 0.959, TLI = .900, RMSEA = 0.050 (Data fit the improved model)*

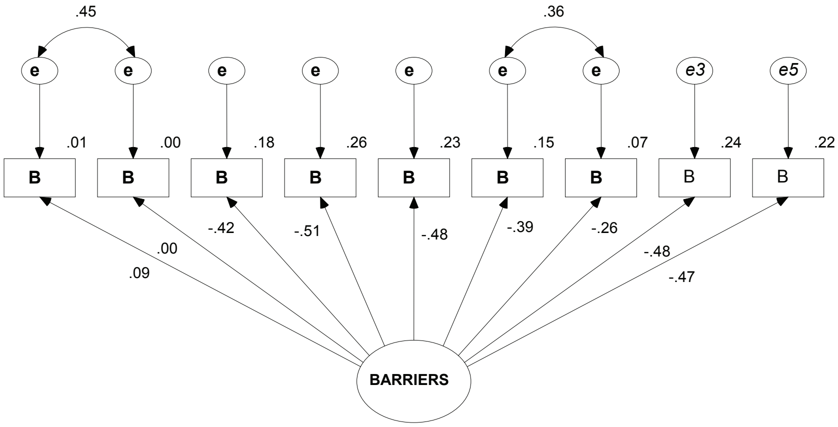


Figure 4. Clinical Usefulness: X² = 30.8, df = 12, p = 0.054, X²/df = 1.492, GFI = 0.959, TLI = .900, RMSEA = 0.050 (Data fit the improved model)

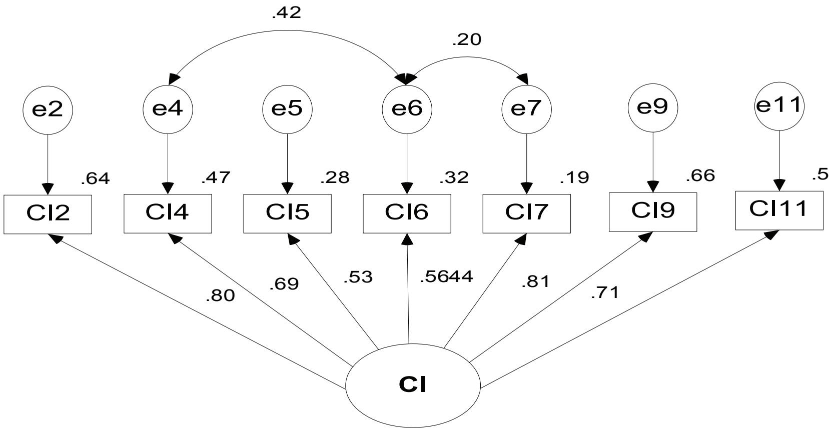
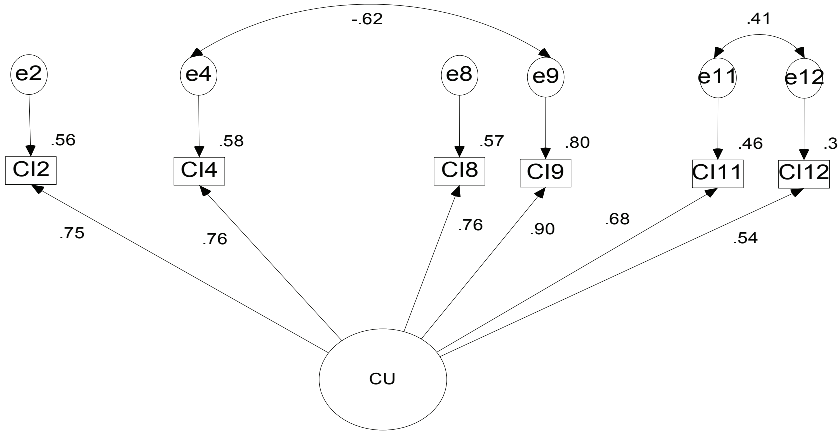


Figure 5. Clinical Usefulness: X² = 9.0, df = 7, p = 0.252, X²/df = 1.28, GFI = 0.986, TLI = .992, RMSEA = 0.038 (Data fit the improved model)



"Clinical Influences" in the complete model for the existing data in order to analyse the influence of drivers and barriers on the clinical influences. Data fit of the model and the indices measures are X² = 41.6, df = 23, p = 0.010, X²/df = 1.810, GFI = 0.955, TLI = .932, and RMSEA = 0.065.

In the above diagram, the latent variable "Clinical Influences" (CI), set of possible predictors, "Usage" (U), "Technology" (T), "Resources" (R), "Organizational" (O), "Clinical" (C), and "Management" (M) are the observed variables. CI is itself indicated by three items, "Technological Management" (TM), "Clinical Communication" (CC), and "General Communication" (GC). As can be seen, the overall structural model fit was good. Criteria used to determined: X² = 41.6, with 23 df, X²/df = 1.810, CFI = , AIC = , GFI = 0.955, TLI = .932, and RMSEA = 0.065, . Based on these results we proceeded to test the two hypothesis mentioned above (H1, and H2) previously proposed. These hypotheses stated that drivers have positive impact and barrier have negative impact on the clinical usefulness. The result supported theses hypothesis, for example in the case of drivers, "Organizational, (t=1.56, p > 0.01)", "Clinical, (t=2.14, p < 0.01)", and "Management, (t=4.4, p < 0.01)" shows that clinical and management drivers are positively contributing to the clinical usefulness, where as the contribution of organizational is not significant. Whereas barrier have vary limited scope, “Usage, (t= -1.98, p > 0.01)”, “Technology, (t=3.13, p < 0.01)”, and “Resources, (t= -0.685, p > 0.01)”. Drivers and barriers are the predictive of the clinical usefulness; results indicate that drivers have stronger influence on the clinical usefulness of the wireless technology than the barrier.

Figure 6. SEM Initial Model: X² = 548.0, df = 202, p = 0.000, X²/df = 2.713, GFI = 0.817, TLI = .755, RMSEA = 0.094 (Data did not fit the improved model)

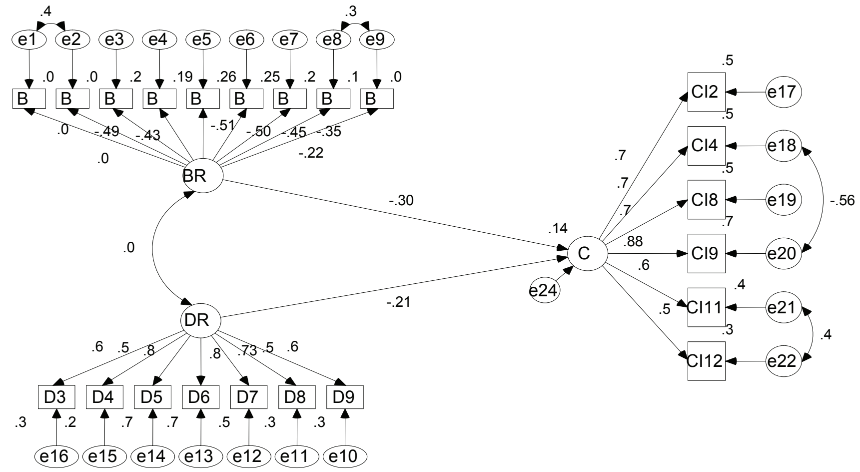


Figure 7. SEM Model: X² = 78.9, df = 50, p = 0.006, X²/df = 1.577, GFI = 0.939, TLI = .910, RMSEA = 0.055 (Data fit the improved model)

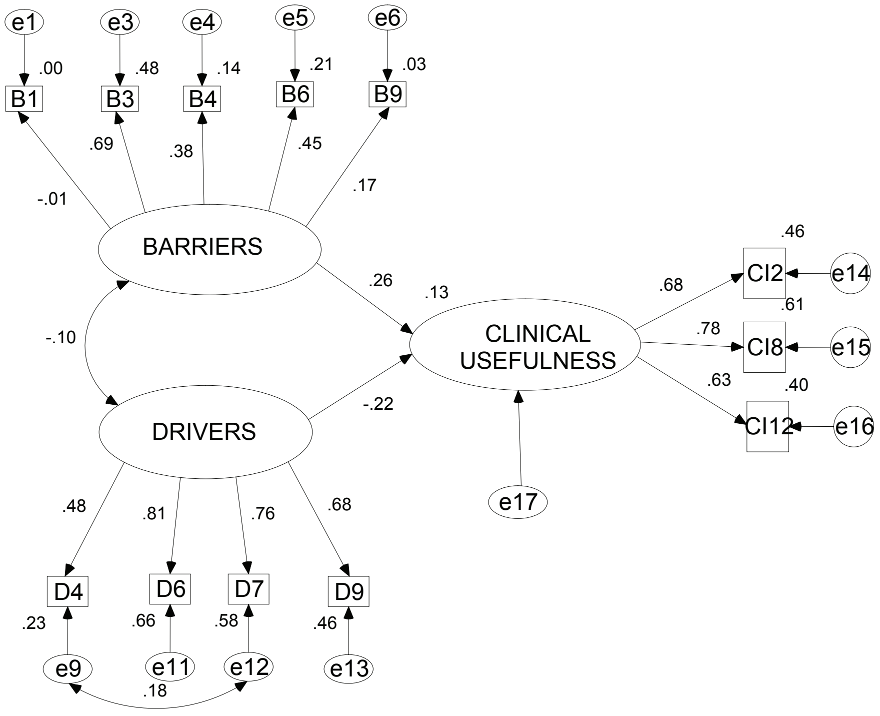
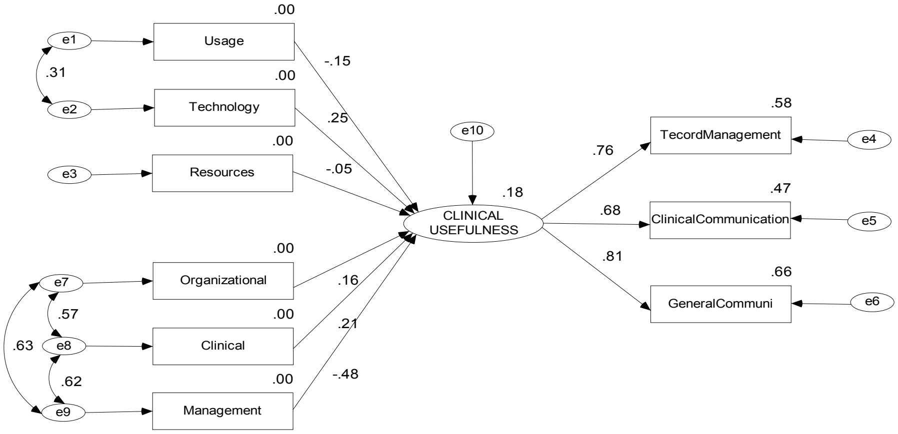


Figure 8. SEM Model: $X^2 = 41.6$, $df = 23$, $p = 0.010$, $X^2/df = 1.810$, $GFI = 0.955$, $TLI = .932$, $RMSEA = 0.065$ *(Data fit the improved model)*



DISCUSSIONS

The Confirmatory Factor Analysis agrees with the outcomes derived from the interview qualitative data in that the set of drivers, barriers and clinical influences are indeed the determinants of wireless technology in the Indian healthcare. Within these three determinants, we are able to identify usage, technology and resources influencing the clinical usefulness. The predictor 'usage' is influenced by the usefulness of technology as identified in recent studies. This study also conforms to the notion that 'ease of use' is not a major influence on technology adoption in the Indian healthcare.

In terms of clinical usefulness, we are able to assert that record management, clinical communication and general communication to be the three major aspects. Our qualitative study had already given us some indication to these predictors. Our interviews revealed that the greatest benefits of wireless technology in clinical settings would be records management because it is possible for clinicians to access patient data at the point of care. We also understood that it is possible to use smart phone type technology to send patient conditions to other clinicians in order to get advice. In terms of general communication, our interview transcripts indicate that it is now possible to provide patient education using the wireless technology.

Thus, wireless technology can be used to facilitate access to clinical information and communications between clinicians, maximise clinician time, increase patient safety, and accomplish the strategic and business goals of health organisations. Taken together, these factors have a direct impact on clinical usefulness and its effectiveness. However, achieving clinical usefulness with wireless handheld devices can be a challenge and has several implications.

Firstly, the highest security standards must be achieved. This includes direct end-to-end data encryption, authentication, authorisation, maintenance of audit logs and session management (Chen et al. 2004). While high security standards are essential, their implementation is likely to affect usability. For example, the download and encryption of patient information from the server where it is stored into a wireless handheld device may not be prompt. Sax et al. (2005) argue that clinicians may experience increasingly longer time lags when they carry out increasingly more complex procedures. This is likely to adversely affect clinical usefulness and, hence, decrease user acceptance.

Closely associated with security is also the issue of patient confidentiality, which is of significant importance and concern. Although wireless handheld devices have locking security features and password protection functions which activate during periods of inactivity, the frequent use of these functions during the clinicians' busy daily schedules may have an impact on clinical usefulness.

A crucial lesson learnt in this study was in the use of qualitative and quantitative components. We approached the healthcare professionals to seek their opinions on the benefits of using wireless technology. This stage was followed up with a survey instrument. We conducted a first order regression analysis to regress the 90 or so factors explored into a set of manageable factors. The lesson was quite valuable because as outsiders (coming from an Information Systems background), we were able to appreciate the complexities of healthcare information systems. Similarly, our open minded approach enabled healthcare professionals to appreciate IS related aspects. We also found out through our informal discussions that the study would have been a stereo-type study had we approached a quan-qual type mixed method because we would have been restricted by what was available in the literature to derive our quan part and this would have restricted our qual part.

To our own surprise, we found both IS and health literature to be limited in catching up with wireless technology related attitude and perception data. While the technology literature such as the IEEE provided us with the technical knowledge, human aspects have not yet been discussed in IS and healthcare literature. The results established through a second order regression are consistent with what we found for the Australian Healthcare (published elsewhere).

We measured only perceptions and attitudes in this study. While there is sufficient information available through interviews on the type of savings and benefits that can be attained by using wireless technology in healthcare, it is still not clear as to the exact quantification of these. Therefore, it would be useful to measure this by employing a wireless technology in a clinical setting and then collecting some evidence as to the savings and benefits.

REFERENCES

Athey, S., & Stern, S. (2002). The impact of information technology on emergency health care outcomes. *RAND Journal of Economics, 33*, 399-388.

Chau, P.Y.K., & Hu, P.J-H. (2002). Investigating healthcare professionals' decision to accept telemedicine technology: An empirical test of competing theories. *Information and Management, 39*, 297-311.

Chismar, W.R., & Wiley-Patton, S. (2006). Predicting Internet Use: Applying teh Extended Technology Acceptance Model to the Healthcare Environment. In T.A.M. Spil & R.W. Schuring (Eds.), E-Health Systems Diffusion and USe: The Innovation, the USer and the USE IT Model. Hershey, PA, USA: IGI Global.

Davies, F.D., Bagozzi, R.P., & Warshaw, P.R. (1989). User acceptance of computer technology: A comparison of two theoretical models. *Communications of the ACM, 35*, 982-1003.

Davis, R (2002). Pursue front end solutions to revenue problems. *Healthcare Financial Management, 56*, 30-36.

Dyer, O. (2003). Patients will be reminded of appointments by text messages. *British Medical Journal, 326,* 281.

Gururajan, R., Toleman, M., & Soar, J. (2004, July 25-27). Necessity for a new technology acceptance model to predict adoption of wireless technology in healthcare. In *Let's Make a Difference with Health ICT, HIC Conference.* Health Informatics Society of Australia (HISA).

Gururajan, R., Moloney, C., & Kerr, D. (2005). Drivers for wireless handheld technology: Views from Queensland nurses. In *Australian Business & Behavioural Sciences Association (ABBSA) Conference,* Cairns, Australia, James Cook University (pp. 258-267).

Gururajan, R., Quaddus, M., Fink, D., et al. (2005). Drivers and Barriers to adoption of wireless handheld system in WA healthcare: Selected views. In *HIC 2005*. Melbourne, HISA.

Gururajan, R., Hafeez-Baig, A., & Gururjan, V. (2008). Clinical Factors And Technological Barriers As Determinants For The Intention To Use Wireless Handheld Technology In Healthcare Environment: An Indian Case Study. In *16th European Conference on Information System*s, National University of Ireland, Galway.

Hafeez-Baig, A. (2007). Technology Management, Data management, Improved outcomes, Efficiency and Software limitation influencing the use of wireless technology for healthcare in Pakistan. In *6th IEEE/ACIS International Conference on Computer and Information Science (ICIS 2007)* (pp. 1104-1110), Melbourne: IEEE.

Holmes-Smith, P. (2000). *Introduction to Structural Equation Modeling Using AMOS 4.0.* Melbourne: SREAMS.

Horan, T.A., Tule, B., & Hilton, B.N. (2006). Understanding physician use of online systems: An empirical assessment of an electronic disability evaluation system. In T.A.M. Spil & W.R. Schuring (Eds.), *E-Health Systems Diffusion and Use: The Innovation, the User and the USE IT Model.* Hershey, PA, USA: IGI Global.

Howard, A., Gururajan, R., Hafeez-Baig, A., et al. (2006). Clinical Usefulness of Wireless Technology in Healthcare: An Indian Study. In *The Australasian Conference on Information Systems*, University of South Australia.

Hu, P.J., Chau, P.Y.K., & Tam, K.Y. (1999). Examining teh technologya cceptance model using physician acceptance of telemedicine technology. *Journal of Management Information Systems, 16*, 91-112.

Hu, P.J., Chau, P.Y.K., & Liu, S.O.R. (2002). Adoption of telemedicine technology by health care organisations: An exploratory study. *Journal of organisational computing and electronic commerce, 12,* 197-222.

Ivers, B., & Gururajan, R. (2006). Management issues in telecommunications: videoconferencing & telehealth. In *International Conference on Recent Trends in Information Systems Proceedings* (pp. 796-806), India: Allied Publishers Pvt Ltd.

Jayasuriya, R. (1998). Determinants of microcomputer technology use: Implications for education and training of health staff. *International Journal of Medical Informatics, 50*, 187-194.

Lapointe, L., Lamothe, L., & Fortin, J. (2006). The dynamics of IT adoption in a major change process in healthcare delivery. In T.A.M. Spil & R.W. Schuring (Eds.), *E-Health Systems Diffusion and Use: The Innovation, the User and the USE IT Model*. Hershey, PA, USA: IGI Global.

Mingers, J. (2001). Combining IS research methods: Towards a pluralist methodology. *Information Systems Research, 12*, 240-259.

Myers, M.D. (1997). Qualitative research in Information Systems. *MIS Quarterly, 21,* 241-242.

Reinecke, I. (2004). *Managing Information in Health.* Melbourne National Health Information Summit.

Rogoski, R. (2003). Wireless by Design. *Health Management Technology,* (pp. 1-7).

Sausser, G.D. (n.d.). Thin is in: web-based systems enhance security, clinical quality. *Healthcare Financial Management, 57*, 86-88.

Simpson, R.L. (2003). The patient's point of view -- IT matters. *Nursing Administration Quarterly, 27,* 254-256.

Siracuse, M.V., Pharm, D., & Sowell, J.G. (2008). Doctor of Pharmacy Students' Use of Personal Digital Assistant. *American Journal of Parmaceutical Education, 72*, 1-7.

Spil, T.A.M., & Schuring, R.W. (2006). *E-Health system diffusion and use.* Hershey, PA, USA: IGI Global.

Stuart, D., & Bawany, K. (2001). *Wireless Services.* UK: Gartner.

Suomi, R. (2006). Introducing electronic patient records to hospitals: Innovation adoption paths. In T.A.M. Spil & W. R. Schuring (eds.), *E-Health Systems Diffusion and Use: The Innovation, the User and the USE IT Model.* Hershey, PA, USA: IGI Global.

Turisco, F. (2000). Mobile computing is next technology frontier for health providers. *Healthcare Financial Management, 54*, 78-82.

Venkatesh, V., Morris, M.G., Davis, G.B. et al. (2003). User Acceptance of Information Technology: Toward A Unified View. *MIS Quarterly, 27,* 425-478.

Versel, N. (2008). Use of Mobile and Wireless Technology Jumps in Hospitals. *Digital HealthCare*. Retrieved from http://www.digitalhcp.com/DigitalHealthCare_Content.aspx?id=72018

Wisnicki, H.J. (2002). Wireless networking transforms healthcare: physician's practices better able to handle workflow, increase productivity (The human connection). *Ophthalmology Times, 27,* 38-41,

Wu, K., & Wu, X. (2007). A Wireless Mobile Monitoring System for Home Healthcare and Community Medical Services. In the 1st International Conference on Bioinformatics and Biomedical Engineering (ICBBE) (pp. 1190-1193).

Zhang, D. (2007). Web content adaptation for mobile handheld devices. *Communications of the ACM, 50*, 75-79.

Zikmund, W. (1994). *Business research methods* (International Ed. Edition). Orlando, FL: The Dryden Press.

This work was previously published in International Journal of Healthcare Delivery Reform Initiatives, Vol. 1, Issue 3, edited by M. Guah, pp. 19-37, copyright 2009 by IGI Publishing (an imprint of IGI Global).

Chapter 3.7

Mobility Support in 4G Heterogeneous Networks for Interoperable M-Health Devices

Eduardo Antonio Viruete Navarro
University of Zaragoza, Spain

José Ruiz Mas
University of Zaragoza, Spain

Julián Fernández Navajas
University of Zaragoza, Spain

Ignacio Martínez Ruiz
University of Zaragoza, Spain

ABSTRACT

In the last years, much work has been done to create a complete solution in m-Health environments. The problem can be summarized as follows: any health professional (medical specialist, sport trainer, nutritionist, etc.) should be able to control a series of measurements related to a person's health. The characteristics of these people vary from those patients with limited knowledge of the control processes and low mobility to sportsmen highly involved in the process and great mobility in the moment the measurements take place. This wide set of characteristics raises two basic challenges: the use of measurement equipment easily adaptable to the control system and the necessity of adding mobility support mechanisms to the design. This chapter focuses on studying these two challenges, illustrates them with several use cases and contributes to the mobility support problem with a new algorithm.

INTRODUCTION

Telecommunications and advanced information technologies have increasingly been used for clinical activities and research to improve healthcare delivery. The design of these e-Health systems has boosted many evolutions in the last years towards integrated solutions and new application environments. Thus, Medical Devices (MDs) and Vital Sensors (VSs) at the Point of Care (PoC) end are now part of very diverse environments: home telemonitoring, mobile solutions (m-Health) for teleemergencies, or on-line follow up while patients

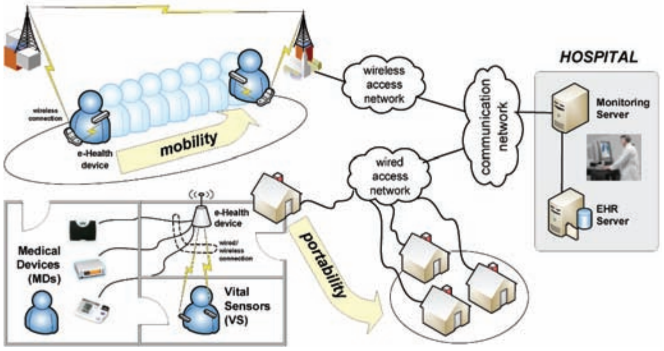
DOI: 10.4018/978-1-60566-046-2.ch027

carry out their daily living activities (Ruiz, Viruete, Hernández, Alesanco, Fernández, Valdovinos, Istepanian & García, 2006). These devices and sensors acquire huge amounts of very valuable information, without the need for manually writing down each measurement, contributing to the generation of the Electronic Healthcare Record (EHR). Moreover, as different manufacturers use their own software and communication protocols (building proprietary solutions that can only work alone or inside a single-vendor system), an important interoperability problem emerges, leading to the need of communication standards (Galarraga, Serrano, Martinez & Toledo, 2005), and their further adaptation to new wireless (Bluetooth, Zigbee, or WiFi) and wired (USB or Ethernet) communication technologies. Some of these standards are EN13606, the European standard for EHR communication (EN13606, 2007); and ISO/IEEE11073 PoC-MDC, the European CEN/TC251 family of standards for PoC-MD Communications also known as X73 (IEEE11073, 2007). Thus, this need for developing open sensor networks in healthcare environments has fostered the development of standard-based specific solutions (Martínez, Fernández, Galarrage, Serrano, Toledo & García, 2007) that allow transparent integration and interoperability inside e-Health systems with monitoring medical devices. Furthermore, the use of standards provides plug-and-play capabilities and auto-configuration features with the lowest level of user intervention, also taking into account users with no technical knowledge (the end user, without the support of a technician, should also be able to substitute or add a device in case of failure or due to a change in the follow-up design).

From this scenario, and in order to propose global e-Health solutions, all this interoperability effort must be integrated in a design scheme to support a network of compatible devices from different patients in different locations (see Figure 1). Thus, information data acquired from the different MDs and VSs is transmitted in a standards-compliant mode to a compatible e-Health device that acts as a gateway. This compatible e-Health device in each PoC connects to the monitoring server to manage different e-Health services, and its design must adapt to the new relevant scenarios in addition to those based on traditional fixed networking. Thus, the e-Health device design must support two additional connection modes: portable (in supervised environments but with changing requirements), and mobile (with changing both environments and requirements). First, in a portable networking scenario, the device design requires allowing intra-network connections and communications to any access network, in order not to depend on the specific requirements related to each fixed location. However, the design does not require continuing the ongoing communication between communicating peers during movements. In a complementary way, a mobile networking scenario requires services to continue ongoing communications while roaming, preferably without interruption or the degradation of communication quality. In fact, the first scenario can be regarded as a special case of the second scenario. Likewise, devices must adapt to the available (wired and wireless) connection technologies, and be able to communicate to several access technologies and seamlessly move between them in an Internet Protocol (IP) environment. These requirements involve the integration between heterogeneous networks, known as 'all-IP,' including mechanisms to provide mobility support for roaming devices and efficient seamless vertical handoff (or handover) schemes to enhance Quality of Service (QoS) and provide flawless mobility (Le, Fu & Hogrefe, 2006).

Today many things have changed in the traditional TCP/IP networks with the deployment of mobile devices, in particular in relation to the scenarios previously described and their service requirements when a mobile device moves across wireless networks. In this situation, its location may change frequently and, therefore, its IP address may change accordingly. Due to the changes of IP address, the ongoing connections of

Figure 1. Network environment for interoperable devices including portability and mobility



a mobile host can be broken and peer nodes may have difficulty to locate a mobile host. Therefore, two key issues for mobility support in wireless IP networks are: how to maintain the continuity of ongoing connections and how to provide location management. To date, many mobility management schemes have been proposed to address these two issues. Many of them have been designed and implemented, and some of them are starting to be deployed. Nevertheless, they demonstrate both pros and cons in dealing with mobility support in terms of efficiency, functionality, security, and so forth. Le et al. (2006) reviews previous works that have developed different mobility solutions, discusses the strengths and weaknesses of implementing mobility at three different layers of the TCP/IP stack, and compares them on various aspects like performance, security, deployment, scalability, robustness properties, and so forth.

In addition, handoff schemes are required to preserve connectivity as devices move about, and at the same time curtail disturbance to ongoing transfers. Consequently, seamless handoff, with low delay and minimal packet loss, has become a crucial factor for mobile users who wish to receive continuous and reliable services. One of the key issues that aid in providing seamless handoffs is the ability to correctly decide whether or not to carry out vertical handoff at any given time. This could be accomplished by taking into consideration two aspects: connection maintenance and network conditions for vertical handoff decisions. These two schemes need to be tightly coupled in order to move seamlessly across different network interfaces. To attain a positive vertical handoff, the network state ought to be constantly measured by means of a suitable handoff metric. In multinetwork environments, this is very challenging and hard to achieve, as there is not a single factor that could provide a clear idea of when to hand off. Signal strength and available resources in the target cell, the main metrics in horizontal handoffs, cannot be utilized for vertical handoff decisions due to the overlay nature of heterogeneous networks and the different physical techniques used by each network. In vertical handoffs, many network characteristics have an effect on whether or not a handoff should take place. Thus, transmission rates, error rates, and other QoS parameters can be measured in order to decide which network can provide improved service levels. The cost of the different services to the user or risks in any wireless technology could sometimes be the decisive factor in the choice of a network.

The previous discussion leads to ask which IP mobility support mechanisms should be chosen for the e-Health device – monitoring server communication, and what specific characteristics should be considered in the handoff decision. Several relevant use cases as home telemonitoring (fixed or portable), and chronics and athletes' follow-up (portable or mobile) have been selected in order to define the specific requirements for the e-Health device – monitoring server communication. They will permit to choose the most suitable solutions for mobility support, propose the characteristics which are particularly important for vertical handoff decisions, and define the most appropriate algorithms for each use case. This methodology deals with the possible future integration of medical standards (X73 and EN13606) in systems provided with IP connectivity and mobility. IP mobility is responsible for carrying out the change between technologies in a transparent way to upper architectural levels, which is often denoted as Media Independent Handover (MIH) (IEEE802.21, 2007). In order to achieve that objective, an algorithm for IP connectivity and mobility management will be presented. It permits to maintain medical and vital data communications in spite of any possible changes in the available IP technologies of the e-Health device.

Thus, this chapter explains initially the requirements needed for Internet mobility support and reviews existing solutions in different layers. Then, it presents fixed/portable and portable/mobile use cases to define the specific requirements for the e-Health device—monitoring server communication. Furthermore, it classifies the characteristics for vertical handoff decision and categorizes them depending on their relevance and applicability. Finally, it defines an algorithm optimized for different e-Health use cases.

MOBILITY SUPPORT IN 4G HETEROGENEOUS NETWORKS

This section presents a summary of the primary aspects of mobility support. The different requirements and solutions for IP mobility are explained first. Vertical handoffs are needed when dealing with heterogeneous networks; therefore the desirable features of the vertical handoff decision are presented in the end.

Requirements and Solutions for IP Mobility

As mentioned, the traditional TCP/IP networks were originally designed for communications between fixed devices and are not appropriate for Internet mobility support. The original situation based on using only well-known single persistent IP addresses is no longer a viable solution. This address orientation was valid when four issues were considered invariants (Nikander, 2001): an address received was the address sent, addresses were stationary, source and destination were reversible, and all hosts knew to which address they should send packets to reach the wanted host. These assumptions cause four fundamental problems in the network layer (Henderson, Ahrenholz & Kim, 2003). The first concerns addressing: mobile hosts usually have an incorrect interface address when they attach to a new network. Second, when changing networks, the mobile host may become unreachable to the rest of the network unless the new address is somehow mediated to other nodes. The third problem is related to session management: as the current transport protocols use the IP address as part of the connection identifier, the change of address breaks active connections. Finally, mobile hosts must be able to authenticate themselves to their peers upon moving and maintain or re-establish network level security associations.

The main issue to be resolved in the current Internet addressing scheme is the separation of address and identifier concepts. Currently, devices connected to the network are identified by their IP addresses. When the mobile device moves between networks, its IP address changes and so does its identifier. The device has two choices to continue the ongoing communication with its peer: the new identifier is mediated to the peer or, alternatively, the device makes itself reachable via the original identifier. Therefore, in order to provide Internet mobility support, a number of fundamental issues arise, which can be summarized as the following functional requirements for Internet mobility support (Le et al. 2006):

- **Handover management.** The most important function needed to support mobility is to keep the ongoing communication alive while a Mobile Node (MN) moves and changes its point of attachment to the Internet. The main objective of handover management is to minimize service disruption during handover.
- **Location management.** Another important function needed to support mobility is the reliable and timely notification of the MN's current location to those other nodes that need it. Location management involves identifying the current location of the MN and also keeping track of their location changes as it moves on.
- **Multihoming.** The future mobile environment will be characterized by diverse wireless access networks, and the MN will be equipped with multiple interfaces supporting different wireless techniques. Thus, it is necessary to require multihoming support by which the MN can access the Internet through multiple links simultaneously and select and switch dynamic links while moving.
- **Applications.** The mobility management mechanism should be transparent, without requiring changes to current services and applications.
- **Security.** Any mobility solution must protect itself against misuses of the mobility features and mechanism.

While developing an Internet mobility solution, the performance metrics also deserve special attention. Some of the most relevant performance metrics for Internet mobility are the following:

- Handover Latency. It refers to the time elapsed from the last packet received through the old network to the arrival of the first packet along the new network during a handover.
- Packet Loss. It is defined as the number of packets lost while maintaining communication during a handover.
- Signalling Overhead. It is defined as the number of messages for the handover and location procedures.
- Throughput. It is the amount of data transmitted over a mobile Internet in a given period of time.

In addition to functional and performance requirements, there are some considerations to take into account for deploying a mobility mechanism in the Internet:

- Minimum changes to the applications. It is desirable not having to change every application when the mobility mechanism is applied in the Internet.
- Avoid adding third-party devices. Adding a third-party device into the network usually generates additional management overhead and security vulnerabilities, and should be avoided if possible.
- Easy integration into the existing infrastructure. Changes to allow integration into the existing infrastructure should be kept simple, as a well-deployed infrastructure implies a significant amount of investment, operational, and administrative/maintenance efforts if it is necessary to make updates to software or hardware in routers.

To date, many mobility management schemes have been proposed, in different layers for extending TCP/IP to support mobility. Because IP is the internetworking layer for the Internet, mobility solutions that build on the existing network layer are considered a natural approach. Mobile IP (MIPv4 and MIPv6) (Johnson, Perkins & Arkko, 2004; Perkins, 2002) and various enhancements to their performance (Gustafsson, Jonsson & Perkins, 2004; Jung et al., 2004; Koodli, 2005; Malki, 2005; Ramjee et al., 1999; Soliman et al., 2005; Valko, 1999) have represented "classic" means for supporting mobility. The Location Independent Network Architecture for IPv6 (LIN6) (Teraoka, Ishiyama & Kunishi, 2003) provides an alternative to mobility support to MIPv6. These protocols apply techniques such as proxies and tunnelling to deal with mobility. MIPv4 provides network-layer mobility and transparency to the higher layers. However, this solution introduces higher latency, extra overhead to the network, and it is vulnerable to single point of failure. Although many enhanced techniques and micro-mobility protocols can improve MIPv4 performance, MIPv4 still has weakness in terms of efficiency and complexity. MIPv6 has the advantages of inherent mobility, security support, and routing optimization compared to MIPv4. However, as in MIPv4, MIPv6 has the same problem of failure probability of communication and it has additional header overhead. Micro-mobility solutions improve the performance by minimizing signalling overhead, packet loss, and handover latency; but their scalability and complexity are a concern. In comparison with MIPv4/MIPv6, LIN6 is more tolerant to errors and it has less overhead due to its avoidance of the extension header and tunnelling.

As the transport layer is subject to the impact of mobility, much work has been carried out over the past few years on TCP performance improvement and mobility enhancement (Bakre & Badrinath, 1995; Caceres & Iftode, 1995; Funato, Yasuda & Tokuda, 1997; Haas, 1997; Maltz & Bhagwat, 1998; Snoeren & Balakrishnan, 2000; Yavatkar & Bhagawat, 1994), including efforts to enhance UDP for mobile environments (Brown & Singh, 1996). More recently, the mobility support for the new transport layer protocols of Stream Control Transmission Protocol (SCTP) (Stewart, Xie & Morneault, 2000) and the Datagram Congestion Control Protocol (DCCP) (Kohler, 2004) have been proposed. The basic idea of enabling transport-layer mobility is to remove network-layer dependences by using indirection, migration, tunnelling, multihoming techniques, and do forth. The TCP extensions proposed for improving transport performance on the mobile Internet cannot deal well with mobility on their own. Their main purpose is merely to minimize degradation of transport performance. Stewart et al. (2000) provides an alternative solution in the transport layer with Mobile SCTP (mSCTP). It can support seamless handover and improve transport performance. However, the current mSCTP proposal only illustrates the basic requirements for Internet mobility. Some essential issues are open to further study. However, mSCTP by itself does not handle location management. Thus, Koh & Xie (2004) proposes reusing MIP for location management in mSCTP. Similarly, the current specification of DCCP is at its primitive stage.

Because the traditional TCP/IP protocols are already heavily loaded down with functionalities, adding new functionalities to support mobility is very difficult. A new idea for mobility support is to introduce a new layer where Internet mobility is deployed. Thus, Host Identity Protocol (HIP) (Moskowitz & Nikander, 2005) can be considered as a layer 3.5 solution for mobility. It decouples network and transport layers by introducing a statistically global unique host identity. In this way, the transport connections are bound to host identity, not IP address. Therefore, the mobility issue can be solved by mapping different IP addresses to the unchanged host identities. However, it is not very simple to add a new layer since the functioning of the network and transport layers is in a way optimized to work together.

Due to the fact that applications can provide mobility support without any modifications of lower-layer protocols, different attempts have also been made at this layer. For example, Session

Initiation Protocol (SIP) (Rosenberg et al., 2002) can be extended to support mobility by resending the INVITE message to the peer to re-establish a session when the IP address of a mobile host changes. Nonetheless, it is adverse to real-time applications since considerable handover latency and overload occur with certain procedures (address renewal, location registration, etc.).

There is no single perfect solution so far; mobility support may require some rethinking of the Internet architecture. Network-layer solutions are based on routing mechanisms, so they require changes to the endpoints and routers for address binding. In addition, they need a third device of agents for packet forwarding and location management. Transport-layer solutions are based on an end-to-end model, so they require no change to intermediate routers, and they are absent from location management by themselves, so there is no need to deploy a third device. Therefore, transport-layer solutions require very little infrastructure change. New layer solutions need modifications of the endpoints and the addition of a third device. In addition, the introduction of a new protocol layer also destroys the traditional TCP/IP infrastructure. Similarly, the application solution of SIP employs a proxy server to relay flows and redirect servers to locate the MN; it also needs to add a third device and change the endpoint.

Vertical Handoff Decision: Desirable Features

All solutions for IP mobility require a handoff algorithm to change the location of a node as it moves or when its current performance degrades. But there are more characteristics that a properly designed handoff algorithm must take into account. These various desirable features depend on the context and, in general, the most relevant features of a handoff algorithm are the following:

- **Reliability.** This characteristic refers to the call quality after handoff. The handoff algorithm should improve, or at least maintain, call quality.
- **Seamless.** Calls should not suffer any kind of interruption or service degradation due to the handoff process. In this sense, the speed of the handoff algorithm is a critical point.
- Interference prevention. A properly-designed handoff algorithm should avoid causing interference to other devices and systems.
- **Load balancing.** The handoff algorithm should be able to balance traffic between different technologies or even cells of the same technology, paying special attention to the trade-off between cost and performance.
- **Improving performance.** The number of handoffs should be kept minimum to avoid heavy handoff loads and to minimize the risk of poor call quality.

Before a handoff takes place, the first phase carried out is the handoff decision phase. Handoff decisions in fourth generation handoffs take many aspects into account:

- **Quality of service.** One of the most desirable metrics of a handoff decision is QoS. If the handoff algorithm is provided with quality of service information from all of the possible target networks of the handoff, the decision process can select the network with better conditions and higher performance to achieve the best service level.
- **Cost of service.** The monetary cost of using the different networks is usually a key metric in the handoff decision process. The handoff decision process should balance performance vs. cost to try to obtain the best performance at the lowest possible cost.

- **Security.** Nowadays, given the availability of wireless networks, security risks are a main concern. Information transmitted can also be very sensible, so the handoff decision process should take security into account.
- **Power.** Power consumption due to handoffs should be kept at minimum. Wireless devices operate on limited battery power and the number of handoffs carried out should cause a minimal impact on the normal operation of the device.
- **Velocity.** Moving devices at high speeds discourage the use of handoffs because it could be necessary to handoff back to the original network in a short time. The handoff decision should take the velocity factor into account.

USE CASES

The ongoing increase of elderly people and chronic diseases in developed countries makes it necessary to extend patient follow-up from hospitals to home and mobile scenarios. Moreover, e-Health applications with high-quality features focused in athletes' control, sport centres, and so forth, are more extended in developed countries. Therefore, new solutions should be adopted to afford the need of assisted living and remote healthcare. In these e-Health scenarios, new use cases emerge and they may require specific analysis. In this section several use cases are proposed in order to constitute the start point to the analysis of the needs in these scenarios, and also imply a contribution to the standards evolution and mobility support. These use cases include home telemonitoring (fixed or portable communication), and chronics and athletes' follow-up (portable or mobile communication). This work allows foreseeing some possible ideal future scenarios far from today's state of the art in telemonitoring and mobility. In summary, scenarios that bring up advantages in interoperability, network transparency, scalability, costs, comfort, and system usability for the patients.

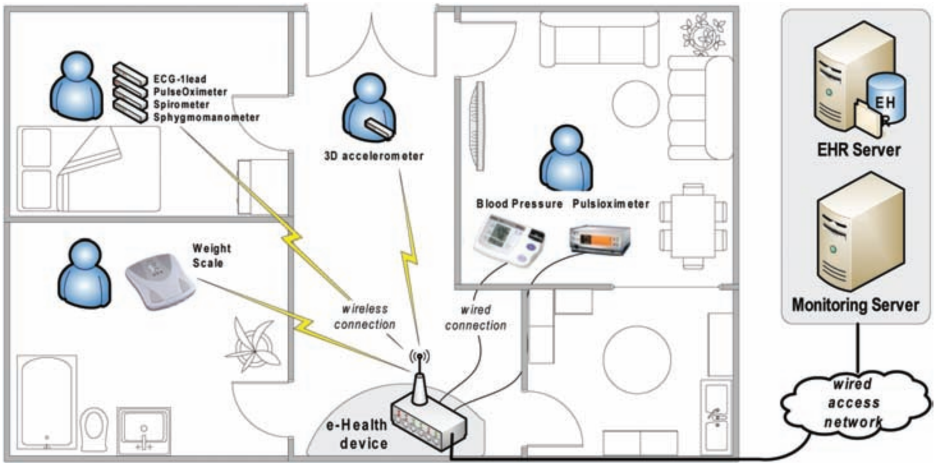
Fixed/Portable Use Case: Home Telemonitoring

This first Use Case (UC1) relates to patients located at home (controlled environments), which monitor different parameters several times a day and send the results to a monitoring server in store-and-forward mode in order to store all this information in the EHR of the hospital (see Figure 2). The MDs considered in this UC1 usually are: blood-pressure, pulse-oximeter, and weight scale. The connections from MDs to the healthcare gateway are usually fixed (wired or wireless). However, a standard-based design that includes plug-and-play and interoperability features must be independent of the particular characteristics related to every location (network access, transmission quality, number of multiplexed MDs in the CE, amount of data flow, etc.) in order to allow its portability obtaining an ubiquity solution. The main requirements for their involved connection technologies and access communication networks are summarized in Table I. Moreover, the healthcare context implies several working requirements to be taken into account (see Table I): remote management of MDs status (no batteries, device not connected or not working properly, warnings via SMS, beeper call, e-mail, Web page, etc.), measurements range in abnormal levels, system's malfunction, absence of patient data after a pre-established period (in order to call to the case manager or social worker for a visit), and so forth.

Portable/Mobile Use Case: Chronics and Athletes' Follow-Up

This second Use Case (UC2) relates to patients with a chronic illness that have to self-monitor their vital signs in order to follow-up: spirometry and pulse-oximetry (for chronic respiratory con-

Figure 2. Design scheme for fixed/portable use case focused on home telemonitoring



dition), non-invasive blood pressure, ECG, and weight (for cardiac diseases), or blood glucose levels (for diabetes); and answers to a symptoms questionnaire. Additionally, the physical activity of the user is estimated using as MD a wearable wireless 3D accelerometer (allowing activity monitoring), which records patient movements during all day, detects falls, and provides a summary of activity level. The case manager provides the patient with the required MDs and a wireless healthcare gateway (i.e., a mobile phone) to allow ambulatory operation and patient comfort. As the patient is continuously moving, the proposed solution must be portable or mobile. Data transmission could be store-and-forward (not time-critical) and being sent within the same day. Case manager could check patient's status daily (pull mode) and receive alarms triggered by the system. The service is supervised by technical staff from the service provider which takes care of the equipment.

An interesting variant of this UC2 include real-time transmission for continuous monitoring: for example, in sport centres of high efficiency for athletes' control (see Figure 3). These situations imply more restrictions in the technical requirements (very low delay, low packet loss, and suitable available bandwidth), and need guaranteeing mobility support (see Table 1).

In summary, each UC requires different desirable features to include in the design of a handoff mechanism. UC1 needs selecting the best access technology (regarding to cost of the service, QoS parameters, etc.) in every moment for providing portability. In this UC the handover is not necessary, but guarantying a suitable buffering capacity according to the maximum number of simultaneous MD is a key point. These portable characteristics are similar for chronic patient's follow-up (UC2). But, on the other hand, the variant of UC2 related to athletes' follow-up requires full mobility, reliability, seamless, and strict conditions of traffic requirements for guaranteeing QoS in real-time communications.

All these considerations have been taken into account in the design proposal of a handoff algorithm that it is detailed in the Solutions section.

SOLUTIONS

Mobility Support

No ideal solution exists to provide with mobility fulfilling all requirements of any situation. However, mobility solutions can be summarized

Figure 3. Design scheme for mobile use case focused on athletes' follow-up

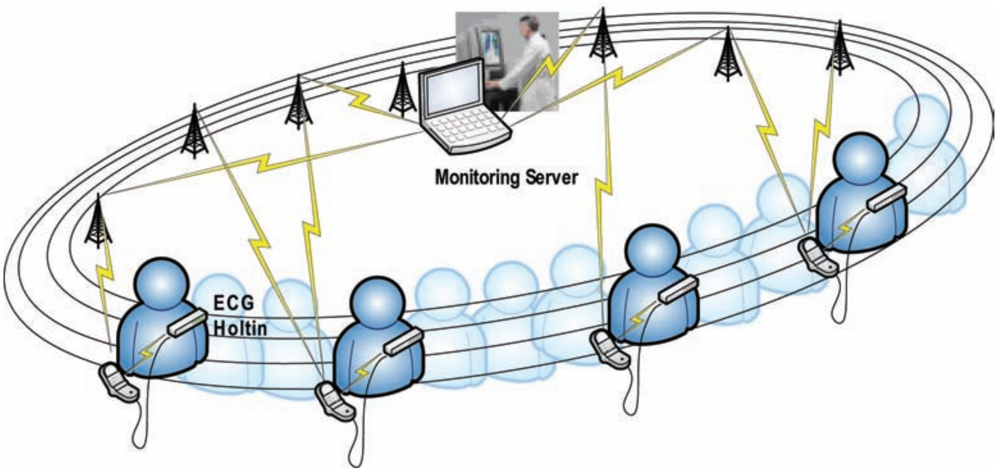


Table 1. Main characteristics and technical requirements for the use cases of this study

Characteristics/requirements	UC1. Home telemonitoring	UC2. Chronics and athletes' follow-up
Related patients	elderly people, post-operatory	chronic diseases, athletes
Acquired vital signs (related MDs)	blood-pressure, pulse-rate, weight scale, pulse-oximetry	blood-pressure, pulse-rate, weight scale, pulse-oximetry, ECG, spirometry, blood glucose, 3D accelerometry.
Service management	user and malfunction warnings, battery status control	user and malfunction warnings, battery status control
Connection mode	fixed/portable	portable/mobile
Connection technologies	wired (USB/RS-232/LAN) wireless (Bluetooth, IrDA, WLAN)	—— wireless (Bluetooth, ZigBee, WLAN)
Access mode	periodic (several times a day)	event-driven or continuous data
Access technologies	wired (xDSL, ISDN, Ethernet)	wireless (GPRS, UMTS, WiFi, WiMax)
Quality of Service thresholds	suitable buffering capacity suitable bandwidth suitable simultaneous MDs number	very low delay suitable bandwidth low packet loss
Other features to guarantee	security, portability, plug-and-play, high multiplexation level	security, mobility, selection of access technology, device location, handover

and compared based on different requirements: handover management, location management, multihoming, security and applications.

Regarding security, most solutions address it to some extent, although some paradigms are not very secure. For example, mSCTP suggests using IPSec or TLS, but does not specify the details, and DCCP does not provide cryptographic security guarantees. MIPv6 has also security problems, but HIP, on the other hand, has been specifically designed with security in mind. However, HIP uses cryptographic methods that require heavy computations that can cause problems in mobile devices with limited CPU power.

Handover management is a critical aspect due to the fact that handovers at the network layer cause high handover latency and packet losses (even inside the network caused by proxies and the lack of support for multihoming). This problem can be alleviated with the use of techniques as make-before-break or anticipated handovers. On the other hand, transport-layer mobility has also advantages: route optimization, multihoming support, and so forth, which facilitate seamless handover and minimize packet loss. The addition of a new layer (like in HIP) might add time to the total handover latency and packet loss due to the use of location management.

Algorithm

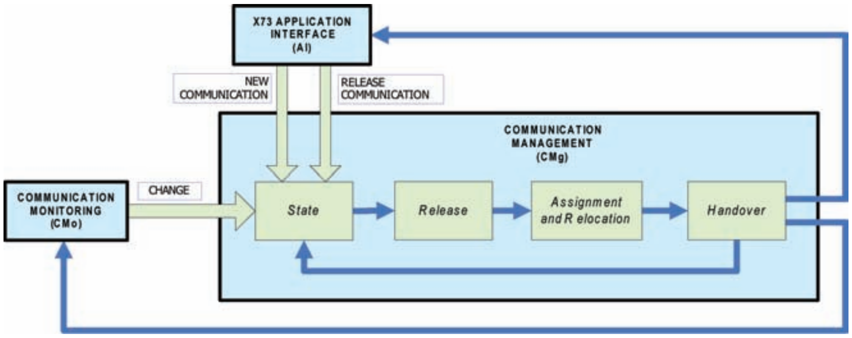
To conclude, an algorithm devised to implement a solid mobility support mechanism is presented next. IP mobility is responsible for carrying out the change between technologies in a transparent way to upper architectural levels, which is often denoted as Media Independent Handover (MIH) (IEEE802.21, 2007). In order to achieve this objective, an algorithm for IP connectivity and mobility management has been designed. It permits to maintain medical and vital data communications in spite of any possible changes in the available IP technologies of the healthcare gateway and is divided into three main blocks (see Figure 4): Communication Management (CMg), Application Interface (AI) and Connection Monitoring (CMo).

CMg is responsible for checking the state of all the TCP/UDP communications and for establishing, maintaining and releasing them, assigning each communication to a proper physical connection. AI requests the establishment of new communications and the release of finished ones to CMg. CMo checks gateway connectivity and the technical characteristics associated to the different IP connections periodically, informing to CMg of any change.

When AI requests the establishment of a new communication to CMg, it informs about the different required parameters: desired priority, communication traffic model, needed capacity, delay, jitter, and so forth. CMg, once the communication has been properly established, sends the confirmation feedback, together with a communication identifier to AI. In parallel, CMo periodically sends the parameters of all the available connections to CMg: capacity, available bandwidth, delay, jitter, packet loss rate, and so forth. In this manner, CMg can release or assign and relocate (through the handover process) the different communications in the available connections depending on their priorities and their required QoS) levels. This information is transmitted in the beginning of the process and every time a change is detected. As feedback information closing the loop, CMg informs to CMo about the assignment state of the parameters to the communications, so that the latter could calculate available bandwidth more easily.

Due to functionality reasons, CMg is divided

Figure 4. IP connectivity and mobility algorithm



into four processes that execute sequentially: *State*, *Release*, *Assignment and Relocation*, and *Handover* (see Figure 4). *State* is the process that receives the establishment, release and change events, and the most up to date information about all the currently established and the available connections from the *Handover* process. The next step carried out (*Release* process) is to release any communications requested to do so, with the aim of offering the next process the maximum available space to assign and relocate communications. Next, in case of new establishment requests, the new communications are assigned to the available connections depending on their current characteristics. If there are not enough available resources, communications have to be relocated depending on their priority and the QoS they require (*Assignment and Relocation* process). Once the proper decisions have been taken in the previous processes (*Release*, and *Assignment and Relocation*), the *Handover* process executes them. There are multiple proposals to carry out its implementation (Nasser, Hasswa & Hassaneim, 2006) but we would like to highlight those under study in the IEEE 802.21 working group (IEEE802.21, 2007). Finally, the *Handover* process returns to *State* process, sending the most up to date information about all the currently established and the available connections, closing the loop. This block diagram in Figure 4 illustrates the behaviour of the algorithm.

CONCLUSION

This chapter has presented an overview of the problem of designing a complete solution for m-Health scenarios. The wide range of characteristics involved in these scenarios regarding patients' knowledge of the system, very diverse VSs and the different mobility situations poses challenges in two directions: new standards are required for the interoperability of medical devices and mobility support mechanisms must provide adequate solutions for any possible mobility situation.

Regarding interoperability, some of the most recent standards are EN13606, the European standard for EHR communication, and ISO/IEEE11073 PoC-MDC, the European CEN/TC251 family of standards for PoC-MD Communications also known as X73. Thus, the need for developing open sensor networks in healthcare environments has fostered the development of standard-based specific solutions that allow transparent integration and interoperability inside e-Health systems with monitoring medical devices. Furthermore, the use of standards provides plug-and-play capabilities and auto-configuration features with the lowest level of user intervention.

In this sense, the chapter has presented different real scenarios (Use Cases) in the assistance area, which require communications standards, but also mobility support. Those scenarios can be classified into fixed/portable and mobile, where the first one can be considered as a particular case of the second. The different solutions to the problems faced in this context have been shown and studied, which lead to the vertical handoff decision. Finally, the solution has been formalized: a complete algorithm is proposed to give response to the mobility situations faced.

REFERENCES

Bakre, A., & Badrinath, B. R. (1995). I-TCP: Indirect TCP for Mobile Hosts. ICDCS'05 Vancouver, Canada, (pp. 136–43).

Brown, K., & Singh, S. (1996). M-UDP: UDP for Mobile Networks. ACM SIGCOMM Comp Commun, (pp. 60–78).

Caceres, R., & Iftode, L. (1995). Improving the Performance of Reliable Transport Protocols in Mobile Computing Environments. IEEE JSAC, pp. 850–57.

CEN/TC251. (2007). “EN13606 - Electronic Healthcare Record Communication. Parts 1, 2, 3 and 4. Retrieved July 20, 2007, from http://www.medicaltech.org.

Funato, D., Yasuda, K., & Tokuda, H. (1997). TCP-R: TCP mobility support for continuous operation. ICNP, pp. 229–36.

Galarraga, M., Serrano, L., Martinez, I., & de Toledo, P. (2005). Standards for medical device communication: X73 PoC-MDC. Medical and Care Compunetics 3. IOS Press - Stud Health Technol Inform (ISSN: 978-1-58603-630-0), vol. 121, pp. 242-256.

Gustafsson E., Jonsson A., & Perkins C. (2004). Mobile IP Regional Registration. Internet draft (work in progress), draft-ietfmip4- reg-tunnel-00.

Haas, Z. J. (1997). Mobile-TCP: An Asymmetric Transport Protocol Design for Mobile Systems. IEEE ICC, pp. NN-NN.

Henderson, T. R., Ahrenholz, J. M., & Kim, J. H. (2003). Experience with the Host Identity Protocol for Secure Host Mobility and Multihoming. *IEEE Wireless Communications and Networking*, *3*, 2120–2125.

IEEE1073. (2007). Health informatics. Point-of-care medical device communication. Standard for Medical Device Communications - Overview and Framework. Retrieved July 20, 2007, from http://www.ieee1073.org.

IEEE802. 21 Working Group. (2007). Retrieved July 20, 2007, from http://www.ieee802.org/21.

Johnson D., Perkins C., & Arkko J. (2004). Mobility Support in IPv6. RFC 3775.

Jung, H. Y., et al. (2004). Fast Handover for Hierarchical MIPv6 (FHMIPv6). Internet draft (work in progress), draft-jungmobileip-fastho-hmipv6-04.

Koh, S. J., & Xie Q. (2004). Mobile SCTP with Mobile IP for Transport Layer Mobility. Internet draft, draftsjkoh-mobilesctp- mobileip-04.

Kohler, E. (2004). Datagram Congestion Control Protocol Mobility and Multihoming. Internet draft (work in progress), draftkohler- dccp-mobility-00.

Koodli, R. (2005). Fast Handovers for Mobile IPv6. *RFC*, *4068*, 2005.

Le, D., Fu, X., & Hogrefe, D. (2006). A review of mobility support paradigms for the Internet. *IEEE Communications Surveys and Tutorials*, *8*, 38–51. doi:10.1109/COMST.2006.323441

Malki, K. (2005), Low Latency Handoffs in Mobile IPv4. Internet draft (work in progress), draft-ietf-mobileip-lowlatency-handoffs- v4-11.

Maltz, D. A., & Bhagwat, P. (1998). MSOCKS: An Architecture for Transport Layer Mobility. INFOCOM, (pp. NN-NN).

Martínez, I., Fernández, J., Galarraga, M., Serrano, L., de Toledo, P., & García, J. (In press). Implementation of an End-to End Standards-based Patient Monitoring Solution. IEE Proceedings Communications - Special Issue on Telemedicine and e-Health Communication Systems (ISSN:1350-2425).

Moskowitz, R., & Nikander, P. (2005) Host Identity Protocol Architecture. Internet draft, draft-ietf-hip-arch-03.

Nasser, N., Hasswa, A., & Hassaneim, H. (2006). Handoffs in Fourth Generation Heterogeneous Networks. IEEE Communications Magazine, NN, 96-103.

Nikander, P. (2001). From Address Orientation to Host Orientation. IP Based Cellular Network Conf IPCN, (pp. NN-NN).

Perkins, C. (2002). IP Mobility Support for IPv4. RFC 3344.

Ramjee, R., et al. (1999). HAWAII: A Domain-based Approach for Supporting Mobility in Wide-area Wireless Networks. ICNP, (pp. NN-NN).

Rosenberg, J. et al. (2002). SIP: Session Initiation Protocol. RFC 3261.

Ruiz, J., Viruete, E. A., Hernández, C., Alesanco, A., Fernández, J., Valdovinos, A., et al. (2006). Design of an Enhanced 3G-Based Mobile Healthcare System. Chapter in "Handbook of Research on Mobile Multimedia, Idea Group Inc. (IGI) Ismail Khalil Ibrahim Eds. (ISBN: 1-59140-866-0), (pp. 521-533).

Snoeren, A. C., & Balakrishnan, H. (2000). An End-to-End Approach to Host Mobility. MOBICOM (pp. NN-NN).

Soliman, H. et al. (2005). Hierarchical Mobile IPv6 mobility management (HMIPv6). RFC 4140.

Stewart, R., et al. (2003). Stream Control Transmission Protocol (SCTP) Dynamic Address Reconfiguration. Internet draft, version 8, Network Working Group.

Stewart, R., Xie, Q., & Morneault, K. (2000). Stream Control Transmission Protocol. RFC 2960.

Teraoka, F., Ishiyama, M., & Kunishi, M. (2003). LIN6: A Solution to Multihoming and Mobility in IPv6. Internet draft (work in progress), draft-teraoka-multi6-lin6-00.

Valko, A. (1999). Cellular IP: A New Approach to Internet Host Mobility. ACM SIGCOMM Comp Commun, (pp. 50–65).

Yavatkar, R., & Bhagawat, N. (1994). Improving End-to-End Performance of TCP over Mobile Internetworks. IEEE WMCSA, (pp. NN-NN).

KEY TERMS

Handoff: Handoff (or handover) is the process used in cellular systems to transfer a call between base stations when link quality decreases due to the mobility of cellular phones to obtain a better service.

Horizontal Handoff: A horizontal handoff (or horizontal handover) is a handoff between two network access points that use the same network technology.

IP Mobility: IP mobility refers to the set of mechanisms that allow an IP mobile node to move freely between different IP networks (possibly with different underlying technologies) while maintaining IP connectivity in a transparent way to upper layers. One of the most desirable features of IP mobility mechanisms is the ability of maintaining connectivity without interrupting ongoing communications. Other desirable features include location tracking and quality of service maintenance.

m-Health: Mobile Health is an emerging area of telemedicine in which the recent developments in mobile networks and telemedicine applications converge. M-Health involves the exploitation of mobile telecommunication and multimedia technologies and their integration into new mobile healthcare delivery systems. M-Health systems take advantage of the new possibilities that wireless and mobile networks offer thanks to the wide coverage provided by cellular networks and the possibility of serving moving vehicles.

Vertical Handoff: Vertical handoff (or vertical handover) generalizes the term "handover" to the transference of calls between different network technologies. Vertical handover denotes the transference of a call between two different network technologies with the purpose of obtaining a better service. Node mobility (e.g., cellular phones, laptops, sensors, etc.) can cause link quality to degrade. If a new network technology is available in the node's coverage area and can provide a better quality, the node's current communications are transferred to this technology, preferably without interruption. This process is called vertical handover.

This work was previously published in Handbook of Research on Mobile Multimedia, Second Edition , edited by I. Ibrahim, pp. 379-393, copyright 2009;by [Information Science Reference (an imprint of IGI Global).

Chapter 3.8

Exploring the Technology Adoption Needs of Patients Using E-Health

Linda M. Gallant
Emerson College, USA

Cynthia Irizarry
Suffolk University, USA

Gloria M. Boone
Suffolk University, USA

ABSTRACT

An extended version of the technology acceptance model (TAM) is applied to study hospital Web sites, one specific area of e-health. In a review of literature, five significant factors from TAM research are identified that are logically related to e-health sites from the user's perspective: usefulness, ease of use, trust, privacy, and personalization. All five factors emerged in the data analysis of 30 participants using a hospital Web site. We discuss the implications of this study for guiding development of effective patient-centered e-health

INTRODUCTION

To design e-health that meets the needs and wants of users, we should consider technology adoption research and user-centered design (UCD) principles. Research in these areas can help e-health producers and providers to develop a successful UCD strategy. In general, producing high quality, functional, and usable Web sites is a goal for all businesses and services on the Internet, but particular industries and disciplines must develop Web site design strategies that encompass the specific needs and concern of their specific users. Currently, businesses are searching for successful e-commerce models (Noteberg, Christiaanse, & Wallage, 2003). In this chapter, we investigate what user-centered design strategies can be applied to develop effective e-health, using the specific example of a hospital Web site. We review the basic premises of the technology acceptance model (TAM) (Davis, 1989) and some of its extensions (e.g., Gefen, Karahanna, & Straub, 2003; Gefen & Straub, 2000; Perea y Monsuwe, Dellaert, & Ruyter, 2004; Wang, Wang, Lin, & Tang, 2003) and apply this to the research in e-health. In synthesizing these two bodies of literature, we develop an approach of experience design for e-health.

DOI: 10.4018/978-1-60566-016-5.ch015

"Eighty percent of American Internet users, or some 113 million adults, have searched for information on at least one of seventeen health topics ... Most health seekers are pleased about what they find online, but some are frustrated or confused," (Fox, 2006, pp. ii). Specifically, 22% felt frustrated during their health searches, and 18% felt confused by the information they found online (Fox, 2006). Another study indicates that significant barriers to use of the Internet to find healthcare information remain for some elements of the population, such as those age 60 and older, people with 12 or fewer years of education, and residents of rural communities (Licciardone, Smith-Barbaro, & Coleridge, 2001). To increase the social and practical value of e-health, research needs to first produce answers as to what basic elements make e-health successful to its users.

What are the basic features that individuals search for on the Web? They want to find information and retrieve information easily. They want tailored health information. They want to trust the information. What is a successful e-health model? Using the technology acceptance model (TAM) as a framework, we propose to identify key factors leading to adoption of e-health. Past TAM research (Gefen et al., 2003; Gefen & Straub, 2000; Perea y Monsuwe et al., 2004; Wang, et al., 2003) gives us a starting point to shed light on the role of trust, privacy, credibility, and user perceptions of technology in the dynamic exchange between patients and provider-delivered e-health. In reviewing past research on TAM and UCD, we identified five relevant factors to explore in a case study of 30 participants using a hospital Web site. The five factors are usefulness, ease of use, trust, privacy, and personalization. These are used as sensitizing concepts in a case study to identify why potential users adopt e-health.

PRIOR RESEARCH

Using proven research approaches such as TAM and UCD to investigate patients' adoption of e-health can provide important insights. "The TAM postulates that user adoption of a new information system is determined by their intention to use the system, which in turn is determined by their beliefs about the system" (Wang, 2003, pp.335). In online technology adoption, the TAM model highlights the importance of trust, usefulness, and ease of use from the user's point of view (Gefen et al., 2003; Gefen & Straub, 2000; Perea y Monsuwe et al., 2004; Wang et al., 2003). More specifically, research using TAM in e-commerce has found that trust, privacy, and user perceptions of technology are central elements of online technology adoption (Gefen et al., 2003; Gefen & Straub, 2000; Perea y Monsuwe et al., 2004; Wang et al., 2003).

Popularity of e-health is growing. While the design and development of e-health is not well researched (Ketchum, 2005), searching the Internet for health and medical information is known to be one of the most common activities for e-health users (Akerkar & Bichile, 2004; Fox, 2006). Given that the Internet has altered the way people gain access to health information (Akerkar & Bichile, 2004; Kreps, 2003; Neuhauser & Kreps, 2003), health professionals need to understand how to design e-health using strategies that meet the needs and expectation of Internet users. In this vein, e-health has the potential to produce innovative care models in healthcare (Nash & Gremillion, 2004).

We propose that four TAM-related factors (perceived usefulness, perceived ease of use, trust, and privacy) are highly relevant to the context of e-health. An additional factor, personalization, has been found by UCD research to be a key driver of adoption and use of hospital Web sites, a form of e-health (Gallant, Irizarry, & Kreps, 2007). We review the literature relating to each of these factors in the following sections.

Usefulness

Perceived usefulness is the chief reason why people intend to use technology systems (Gefen & Straub, 2000). In TAM, usefulness is the most important source of user acceptance of new technologies (Perea y Monsuwe et al., 2004).

Perceived usefulness is defined as the extent to which a person believes that using a particular system will enhance his or her job performance, while perceived ease of use is defined as the extent to which a person believes that using a particular system will be free of effort (Wang et al., 2003, pp. 503).

Perceived usefulness is a major predictor of intended use of online technologies (Gefen et al., 2003), including e-health (Wilson & Lankton, 2004).

Ease of Use

In the sphere of the Internet, Gefen and Straub (2000) found that perceived ease of use influences individuals' intention to use an e-commerce system. Their research indicates that perceived ease of use is dependent on the tasks or types of use people expect to perform. In particular, when users perceive an intrinsic system task as easy to perform, this has a positive influence on the adoption of a technology. In the e-health context, a main task of users is searching for accurate health and medical information, which Wilson and Lankton (2004) found to be significantly correlated with patients' perceived ease of use.

Trust

Trust has been found to be a multidimensional construct invested with consumer beliefs in integrity, benevolence, ability, and predictability of the vendor (Gefen & Straub, 2004).

High levels of consumer trust encourage e-commerce, however, the appropriate conceptualization of trust has been much debated in online research, with trust levels of users being associated with personal propensity to trust (McKnight, & Chervany, 2001), perceived severity of user health problems (Fruhling, 2003; Fruhling & Lee, 2006), and Web site design factors (Shanker, Urban, & Sultan, 2005). In response, there has been a call for online trust transactions to be studied in more context and application specificity (Riegelsberger, Sasse, & McCarthy, 2005). Studying trust is important as "understanding how online trust is created and maintained can lead to improved Web sites, sales revenues, profitability, and ultimately shareholder value" (Shanker et al., 2005, pp. 326). In the context of e-health, trust is both situational and context dependent (Noteberg et al., 2003). Users provide personal information that can carry significant privacy risk (Culnan & Armstrong, 1999).

Online trust has been described as an association of networked relationships which depend on the degree of trust between the parties involved (Durkan, Durkin, & Gillen, 2003). All partners in this known network must be seen as trustworthy for members to willingly assume risk. The networking of trust extends to e-health. In the exchange between a patient and his or her healthcare provider, the provider's e-health system can provide structural assurance that the online technology environment, even with network partners, is safe and under control. This type of assurance helps to build a trusted reputation for all parties involved (Hsiao, 2003). Online interactions "include different types and levels of risk, and they are only possible if users trust each other and the systems they use to meet, communicate and transact–as well as the organizations that provide them." (Riegelsberger et al., 2005, pp. 382).

Branding is another area impacting online trust. Online trust rests in part upon the perception of a vendor's credibility. Research has shown that brand recognition can influence trust of online vendors. Durkan et al. write "Often a recognized brand name will provide a measure of credibility and thus stimulate consumer trust" (2003, pp. 99). Endorsements can also work to increase trust by decreasing uncertainty in online transaction (Noteberg et al., 2003).

Privacy

Culnan and Armstrong (1999) identify two major risks to privacy in online transactions. Once users provide personal information, they may be unable to control and protect it. Secondly, personal information could be used in other ways than were intended. Institutions must strike an appropriate balance between the personal privacy and business needs, noting that concern for privacy can be mediated by expected benefits. People will provide personal information online when an economic or social benefit can be expected (Culnan & Armstrong, 1999; Durkan et al., 2003).

Given the high sensitivity of personal health and medical information, advancement of e-health could be obstructed if users fear that their privacy is at risk. Fear of revealing personal information "to third parties without their knowledge or permission" provides a development and design challenge to e-health adoption (Wang, 2003, pp.339). Privacy is a fundamental right in most democracies (Basu, 2004), and the loss of personal privacy is a major concern of consumers in e-commerce (Noteberg et al., 2003).

Personalization

The goal of personalized care is to provide "the right information, to the right person, at the right time" (Hesse & Schneidermann, 2007, pp. 7). Hawkins, Pingree, Shaw, Gustafson, Gatzke, McDowell, and Tryon-Petith (2006) point out that the efficacy of tailored health messages has been supported across a variety of general health education domains. Other research has demonstrated that personalized or tailored information is viewed by users as more relevant and thus, more likely to be valued (Oenema, Brug & Lechner, 2001). In their study of a hospital Web site, Gallant et al. note that "users want personalized information geared to their health needs presented in a seamless and easy-to-use manner" (2007, pp. 20). While this point may seem intuitive, it is important to remember that not all e-health interfaces are designed with user goals in mind. Rigorous human-centered testing is essential for effective and useful personalization strategies.

Personalization of e-health holds much potential for preventative medicine and patient-centered care. Applying personalization strategies to e-health Web sites provides the capacity for online technologies to act in the tradition of telehealth, which has been used successfully to implement tailored healthcare management of chronic diseases, such as diabetes and asthma, and risk factors, such as high cholesterol.

METHOD

Through systematic investigation, qualitative research traditions answer questions of process, understanding, social meaning, and human action. Since we are inquiring about a process of knowledge production arising from human actions that infer meanings from product use, a qualitative research design is most appropriate. We use a case study method. Typically in qualitative case work, data is prerecorded (Stake, 2005, pp. 450). Our data was transcribed from the prerecorded usability tests and interviews. The data was analyzed for classification and pattern recognition. We conceived participant users as evaluators. From this point of view, we analyze the user data in accordance with the five sensitizing concepts described in our review of prior research. This analysis method is in accordance with an instrumental case study approach.

"…the methods of instrumental case study draw the researcher toward illustrating how the concerns of researchers and theorists are manifest in the case. Because the critical issues are more likely to be known in advance and to follow disciplinary expectations, such a design can take greater advantage of already-developed instruments and preconceived coding schemes," (Stake, 2005, pp. 450).

Participants

The 30 participants were recruited for the usability testing of a hospital Web site redesign project. Participants were paid $85.00 for up to 90 minutes of their time. Participants were selected to have a group mixed in demographics in age, gender, education, and income. See Appendix A for a breakdown of participants' demographics. All selection criteria were based on the hospital's typical patient demographic. Gender of participants was split evenly with 15 female participants, and 15 male participants. The age of participants was classified into three categories. For education, there were three categories. All participants were able to name their primary care hospital. A professional recruiting firm was hired to screen and recruit participants. The testing was done in a professional usability lab during five consecutive days of testing.

Data Collection

A high fidelity prototype of a working Web site for a Northeastern hospital was tested in a traditional usability lab. Study participants performed a task on the prototype that was accessed over the Internet from the hospital's servers. There were 34 task scenarios performed by 30 participants using a think-aloud protocol. There are three sections of the usability test designed for measuring the medical center's typical user profile. The task script was pretested on three pretest participants and minor wording changes were made. Participants had the option of reading the task along with the task being read aloud by the test facilitator.

Think-aloud protocol. This produces a verbal text of user participants' performance of task scenarios. Usability testing falls into the category of "natural techniques" in the knowledge acquisition process (Shadbolt & Milton, 1999, pp. 314). The traditional usability data collection technique of think-aloud is a process tracing method with its root in decision making research. Process tracing endeavors to let researchers observe the "natural" decision making process that participants engage in when given a task. With a think-aloud protocol, researchers gain participants' verbal utterances without interjecting any interaction that would cause a change in the participants' actions.

In-Depth Interview and Adaptive Questioning. Layering the think-aloud protocol with in-depth interviewing produces a text that provides observable and knowledge-centered data. After a participant finishes the task, the facilitator uses probing questions to elicit the user's understandings and meanings of the task, design, and overall system. As the task being performed comes to an end, the research method data collection process using interviewing becomes a codiscovery process between the participant user and test facilitator. This adaptive usability technique allows system testers the traditional behavioral measures while further providing user-centered knowledge concerning how potential customers perceive a product and its use. The latter data can be valuable to business teams across the organization.

Interviewing is a method of data collection that is well matched in the collection of information and processes "that cannot be observed effectively by other means" (Lindlof & Taylor, 2002, pp.174). Enhancing data collection with in-depth questioning at the end of tasks produces an interview procedure aimed at capturing user evaluations and knowledge of product uses and meanings. Unlike the task scenarios, the in-depth questions and probes are not predetermined. The task facilitator turns to an interviewing format that constructs a conversational environment producing questions and probes that are based on participant users' task experiences. Two trained facilitators conferred on how to approach the testing process for layering the technique of traditional think-aloud with interpretive questioning and probing, adaptive usability testing. Thus, the facilitator must adapt the post-task environment to an interviewing format. This acts as a summary of users' experiences, opinions, and evaluations of products.

Data Analysis Procedures

There were 34 task scenarios designed to measure important interaction dimensions of the Web site. The task list was developed by the lead researcher along with the hospital's marketing department team, which was responsible for the Web site development and upkeep. Tasks were divided into sections such as homepage usage, navigation, patient resources, employment, and health information. In the first part of the current investigation, a content analysis is used to measure usability problems. Measurements of the think-aloud analysis model should distinguish whether or not the usability problem was detected by observation or participant verbalization before developing a categorization of usability problems (Van Den Haak, Jong, & Schellens, 2003). The second part of the analysis seeks to learn what types of data arise from participants' responses in the post-task interviewing situation. A grounded theory approach is used. This approach is sometimes referred to as a constant-comparative method (Lindlof & Taylor, 2002, pp. 218). The analysis by the researcher is grounded in analyzing the data by aptly naming categories, making data comparisons, and overall extracting "an innovative, integrated, realistic scheme from masses of unorganized raw data" (Strauss & Corbin, 1998, pp. 13).

Traditional Analysis of Think-Aloud Data

Think-aloud protocols have been used in a variety of ways. Boren and Ramey (2000) identify that the practice of think-aloud protocols in usability testing diverge from its theoretical basis proposed by Ericsson and Simon's (1984) three-level model of verbalizations. This model in usability testing is used to identify system deficiencies (Boren & Ramey, 2000). This traditional concurrent cognitive verbalization model favors level one verbalization. Here verbalizations are not cognitively transformed before thinking aloud during a task performance (Boren & Ramey, 2000). At level two, more complex cognitive processing occurs before verbalization. Concepts such as images must be transformed into words. Level three produces the greatest amount of cognitive processing and is the least desired according to Ericsson and Simon's (1984) three-level model. Instead of simple verbalization, participants engaged in cognitive processes at level three go beyond direct task performance and verbalizing.

Analysis of Adaptive Usability and Knowledge Centered Data

At level three verbalizations, information retrieval from participants' memories is called upon to verbalize a response. Knowledge of how people perceive the usefulness of a product in their work or private life comes to bear. Knowledge management literature suggests that conversation is the key to sharing knowledge (McInerney, 2002, pp.1012). Gaining user knowledge on products is the goal of adaptive usability testing. In a qualitative interpretive methodology, talking and eliciting information can be the basis of data collection. As such, talk between the user and researcher is not a biasing factor. Using speech communication as a basis for analysis is a promising approach to usability testing.

> *[S]peakers cannot ignore listeners, even silent ones. Speakers expect that listeners will react to what they say, and that listeners' actions (or interactions) are reflective of that response…if we accept the view of human communication, the issue in usability testing becomes not one of disappearing from participants, but rather one of creating a highly asymmetrical speaker/listener relationship, one which maximizes the speakership of the participant and minimizes the speakership of the usability practitioner. (Boren & Ramey, 2000, pp. 268)*

DATA ANALYSIS

Data used for content categories should "provide useful evidence for testing hypotheses or answering research questions," as well as "communication," an understanding of a subject (White & Marsh, 2006, pp. 27). This analysis allows participants' descriptions and opinions about hospital Web site to be communicated. It allows users' knowledge to be known.

Using five analytic constructs (usefulness, ease-of-use, trust, privacy, and personalization) drawn from TAM and UCD research, an analysis was performed on 1,800 pages of data transcripts. The five descriptive codes can also be referred to as analytic constructs. Descriptive codes "entail little interpretation" in "attributing a class of phenomena to a segment of text" (Miles & Huberman, 1994, pp. 57). Descriptive codes are more denotative in attaching face value meanings to participants' discursive text than with interpretive coding that is more connotative given a constant comparative analysis process between the developing codes and the text.

The lead author performed and initial coding analysis and developed a description of each code for hospital Web site use; participant statements that matched any category of the five codes were tagged. Appendices B through F present representative supporting quotes for each descriptive code. Based upon the set of quotes for each code set, a more precise conceptual structure for the use of hospital Web sites was defined. As a validity check, both co-authors next independently read the conceptual codes and representative quotes to compare these with the raw textual data. The coding, definition, and quotes were found to be valid and credible in transferability, dependability, and conformability.

RESULTS

The results of our analysis relating to each of the constructs we studied are reported below.

Usefulness

The usefulness of the hospital Web site as an e-health artifact centers on obtaining information about personal and family health matters, physicians, diseases, insurance plan acceptance, medical specialties, and types of medical procedures offered at the facility.

Ease of Use

Having information organized in a logical and familiar arrangement provides users a sense of flow. Especially important in this e-health context is the user's sense of timely interaction with health appointment scheduling. Participants stated the importance of having a direct sense of communicating with a medical professional instead of interacting with a nonhuman information system. Participants also emphasized the need for appropriately labeling sections and their content so that Web site users can easily find information that they need. A search function on the Web site was seen as an important user tool for finding information.

Trust

Trust was viewed as the standard of medical care associated with the reputations and specialties of physicians at the healthcare facilities. Participants wanted to view physicians' background information, including medical degrees, years of practice, and even lawsuits.

Privacy

Privacy was a concern among participants with sensitive medical conditions. Additionally, participants were more apprehensive of trusting an automated information system to properly make appointments. Participant responses suggest that as users get to know and trust a system, they feel more secure with it.

Personalization

Participants foresee an ongoing interest in acquiring tailored and up-to-date healthcare and medical information. Many participants have particular health conditions and diseases for which they are interested in obtaining targeted health information and news updates. Participants wanted to be able to access their medical records online and make appointments online.

DISCUSSION

Using an illustrative case study of a hospital Web site, we found usefulness, ease of use, trust, privacy, and personalization to hold considerable importance for participants. The finding of our case study corroborates prior research on technology adoption and suggests that these five factors should be considered when designing and building e-health systems.

Since the usefulness of new technology is a primary motivator for adoption (Perea y Monsuwe et al., 2004), people will most likely adopt e-health systems that are situationally useful in relation to illnesses, health problems, or past medical histories. This phenomenon was seen in participant quotes that show usefulness as having an easy-to-navigate hierarchy. For example, within a topology of illnesses, some users verbally distinguish aspects such as medical condition, visitor, patient, and medical professional. For others, usefulness merged with perception of ease of use. This included easy viewing and clear navigation on the Web site. Participants wanted pages that are easy to read, have large font sizes, and organize information into small segments. Factors related to navigation included a global search function, a clear primary and secondary navigation, and clear organizational principles such as alphabetical or chronological ordering. Participants wanted clear directions on how to complete forms relating to healthcare, insurance, contact information, selecting doctors, and making appointments. They wanted to be able to quickly retrieve information on financial and insurance aspects of their healthcare. Participants wondered, for example, if they could go to specific doctors with their insurance or get prescriptions filled.

While the role of trust in e-commerce has been studied by numerous researchers, proposed strategies may not be adequate to understand trust in the context of e-health (Fruhling, 2003). Yet, a mainstay of healthcare organizations' relationships with their patients and other stakeholders is trust (Hesse, Nelson, Kreps, Croyle, Arora, & Rimer, 2005). Internet users' trust of health information Web sites has also been growing (Rosenvinge, Laugerud, & Hjortdahl, 2003), with personal doctors, medical universities, and the federal government being seen as the most trusted sources of online health information (Dutta-Bergman, 2003; Kind, Wheeler, Robinson, & Cabana, 2004). This issue is prominent in our data. Participants want to search for doctors' credentials to judge whether or not the information presented and the institution owning the Web site are credible.

Online healthcare information needs to be seen as credible by users before they trust it (Rosenvinge et al., 2003). The stakes are high because use of health information can impact people's health positively or negatively (Al-Bahrani & Plusa, 2004; Luo & Najdawi, 2004; Williams, Nicholas, Huntington, McLean, 2002). A component of trust is credibility. In general, perceived credibility of an online technology attracts users (Wang et al., 2003). Our findings are in agreement with past research (Eysenbach & Kohler, 2002; & Luo & Najdawi, 2004), in that participants view e-health Web sites as more credible when source and ownership are disclosed. Trust is part of the name and reputation of the institution. Trust is also a consideration when selecting doctors as our findings suggest prospective patients want to see the biography of the doctor including specifics on education, specialties, and years of experience.

We find perceptions of online trust and privacy are contrasted to other communication methods. Participants compared the Web site functions with traditional ways of accomplishing tasks. For example, they would search to make an online appointment until they felt it was easier to fall back on the traditional communication method of making an appointment by telephone. Participants would often compare the online task to what they would do in a face-to-face interaction with a hospital employee. Thus, e-health should try to support communicative interactions people expect to have within traditional telephone and face-to-face communication with administrative and medical staff in the healthcare process. Web site users should be able to have a choice to leave the Web site to interact by telephone or in person. This would be especially helpful with users who are low in trust of general Web transactions. While some evidence in the data suggests that placing sensitive personal information on a Web site for healthcare users is an Internet privacy concern, our research design did not allow us to explore this research dimension. Future research should be undertaken to provide more insight into e-health privacy and security concerns of users.

Personalization can have impacts on issues of privacy, ease of use (usability), and usefulness. To meet the diversity needs of users, e-health Web sites can employ a personalization strategy. This process presents tailored information to users based on their personalized profile. Knowledge about a user can be used in a dynamic Web site that can specifically target information, content, and services to individual users (Adomavicius & Tuzhilin, 2005). Personalization of e-health can solve usability problems relating to user characteristics, such as disabilities and illiteracy (Denny, Ginsberg, Papp, Browne, Morgan, Kushins, & Solina, 2002). Further, the strategy of personalizing Web sites as individualized patient portals can be a useful tool for patients to gain greater access to personal health information and make better informed decisions for their health (Nguyen, Carrieri-Kohlman, Rankin, Slaughter, & Stulbarg, 2004). Personalization strategies are especially pertinent given that patients are increasingly using electronic personal health records to manage their own health (Lorbach & Detmer, 2007). Our case study data suggests that people with particular health concerns such as diabetes want to find up-to-date information on their medical conditions. People search for health information upon being diagnosed or having a family member diagnosed with a medical condition. In addition, personalization appears to enhance the expectation of usefulness. For example, personalization can allow e-health users to access RSS feeds that enable them to select useful topics, sources or information channels to access the health information.

CONCLUSION

Through analyzing several factors drawn from TAM and UCD from the user's perspective, we were able to identify a number of implications for developers of patient-centered e-health. As

Hesse & Shneiderman, (2007) observed, many elegant theoretical interfaces have failed when used in real-world settings because they fail to take user needs into account. A patient-centered design focus can avoid these problems, providing e-health that is both effective for healthcare providers and empowering to patients.

REFERENCES

Adomavicius, G., & Tuzhilin, A. (2005). Personalization technologies: A process-oriented perspective. *Communications of the AMC*, *48*(10), 83–90. doi:10.1145/1089107.1089109

Akerkar, S. M., & Bichile, L. S. (2004). Health information on the Internet: Patient empowerment or patient deceit? *Indian Journal of Medical Sciences*, *58*(8), 321–326.

Al-Bahrani, A., & Plusa, S. (2004). The quality of patient-orientated Internet information on colorectal cancer. *Colorectal Disease*, *6*, 323–326. doi:10.1111/j.1463-1318.2004.00604.x

Basu, S. (2004). Implementing e-commerce tax policy. *British Tax Review, (1),* 46–69.

Boren, M. T., & Ramey, J. (2000). Thinking aloud: Reconciling theory and practice. *IEEE Transactions on Professional Communication*, *43*(3), 261–278. doi:10.1109/47.867942

Culnan, M. J., & Armstrong, P. K. (1999). Information privacy, Procedural fairness and impersonal trust: An empirical investigation. *Organization Science*, *10*(1), 104–115. doi:10.1287/orsc.10.1.104

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly*, *13*(3), 319–329. doi:10.2307/249008

Denny, J. T., Ginsberg, S., Papp, D., Browne, G., Morgan, S., Kushins, L., & Solina, A. (2002). Hospital initiatives in promoting smoking cessation: A survey of Internet and hospital-based programs target at consumers. *Chest*, *122*, 692–698. doi:10.1378/chest.122.2.692

Durkan, P., Durkin, M., & Gillen, J. (2003). Exploring efforts to engender on-line trust . *Entrepreneurial Behaviour and Research*, *9*(3), 93–110. doi:10.1108/13552550310476184

Dutta-Bergman, M. (2003). Trusted online sources of health information: Differences in demographics, health beliefs, and health-information orientation. J*ournal of Medical Internet Research, 5*(3), e21. Retrieved May 27, 2008, from http://www.jmir.org/2003/3/e21/

Ericsson, K. A., & Simon, H. A. (1984). *Protocol analysis: Verbal reports as data.* Cambridge, MA: MIT Press.

Eysenbach, G., & Kohler, C. (2002). How do consumers search for and appraise health information on the world wide Web? Qualitative study using focus groups, usability tests, and in-depth interviews. *BMJ (Clinical Research Ed.)*, *324*, 573–577. doi:10.1136/bmj.324.7337.573

Fox, S. (2005). Health information online. Eight in ten Internet users have looked for health information online, with increased interest in diet, fitness, drug, health insurance, experimental treatments, and particular doctors and hospitals. *Pew Internet and American Life Project*. Retrieved May 27, 2008, from http://www.pewInternet.org/pdfs/PIP_Healthtopics_May05.pdf

Fox, S. (2006). Online health search 2006. Most Internet users start at a search engine when looking for health information online. Very few check the source and date of the information they find. *Pew Internet & American Life Project.* Retrieved May 27, 2008, from http://www.pewInternet.org/pdfs/PIP_Online_Health_2006.pdf

Fruhling, A. L. (2003). *An empirical study of human-computer interaction: Usability factors affecting perceptions of trust of e-health consumers.* Doctoral Dissertation, University of Nebraska, 2003. Proquest, AAT3092541.

Fruhling, A. L., & Lee, S. (2006). The influence of user interface usability in rural consumers' trust of e-health services. *International Journal of Electronic Healthcare*, *2*(4), 305–321.

Gallant, L., Irizarry, C., & Kreps, G.L. (2007). User centric hospital Web sites: A case for trust and personalization. *e-Service Journal, 5*(2), 5–26.

Gefen, D., Karahanna, E., & Straub, D. W. (2003). Trust and TAM in online shopping: An integrated model . *MIS Quarterly*, *27*(1), 51–90.

Gefen, D., & Straub, D. W. (2000). The Relative importance of perceived ease-of-use in IS adoption: A study of E-commerce adoption. *Journal of the Association for Information Systems*, *1*(8), 1–30.

Gefen, D., & Straub, D. W. (2004). Consumer trust in B2C e-commerce and the importance of social presence: Experiments in e-products and e-services. *Omega: The International Journal of Management Science*, *32*, 407–424. doi:10.1016/j.omega.2004.01.006

Hawkins, R., Pingree, S., Shaw, B., Gustafson, D., Gatzke, K., McDowell, H., & Tryon-Petith, C. (2006) *Creating a dynamic, tailored, online health education and support program for women with breast cancer: A case study of the CHESS program.* Paper Presented at the Annual Meeting of the International Communication Association, Sheraton, New York. Retrieved May 27, 2008, from http://www.allacademic.com/meta/p14986_index.html

Hesse, B. W., Nelson, D. E., Kreps, G. L., Croyle, R. T., Arora, N. K., & Rimer, B. K. (2005). Trust and sources of health information. The impact of the Internet and its implications for healthcare providers: Findings from the first health information national trends survey. *Archives of Internal Medicine*, *165*, 1–7. doi:10.1001/archinte.165.22.2618

Hesse, B. W., & Shneiderman, B. (2007). eHealth research from a user's perspective. *American Journal of Preventive Medicine*, *32*(5s), S97–103. doi:10.1016/j.amepre.2007.01.019

Hsiao, R. L. (2003). Technology fears: Distrust and cultural persistence in electronic marketplace adoption. *The Journal of Strategic Information Systems*, *12*(3), 169–199. doi:10.1016/S0963-8687(03)00034-9

Ketchum, A. M. (2005). Consumer health information Web sites: A survey of design elements found in sites developed in academic environments. *Journal of the Medical Library Association*, *93*(4), 496–499.

Kind, T., Wheeler, K. L., Robinson, B., & Cabana, M. D. (2004). Do the leading children's hospitals have quality Web sites? A description of children's hospital Web sites. *Journal of Medical Internet Research, 6*(2). Retrieved May 27, 2008, from http://www.jmir.org/2004/2/e20/

Kreps, G. L. (2003). E-health: Technology-mediated health communication. *Journal of Health Psychology*, *8*(1), 5–6. doi:10.1177/1359105303008001425

Licciardone, J. C., Smith-Barbaro, P., & Coleridge, S. T. (2001). Use of the Internet as a resource for consumer health information: Results of the second osteopathic survey of healthcare in America (OSTEOSURV-II). *Journal of Medical Internet Research 3*(4):e3. Retrieved May 27, 2008, from http://www.jmir.org/2001/4/e31/

Lindlof, T. R., & Taylor, B. C. (2002). *Qualitative communication research methods (second edition).* Thousand Oaks, CA: Sage.

Lorbach, D. F., & Detmer, D. E. (2007). Research challenges for electronic health records. *American Journal of Preventive Medicine*, *32*(5s), S104–111. doi:10.1016/j.amepre.2007.01.018

Luo, W., & Najdawi, M. (2004). Trust-building measures: A review of consumer health portals. *Communications of the ACM*, *47*(1), 108–113. doi:10.1145/962081.962089

McInerney, C. (2002). Knowledge management and the dynamic nature of knowledge. *Journal of the American Society for Information Systems and Technology*, *53*(12), 1009–1018. doi:10.1002/asi.10109

McKnight, D. H., & Chervany, N. L. (2001). What trust means in e-commerce customer relationships: An interdisciplinary conceptual typology. *International Journal of Electronic Commerce*, *6*(2), 35–59.

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook (second edition).* Thousand Oaks: Sage.

Nash, M. G., & Gremillion, C. (2004). Globalization impacts the healthcare organization of the 21st century: Demanding new ways to market product lines successfully. *Nursing Administration Quarterly*, *28*(2), 86–91.

Neuhauser, L., & Kreps, G. L. (2003). The Advent of e-Health: How interactive media are transforming health communication. *Medien and Kommunikations-wissenschaft*, *51*(3–4), 541–556.

Nguyen, H. Q., Carrieri-Kohlman, V., Rankin, S. H., Slaughter, R., & Stulbarg, M. S. (2004). Supporting cardiac recovery through ehealth technology. *The Journal of Cardiovascular Nursing*, *19*(3), 200–208.

Noteberg, A., Christiaanse, E., & Wallage. (2003). Consumer trust in electronic channels: The impact of electronic commerce assurance on consumers' purchasing likelihood and risk perceptions. *e-Service Journal, 2*(2), 46–67.

Oenema, A., Brug, J., & Lechner, L. (2001). Web-based tailored nutrition education: Results of a randomized clinical trial. *Health Education Research*, *16*, 647–660. doi:10.1093/her/16.6.647

Perea y Monsuwe, T., Dellaert, B. G. C., & Ruyter, K. (2004). What drives consumers to shop online?: A literature review. *International Journal of Service Industry Management*, *15*(1), 102–121. doi:10.1108/09564230410523358

Riegelsberger, J., Sasse, M. A., & McCarthy, J. D. (2005). The mechanics of trust: A framework for research and design. *International Journal of Human-Computer Studies*, *62*, 381–422. doi:10.1016/j.ijhcs.2005.01.001

Rosenvinge, J. H., Laugerud, S., & Hjortdahl, P. (2003). Trust in health Web sites: A survey among Norwegian Internet users. *Journal of Telemedicine and Telecare*, *9*, 161–166. doi:10.1258/135763303767149979

Shadbolt, N., & Milton, N. (1999). From knowledge engineering to knowledge management. *British Journal of Management*, *10*, 309–322. doi:10.1111/1467-8551.00141

Shanker, V., Urban, G. L., & Sultan, F. (2005). Online trust: A stakeholder perspective, concepts, implications, and future directions. *The Journal of Strategic Information Systems*, *11*, 325–344. doi:10.1016/S0963-8687(02)00022-7

Sienot, M. (1997). Pretesting Web sites: A comparison between the plus-minus method and the think-aloud method for the World Wide Web. *Journal of Business and Technical Communication*, *11*(4), 469–482. doi:10.1177/1050651997011004006

Stake, R. E. (2005). *Qualitative case studies. The Sage handbook of qualitative research (third edition).* In N. Denzin, & Y. Lincoln (Eds.), (pp.443–466). Sage Publications.

Strauss, A. L., & Corbin, J. (1998). *Basics of qualitative research: Techniques and procedures for developing grounded theory (second edition).* Sage Publications.

Todd, P., & Benbasat, I. (1987). Process tracing methods in decision support systems research: Exploring the black box. *MIS Quarterly*, *11*(4), 493–512. doi:10.2307/248979

Van Den Haak, M.J., Jong, de, M.D.T., & Schellens, P.J. (2003). Retrospective vs. concurrent think-aloud protocols: Testing the usability of an online library catalogue. *Behaviour & Information Technology*, *22*(5), 339–351. doi:10.1080/0044929031000

Wang, Y. S. (2003). The adoption of electronic tax filing systems: an empirical study. *Government Information Quarterly*, *20*(4), 333–352. doi:10.1016/j.giq.2003.08.005

Wang, Y. S., Wang, Y. M., Lin, H. H., & Tang, T. I. (2003). Determinants of user acceptance of Internet banking: An empirical study. *International Journal of Service Industry Management*, *14*(5), 501–519. doi:10.1108/09564230310500192

White, M. D., & Marsh, E. E. (2006). Content analysis: A flexible methodology. *Library Trends*, *55*(1), 22–45. doi:10.1353/lib.2006.0053

Williams, P., Nicholas, D., Huntington, P., & McLean, F. (2002). Surfing for health: User evaluation of a health information Web site. *Health Information and Libraries Journal*, *19*, 98–108. doi:10.1046/j.1471-1842.2002.00374_2.x

Wilson, E. V., & Lankton, N. K. (2004). Modeling patients' acceptance of provider-delivered e-health. *Journal of the American Medical Informatics Association*, *11*(4), 241–248. doi:10.1197/jamia.M1475

APPENDIX A

Demographic	Categories	Number (percentage)

APPENDIX B

Usefulness
User 2: "Primary – wait a minute, primary – Finding a primary care physician. I definitely would be interested in that to see where would I go for daily checkups. And finding out the type of physician that I would want for me. And I'd probably click here to find that information out…I have a child as well and I would be interested in – especially if I'm in another healthcare, like I'm in Tufts, I'd be interested in would I have to switch doctors, especially for my son where he already has a doctor. And if I switch to [hospital name], would that same doctor be there, would be offered for me to go to that same doctor. And I would click here for that information."
User 3: "Oh, for someone like me, the most important thing would be uh – oh, let me go back to it – would be – seems like the healthcare information because this is for me, I'm trying to learn about trying to find a doctor. If I wanted to become a patient or a member, I have to – I need to know all this information. So, healthcare information."
User 7: "Maybe they would list the physicians that are affiliated with the [hospital name] and then what I would have to do is – now if my personal doctor, for example, from Watertown, I'd have to see if he's listed there. If I didn't want to bother to call his office, I'd look to see if he's affiliated with [hospital name], if I could have procedures done there, whatever. Or maybe you're looking up the names of some physicians that maybe – Maybe some information about their specialties or whatever.
User 10: "Personally? What I would use it for? I probably would – knowing me, I would probably be looking up diseases and getting information, just a general overview of it. And specifically, the type of service that's offered for that particular disease. I'm sure they don't cover everything, but I find it, what little I've moved around in it, it's very informative, so that. And I think the obvious with the patient, with the patient information, I know that with Tufts that I have a book, I don't believe there's a Web site that you can search for doctors."
User 17: "Depending on the most important to me is looking for a PCP [Primary Care Physician] that meets in my plan because if he doesn't meet your plan, I can't go to him."
User 23: "For example, my situation now, I had pain in my back, couldn't walk, my leg and so on. I want to know what was wrong, and who could treat it…So I would look for back, for example, or spinal or neurosurgery. I want to know who the doctors are, who neurosurgeons are, and how good they are. And the backgrounds they have. Their bios."

APPENDIX C

Ease of Use
User 5: "But a lot of times that's what I do. I just go to the search part of some Web sites unless it shoots out at me right away."
User 7: "Oh, I – oh, patient pharmacy. I would never think to look under there. Again I'm thinking little specialty shops. I want to get a gift. I want to get dinner. I want to get flowers or something. I would never put that together."
User 9: "This takes three days to make an appointment. If I thought it was very important, I would call up myself…This was good for – to get information. If I was going to make an appointment, I would try to do it this way if I didn't have to have it right away…I find that when I call at least the people I deal with, if they say well, can't see the doctor for two or three weeks, I'd try to speak to the doctor himself if I'm a patient of his. And tell him what my problem is and I'd tell him I need to see him sooner than three weeks. But you're on the computer, you have nobody to talk to."
User 13: "Just – it [specialty shops] could be anything. It could be a place where you just get – go buy a newspaper or you can get gifts and things like that. Flower shops or something like that. That's what I would associate it with… outpatient pharmacy, OK. Wow, I never would have looked there. Never would have looked there… Just too – not – it's more something you were going to shop for."

Ease of Use
User 15: "You know what I'm finding, that patient service is an awfully large and important button. In fact, I would suspect that for patients or patients who are going to be referred there, that may even have to be broken out. And I can think of something here. Healthcare information divided between in-house physicians, nursing services. Something that they would like on their homepage, but for their own information. And patient related or just for newbies. People new to Lahey Clinic. The great unwashed plus patients. And I'm not saying that you have to dummy it down. But you need to make that – for example. It's nice. Medical research at Lahey, residencies and fellowships. But I'm new here. Where would I go, and it seems that oftentimes we're going through this patient service center."
User 18: "And there'd be a roster of all the physicians. And what they do and all that. After physicians, they'd do it by specialties and then the more you click on them and then get a list of the roster there. That's how I would logically go about it...And I'm sure they all link, because if you go under the disease, and then I'm sure there'll be something on the page of whatever say, kidney, that would have the physicians that would – clearly, I would think it would connect you right into the physicians, too, so there'd be a link, whether you went in one way or the other."
User 20: "OK. Specialty shops and services … I wouldn't put it with shops because as soon as shops comes into my brain, I'm seeing gift shops…And services, well, I don't know. Send a telegram. I don't know. But it doesn't say pharmacy to me."

APPENDIX D

Trust
User 2: "I'm going to scroll down to see…. Physician finder. Maybe I should look him up first before the appointment…OK, let's see. OK, so here we find him right here, residency. So I'd probably want to read a little about him."
User 6: "And then I think for – one thing that sort of provides security for patients is just seeing a little bit, like what each medical background is, like where they got their medical degree, where they've studied. You know."
User 11: "And you want to find out information like where she graduated, and her medical school, and everything … I want to know about this doctor's background…I thought it was very important when you were getting a physician finder, to be able to pull up that physician and find out – maybe that physician went to a school that you heard was really awful…I thought that was really important."
User 12: "If someone's going to [hospital name], they're going to go to [hospital name] for whatever reason, the doctors, their doctor's there, or they're good for their specific condition. No one's going to look at it [the Web site] and go oh my God what a fabulous Web site. I'm going to that hospital. Or, oh my God, this is ridiculous. I'm not going to that hell-hole."
User 20: "And I've also learned once I find that person's name, I may not be able to get it through here but, I forget now, but someone told me how to look up that person, see whether there have been lawsuits against him or things like that. It's a very helpful thing to know. I think I would definitely go to here."
User 23: "To me the most important thing is the staff, who is there, what their specialties are. Where can I get my condition treated the best. The best facilities and the best people doing it. One of the things I always look for – we're looking for a family doctor now. Our family doctor retired. We loved him and we can't find a replacement… We're looking for a family doctor, my wife and me. Internal medicine. I'm looking for somebody who is not too old, is not too young. And what I find at [hospital name], for example, is that most of the – most of the long, long lists of people in Internal Medicine, most of them got out of school in 2000, 1999, 1998. They're probably very sharp but I want somebody who said Oh, yeah, I had a case like this 12 years ago….And I like to see people who are board certified. So that page on the whatever – whatever [hospital name] is doing is very, very important to me."

APPENDIX E

Privacy
User 2: "OK at this point, honestly, at this point I'd pick up the telephone. You know? I – I use the computer a lot for information. Even when I hear some of my customers talk about – yeah, we're going on a cruise, we went through the computer to get the tickets –I go to Orbitz and (inaudible) tickets cheaper. - I'm always leery of it. I'd rather talk – after talking to all the answering machine messages, the mechanical stuff, when you finally get a hold of a human being to make an appointment, to make sure that there's no mix-up…If I was familiar with the Web site I would do that. But if I'm unfamiliar with something, I would just get on the phone and make the phone call."

Privacy
User 12: "Well, I'm thinking I guess to make an appointment I've got to fill out some forms. And they're telling me about the security, that it's OK…it's not totally important to me but depending on what I'm using this for, but I could see a person that might have a problem with it, like maybe has AIDS and doesn't really need the whole world to know, or there's certain privacy issues. I always assume if it's a hospital that they have to put that here, but I am maybe naively assume that it's safe…but maybe it makes them feel good to see security but if you just saw a link I think you'd feel good knowing oh, it must be secure"
User 28: "Initially I would think to click it, to keep going, but I think it has to do with the privacy statement. So if I click on it, I think I'd probably get that click on thing…Because it's blue and it says read the privacy statement right there under it, but this made me think, keep going…But initially, that's what I want to know. You think oh, no I want to read more about the privacy statement."

APPENDIX F

Personalization
User 1: "That's what I would look for. There's very specific information about that hospital, or that organization like how to reach me, how to make an appt… If I were a regular customer with the ability to get into my records… to the extent that that's allowed, I might be able to use my SSN or some other access code to check on one big thing."
User 6: "Right, because I'm diabetic…So that's why I go online, most of the time, is to find out current news about treatments for diabetes like if there's anything new about diets, you know, for diabetics, so – you know, and not every – not every hospital or clinic treats diabetes, you know, in that sort of way, so I'd look for something. Plus I always go and look at who the doctors are, who the care – medical care givers."
User 15: "Read health information. Health information. Now that's an interesting one. Is this one the disease of the day? Can I scan, or can I search according to what I think I have, and is there information on that."
User 21: "I think it would break down into three things. An existing patient, and then what does an existing patient want to do?...Make an appointment. Check out doctors that they'd been referred to. Learn more about conditions."
User 23: "If I pop that, that's what I would expect to happen. Request an appointment – I think this would take me to some central appointment office, not to any particular doctor, and tell him who I wanted, Dr. Ollie, and I'd like an appointment for this, and that central office would somehow have available to them his free times. That's been my experience I think."
User 24: "Primarily for research, that's why I go to the other medical Web sites that I do, just for my own edification or just out of curiosity if there's something in the news, I'll just check different Web sites and plug into just, like, the general search and see what articles come up."
User 25: "I guess more articles. Articles, articles. You know, articles regarding health…Yeah, health topics….will I see news here. Sometimes – I guess…Sometimes if you're – I don't think I'd design anything – other Web sites, anyway, but – I'm just saying, sometimes, if you're in a Web site, then it'd be pretty good if it had news, you know, up-to-date news."
User 28: "Yes, see this is what – this isn't really going to help me get an appointment. I'd have to call and talk with someone. So up until this point, it's like good to use the Web site, to get the information but there's no appointment schedule that I see right away, so I would just get the phone."

This work was previously published in Patient-Centered E-Health, edited by E. Wilson, pp. 201-216, copyright 2009 by Medical Information Science Reference (an imprint of IGI Global).

Chapter 3.9

Technology Enablers for Context-Aware Healthcare Applications

Filipe Meneses
Universidade do Minho, Portugal

Adriano Moreira
Universidade do Minho, Portugal

ABSTRACT

The increasing availability of mobile devices and wireless networks, and the tendency for them to become ubiquitous in our daily lives, creates a favourable technological environment for the emergence of new, simple, and added-value applications for healthcare. This chapter focuses on how context and location can be used in innovative applications and how to use a set of solutions and technologies that enable the development of innovative context and location-aware solutions for healthcare area. It shows how a mobile phone can be used to compute the level of familiarity of the user with the surrounding environment and how the familiarity level can be used in a number of situations.

DOI: 10.4018/978-1-60566-332-6.ch013

INTRODUCTION

"The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it." (Weiser, 91)

In 1991, Mark Weiser had a vision that still inspires many researchers in the ubiquitous and pervasive computing area. In a perfect world people needs would be detected and fulfilled by a set of devices that would act in the background to provide the means or data necessary to the users' activities. Current technology does not allow to entirely fulfilling the Weiser vision but allows realizing many aspects of this pioneer vision.

Continuous monitoring of the health condition of people has been desired for many years, in particular for impaired persons or for people requiring special health treatments. In certain cases, these requirements for continuous monitoring force people to stay at the hospital facilities for a few days, such as when monitoring cerebral activity, or force them to visit the hospital every few days for downloading data from portable monitoring equipment to a server, such as when monitoring the hearth rate.

The increasing availability of mobile devices and wireless networks, and the tendency for them to become ubiquitous in our dally lives, creates a favourable technological environment for the emergence of new, simple, and added-value applications for healthcare.

One major opportunity resulting from this technological evolution is that electronic health assistants can now be used by everyone, independently of their health condition.

The technological evolution achieved during the lasts years lead to more sophisticated environments. We have more sophisticated users in the sense that more people use more technology in their living and have their lives controlled by technology, and also because more technological devices exist to assist people that search for healthcare services. WLAN, Bluetooth, mobile phones, digital diaries are among some of the most popular technologies used today by many people. Others technologies control peoples' life individually or collectively, many times without people noticing it, like remote video surveillance or remote traffic control systems.

To explore and take advantage of these new technologies it is necessary to solve a set of technical, ethical and legal problems. Pervasive and ubiquitous computing devices can be very useful to people, providing important information and establishing an infrastructure that enables the emergence of a new kind of applications and services: the context-aware services and applications.

In context-aware computing, applications adapt their behaviour accordingly to the context of its users. The context is all the information that characterizes the user in a specific moment. It may include the location, position, a list of nearby objects (e.g. people), the user's activity, the available resources, some user's vital signals, and even the familiarity of the user with his/hers surroundings.

Among the technical problems that need to be worked out are the notion of context and the context management. Until today, many location-based and context-aware services and applications were built based on specific solutions, where location or other data was directly used from the sensors.

Context management should be done through an open and generic entity capable of supporting virtually any sensor or positioning service, without imposing a specific space model and by being capable to support a context based on multiple dimensions.

Context is all the dimensions (all the information) that characterize a user in a specific moment. Some basic dimensions of a context may be obtained directly from physical sensors, while some others may be calculated from raw data or may even be estimated from the information provided by other dimensions.

Location and position have been the most used dimensions when creating context-aware applications and services because there are more sensors and services capable of provide this kind of data than any other dimension. Moreover, position and location are among the dimensions that, in fact, influences a lot the interaction of people with computing devices. Context-aware applications that rely primarily on location are known as location-aware. Location-aware applications provide to mobile users the possibility to access services and information that are relevant to the user in a specific moment and location.

A number of technologies can be used to acquire the user's position and location, inside and outside buildings. In the last decade, research in context and location-aware computing produced frameworks and solutions that enable the easy development of context-aware applications. In particular, several developments in context management frameworks provided the tools for programmers to access the context of users without the need to deal directly with the low-level technical details of the sensors used to acquire the context, and allowing the use of several technologies simultaneously to provide position and location with more precision and in more places. For example, the Place Lab system (LaMarca, 2005) exploits the beacons broadcasted by many wireless networks to estimate the geographic position of mobile users.

Many of these technologies enable the development of new solutions for healthcare, improving the cares with people in a hospital, for sick persons that are at home, for an accident victim, for the doctors and for those who rescue the victims of accidents. In this chapter we discuss how context and location can be used in innovative applications and how to use a set of solutions and technologies that enable the development of innovative context and location-aware solutions for the healthcare area.

This chapter is organized as follows: section 2 presents what is a user' context and how it should be managed. Section 3 presents some technologies that can be used to acquire some of the user' context dimensions. Section 4 shows how an ordinary mobile phone can be used to detect the user movement and the data collected by the phone can be used to create a personal space model and to infer the familiarity of the user with a place. The last section presents the conclusions of this chapter.

CONTEXT AND CONTEXT MANAGEMENT

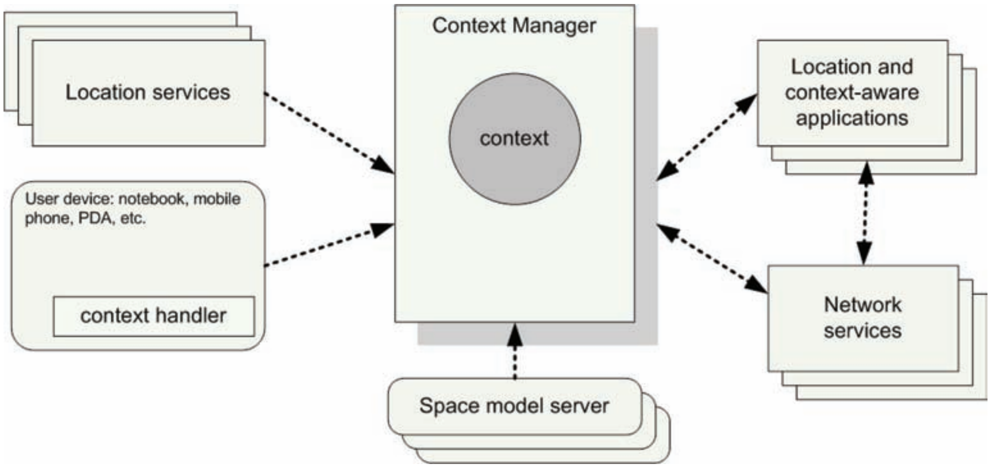
Considering that a user' context is something very wide, that can contain a considerable and variable number of dimensions, we sustain that context should be represented by an unbound and dynamic list of attributes, represented by standardized and non-standardized data structures, with mandatory and optional attributes. Context is a cumulative storage of knowledge, being able to describe the current situation of a person and also remember past experiences.

Context management should be done by a pervasive universal service, capable of dealing with any number of context sources. In (Meneses, 2004) we proposed a generic context manager capable of receiving data from virtually any sensor or location service, that provides an interface that allow authorized client applications to access to user' context represented by a XML stream. The developed solution also allows some other functionalities like the use of space model servers to complete the context information and a publish-subscribe mechanism that allow applications to request to be notified by the context manager when the context (or a specific dimension of the context) changes. Figure 1 shows the context manager and the main entities that interact with it.

The context manager holds and manages the context object which contains the user' context. It receives contextual information from location services that can exist on the infrastructures (like, for example, a positioning mechanism on a wireless network or soft sensor that detects the presence of the user mobile phone nearby an Bluetooth access point) and from context handlers that run on a user device. An example of a simple context handler, to be run on the user device, is a software that detects and updates the context with the BSSID of the WiFi networks detected or a software that updates the context with the geographic coordinates that retrieves from a GPS receiver. Data received by the context manager is integrated into the user context becoming available to be used by applications and services that can run on the user device or in the network.

The context manager, besides integrating the data received from sensors, can also improve

Figure 1. The context manager that manages the context and interacts with a set of external entities



the user' context using some external services capable of providing additional information about the collected data, and can also execute inference algorithms that supply new contextual dimensions. For example, the context manager can execute an algorithm that by processing the GPS coordinates is able to automatically determine if the user is at home or at his/her workplace (Moreira, 2005). Other example is the possibility of using data available at GSM phones to automatically infer high level information about the current situation of a user.

AVAILABLE TECHNOLOGIES AND SOLUTIONS

Today, there are a wide number of technologies that can be used to acquire the user' location and position. Some of those technologies, like the Active Badge (Want, 1992) or Active Bat (Ward, 1997), were specifically developed to acquire the user' location or position inside buildings. Other technologies, like WiFi networks or Bluetooth access points, were initially developed for a different proposes but can also be used to locate a user.

The lack of a universal pervasive solution for location/position is one of the main problems that block the bootstrap of location-based services and applications. Even GPS receivers, that become popular in the last years, are not a universal solution because it only works in open areas and not everybody has a receiver.

What is necessary is a solution that can be deployed by anyone, everywhere, and pervasive enough to not interfere on people's life. Currently, the best possible solution is to use mobile phones. If we look to a person on the street, at home, at work, going out with friends, etc., we observe that a mobile phone is the technological device that is always present and always turned on. Unlike a laptop that only some people have and it is only turned on when it is needed, or a GPS receiver that people use mainly in car, mobile phones are almost universal (ubiquitous): almost everybody has one, it is kept turned on most of the time and the user takes it everywhere.

Several mechanisms were developed to acquire the mobile phones' position. Angle of Arrival (AOA), Time Difference-Of-Arrival (TDOA) and Enhanced-Observed Time Difference (EOTD) are some of the solutions developed to acquire the location of mobile devices in GSM cellular networks.

These technologies provide the positioning data of mobile phones to network operators which usually do not make this information accessible to applications running outside their backbones. Hopefully, there is a basic position mechanism, known as cell-ID positioning, that is done at the mobile terminal by identifying the network cell being used in that moment by the handset. The accuracy of cell-ID method is reduced when compared with the others mechanisms but has the advantage of being possible to be done on the user handset, without depending on any network service.

GSM networks are made of cells with each cell covering an area. In rural areas, with fewer users per square kilometre the cells are usually bigger, covering a wide area. In contrast, in urban areas cells are usually smaller. Each cell supports a limited number of users thus in urban areas the cells are usually smaller with more cells covering the same area in order to support the communications requirements of all the users.

Each cell has a numeric unique identifier, generically called cell-id. Mapping each cell-id into a geographic position would allow finding the location of the user in a well known referential. However, this mapping is a difficult task because network operators do not make their network configuration or base station positions public. Mapping each cell manually would be a big effort considering that new cells and changes in the network configuration would have to be detected in order to keep the service updated.

Medical equipment with network connectivity is also becoming available, enabling the development of integrated systems where the patient's data is available and monitored remotely. Moreover, automatic collection of data from medical devices allows more complete patient medical histories (with less mistakes introduced by manually collecting data and with more data – data collected more often). Reasoning algorithms that process this data can detect and foresee health problems based on the user history or simply remember or automatically instruct medical devices to apply certain drugs.

Users' history and scientific knowledge can be joined in data mining and machine learning algorithms to create knowledge and predict the user medical evolution.

Current technology allow to locate doctors inside an hospital, access patients records automatically when a doctors gets near a patient or to locate a patient that may suffer from memory problems and get lost on a street, etc. However, smarter applications can be developed.

Some health services and equipments already provide medical records in an electronic format. The next stage of the technological development should be the integration of the records into the user context. The integration would allow to simultaneous access to the medical records and to other dimensions of the user context which could benefit the user and medical staff. Information like the familiarity of the user with the surrounding environment or the user location can help medical rescue services. Information about the presence of familiars or friends nearby can provide valuable information that benefit the medical staff and also the patient, allowing to have information about what happened to the patient before the lost of conscience or to find out if any other person would be with the injured patient at the moment of a accident and it is still missing. Having a user' context that keeps memory of the user movements will help to know easily where the user was before and to find and contact the persons that were with the ill person.

IMPROVING CONTEXT WITH TODAY'S TECHNOLOGY

If a person is involved in a medical emergency situation, the attitude changes according to the place where the emergency occurs, whatever the person is the victim or the rescuer that provide assistance to injured persons. A certain health problem can be less critical if the person is in a familiar place and surrounded by friends in contrast to a situation where the victim is alone in an unfamiliar place. A context management system can provide such a support for this kind of applications.

The user's context is valuable information in case of emergency because it can include the user's position and location and also provide additional valuable information like the familiarity level with the current place, the presence of nearby friends and relatives or information about the user medical history and known problems. The context of the user can even include information that may suggest the causes of the emergency if it is feed by temperature or acceleration sensors. The ubiquity of mobile phones and networks provide a particularly rich technological environment to gather such information and enable assistance applications for the health care mass market. Most of these applications can rely on the phone's hardware only and be easily deployed in the majority of the current mobile phones. Therefore, all the conditions for a fast dissemination of these applications are fulfilled.

Mobile phones are small and people take them to everywhere, being common the presence of a mobile phone on every people's pocket (including injured victims). Just by using the cell phone it is possible to infer when the user is moving or visiting a place and compute a familiarity level with the user's current location. This kind of information can be computed on the mobile phone and does not need to use any network services.

Detecting the User Movement

When turned on, a GSM phone is linked to a cell - the active cell - which is selected among the cells available in a certain place. The handset movement can not be detected just by analysing the changes in the cell-id because the handset changes from a cell to another when fluctuation occurs in the radio signal level, when it becomes weaker or because the user moves to another place. Thus, even if a terminal stays for a long period in a single place it may change several times the active cell. While remaining in the same place, sometimes a handset stays for hours in one cell while in other occasions it stays only some seconds or minutes in each of the available cells.

By analysing the changes of the active cell during a period of time it is possible to detect the movements. When the terminal is stopped in a certain place it will change between the set of cells available on that place. When the terminal moves to a new place, new cells will become available and will be used. Thus, when the user is moving we observe the use of different cells and faster variations in the active cell.

Computing a Mobility Distance and a Mobility Index makes it possible to detect the user movement (Meneses, 2006). Considering that a record has the identification of a cell being used in a certain moment and that instant timestamp, the Mobility Distance measures the distance between two records. If the user in both moments is in the same cell then the distance is zero. If not, the distance is the inverse of the time spent on each cell. For a list of records, the Mobility Index gives the sum of the mobility distance between each record and all the previous ones. Thus, the Mobility Index allows to estimate the user movement, computing the index from the current time instant back to a certain amount of time back.

CREATING A PERSONAL SPACE MODEL

Considering always the last cells used by a mobile phone it is possible to find out if the user is moving or not, computing the Mobility Index of the records collected during the last minutes (the used cells). When the user is not moving it is possible to characterize the place based on the set of cells used during that time. The place is characterized by the set of cells used and by the percentage of time spent on each cell. The characterization allows create "an image" of the GSM network in that place: we call it a fingerprint.

If the user visits the same place several times then a fingerprints is created in each visit to that place. Several visits to a place result in several fingerprints, which are not necessarily equal because the user' handset spends different amounts of time on each of the available cells (the percentage of time spent on each cell is different). Although different, the fingerprints have some similarity because they were created on the same place served by the same subset of cells.

By clustering similar fingerprints it is possible to group fingerprints, creating a cluster for each place. A cluster is created by the union of fingerprints (that are created based on the cellID) and represents a place visited by a user. To measure the similarity between fingerprints and clusters two functions are used. The first function calculates the percentage of cells in a fingerprint that are also member of a cluster. This function ignores the cells of the fingerprint with less than 1% of time because so small amount of time is not representative of a place. The second function calculates the absolute difference between the percentage of time spent in that cell in each fingerprint (or in a fingerprint and a cluster).

Based on the total distance the system can join a fingerprint to a cluster or create a new one. A new clustering algorithm was created to deal with this data. The new clustering algorithm deal with symbolic data (the fingerprints), supports an endless number of fingerprints and can be applied as the data becomes available. The clustering process allows to create clusters that are continuous changing as new data (new fingerprints) are generated by the user movement.

Inferring the Familiarity of a User with a Place

A cluster contains the same basic information that a fingerprint has. It allows to know which cells exist in the place represented by the cluster and the exact moment (timestamp) the user arrived and leaved the place. Using timestamp data it is possible to know the total amount of time spent in a cluster (place) and the time elapsed since the last visit to that place. Based on the total amount of time spent in a place it is possible to estimate how well a user knows that place – the places best know are the places where a person spends more time. The Knowledge Index represents the knowledge the user has about a place based on the total time spent in it.

Places change as time goes by, with the construction of new buildings, new roads, etc. If a person does not visit a place for a long period then when he/she goes back to that place the changes will be noticed and the person will not feel so familiar with the place. Based on the time elapsed since the last time the user visited a place it is possible to calculate a Forget Index. Combining the Forget Index and Knowledge Index it is possible to obtain a Familiarity Index.

The Familiarity Index expresses the familiarity with the current place and can be very useful to a number of applications. It allows applications to adapt themselves according to the familiarity of the user. For example, in a very familiar place a user will not need help from a GPS guidance (navigation) application – the user knowledge should be enough to know which direction take to go to another place. On the opposite situation, in a completely unfamiliar place, the familiarity index can be useful to trigger an application that guides a user based on GPS coordinates, or an application that provides information about local attractions or about where to get a hotel or a restaurant in the surrounding area. An injured people, in a familiar place, will fell more comfortable and eventually more capable to request help and provide information about his location or get help from a relative. In contrast, an injured people in an unfamiliar place with the anxiety of get medical help will probably fell lost and be much less capable to provide his/her location or other information describing the current situation.

Table 1. Results achieved by the three users

	User A		User B		User C	
Visits to different places	59		123		147	
Visits correctly detected	53	(89,8%)	95	(77,2%)	121	**(82,3%)**
Clustering errors	3	(5,1%)	12	(9,8%)	4	**(2,7%)**
Partially well detected	0	(0%)	11	(8,9%)	9	**(6,1%)**
Faults	3	(5,1%)	5	(4,1%)	13	**(8,9%)**
False Positives	31		10		11	

Results

The technology described in the previous section was tested by three different users, clients of two different GSM networks, during several consecutive weeks. The users kept their normal life and manually registered their activities in a diary. The computed results were them compared with the user's diary (ground truth) to access the quality of the results achieved.

The system was tested considering the cells used by the phone during the last 10 minutes, considering the user was immobile when the Mobility Index was less than 6. Results show that the user movements were well detected in most of the occasions. Table 1 summarizes the results achieved considering all the visits made by the users to the different places that took at least twenty minutes.

Between 78% and 90% of the visits made to the several places were correctly detected. The amount of errors is small and a detailed analysis of the data show that those errors occur in very specific situations or places. False positives occur when the user is moving and the system classifies the user as visiting a place while clustering errors represent visits that were correctly detected but the clustering process joined the fingerprint to a cluster that represents other place. Generally the results are very good, considering that two of the users live and work inside cities and visited places very near. If we consider also the visits that takes less than twenty minutes the results range from 70% of visits correctly detected to user B to 86% to user A.

The main problem with the proposed solution are the places visited for very short period of times that sometimes are not detected and places that are very near each other that not always are distinguished. However, even some of the places geographically near and places visited for short periods of time were detected and correctly clustered.

An analysis of data allows explain most of the errors detected. User A lives inside a big city and works in another city located 35 km away from his house. Everyday, he goes to work by car, crossing a rural area, travelling in a narrow and sinuous road. Analysing the user data we see that false positives are the most common error in user A data and always occur when the user is going to work. Because he drives in relative slow speed in a rural area (where the number of GSM cells is small and each one covers a wide area) then he uses the same set of cells for several minutes. The use of the same set of cells makes the mobility index to decrease below the threshold that defines the boundary between considering the user moving or not moving. Thus, the system considers the user is visiting a place when, in fact, he is travelling. Although this is a false positive, it is not a completely mistake because in fact the user knows the area has he travels by that road everyday.

Many of false positive registered for the others users can also be explained by analysing data detailed. For example, false positives occur when user B is travelling with the family and when user C travels in a natural park, in an inhabited area. User B diary shows that the users travelled, by car, near the sea. Considering the distance and the amount of time the trip took, it is possible to conclude that the user travelled very slowly and/or stopped to visit a place. User B does not remember exactly what he has done on that afternoon but admitted that stopped visiting some beaches in the shore. User C travelling in a natural park with narrow and twisted roads experimented the some problem that occurred to user A: he drove even more slowly and for a long time inside the same cell (being an inhabited area it has only one or two GMS cells). Thus, by an analysing data it is possible to explain many of the errors.

In (Maitland, 2006) it is presented a solution to detect the users' daily activity, through the use of am unmodified mobile phone. The solution is based on an application that works detecting patterns in signal strength fluctuation and changes in the active GSM cell to infer whether the user is sitting still, walking or travelling by car.

Although not completely accurate in the inference of the user' activity and in the detection of the amount of exercises done by the users, the study shows that people are willing to accept applications that do not produce 100% accurate results. Running on a mobile phone (which is a device originally developed for communications proposes) the application has the merit to also encouraged people to do more exercise which brings recognized benefits for people health. Even having knowledge of the accuracy of the application results people felt motivated to do exercise in order to be healthier (and achieve higher values in the application). In (Tsai, 2006) it is presented another solution based on mobile phone which allows users to self-monitor caloric balance in real time.

There is a big set of new technologies can be applied to help patients and emergency personnel. However, apply technologies to complex, stressed and emergency situations imply some constrains. Data networks can fail, wireless systems are even more unreliable and in stressful situation the interfaces and systems must be simple and reliable. Medical and emergency equipment does no comply with unreliable, inaccurate and not easy to use systems.

Location based on GSM cell-ID is not the most accurate positioning system but still produces very valuable data for the user context, which can be useful in many circumstances, including emergency situations. We do not propose a medical system based on cell-id but the use of position data to improve the context and enable a new set of applications that can use the familiarity level.

All information related to an ill person is important to emergency services and, sometimes, as the result of panic or stressful situation people are not capable of provide detailed and complete information. The presented solution can be valuable for users in many circumstances, including injured people, victims of accidents or sudden illness.

A simple alarm application that is executed in a mobile phone by pressing a button can trigger medical assistance providing valuable information about the user context to rescuers. By pressing the button, the user activates an application that collects information about the current situation/environment and sends an alert message based on the detected situation. The alert message can transmit information like the location of the user (available in the user context), the user familiarity with the surrounding environment, the identification of the user (which could allow access to his medical records by the emergency services) or even some dimensions of the user context that express the user medical history.

CONCLUSION

The existent technology allows create a new class of applications that explores the rich technological environment that today exist almost everywhere. The pervasive and ubiquitous technologies present everywhere and the use of inference techniques enables the creation of innovative applications in the healthcare domain. The solution presented in the previous section is just an example of these inference techniques. Although it has not been tested in any specific case in the healthcare domain, we foresee that the application of the proposed system can bring important benefits to this domain.

REFERENCES

LaMarca, A., Chawathe, Y., Consolvo, S., Hightower, J., Smith, I., Scott, J., et al. (2005). *Place Lab: Device Positioning Using Radio Beacons in the Wild*. Paper presented at the Third International Conference Pervasive Computing (PERVASIVE 2005), Munich, Germany.

Maitland, J., Sherwood, S., Barkhuus, L., Anderson, I., Hall, M., Brown, B., et al. (2006). *Increasing the Awareness of Daily Activity Levels with Pervasive Computing*. Paper presented at 1st International Conference on Pervasive Computing Technologies for Healthcare Innsbruck, Austria.

Meneses, F., & Moreira, A. (2004). *A Flexible location-context representation*. Paper presented at the The 15th IEEE international Symposium on Personal, Indoor And Mobile Radio Communications (PIMRC2004), Barcelona, Espanha.

Meneses, F., & Moreira, A. (2006). *Using GSM CellID Positioning for Place Discovering*. Paper presented at the First Workshop on Location Based Services for Health Care (LOCARE'06) at the 1st International Conference on Pervasive Computing Technologies for Healthcare Innsbruck, Austria.

Moreira, A., & Santos, M. (2005). *Enhancing a user context by real-time clustering mobile trajectories*. Paper presented at the International Conference on Information Technology: coding and computing – ITCC 2005, Las Vegas, NV, USA.

Tsai, C., Lee, G., Raab, F., Norman, G., Sohn, T., Griswold, W., & Patrick, K. (2006). *Usability and Feasibility of PmEB: A Mobile Phone Application for Monitoring Real Time Caloric Balance*. Paper presented at 1st International Conference on Pervasive Computing Technologies for Healthcare Innsbruck, Austria.

Want, R., Hopper, A., Falcão, V., & Gibbons, J. (1992). The Active Badge Location System. *ACM Transactions on Information Systems*, *10*, 91–102. doi:10.1145/128756.128759

Ward, A., Jones, A., & Hopper, A. (1997). A New Location Technique for the Active Office. *IEEE Personal Communications*, *4*, 42–47. doi:10.1109/98.626982

Weiser, M. (1991). The computer for the 21st century. *Scientific American*, *265*(3), 94–104.

This work was previously published in Mobile Health Solutions for Biomedical Applications, edited by P. Olla; J. Tan, pp. 260-269 copyright 2009; by Medical Information Science Reference (an imprint of IGI Global).

Chapter 3.10

Electronic Patient Monitoring in Mental Health Services

Werner G. K. Stritzke
University of Western Australia, Australia

Andrew C. Page
University of Western Australia, Australia

ABSTRACT

This chapter reviews advances in electronic patient monitoring in mental health service delivery. The first part focuses on interactive-voice-response (IVR) technology and its dual role of enhancing the efficient and reliable access to vital patient information and reducing the need for human resources in using that information to guide patient care. Future directions for IVR-mediated mental healthcare are outlined and challenges to dissemination and routine implementation are discussed. The second part of the chapter focuses on touch screen technology as a clinical tool for continuing, flexible treatment planning in mental health inpatient clinics. It reports on a successful trial of linking an innovative mental health 'well-being thermometer' to a touch screen interface for keeping electronic patient reported outcome data at the clinician's finger tips. The authors argue that the field needs to move beyond feasibility studies and identify the drivers of and barriers to routine implementation.

DOI: 10.4018/978-1-60566-356-2.ch006

INTRODUCTION

In this chapter we review innovative uses of two emerging technologies in mental health service delivery. The first part of the chapter focuses on interactive-voice-response (IVR) technology and its dual role of enhancing the efficient and reliable access to vital patient information and reducing the need for human resources in using that information to guide patient care. The second part of the chapter will focus on touchscreen technology as a clinical tool for continuing, flexible treatment planning in mental health inpatient clinics.

INTERACTIVE VOICE RESPONSE (IVR) TECHNOLOGY EXTENDS THE REACH OF MENTAL HEALTH OUTPATIENT CARE

Information captured directly from patients using electronic methods is known as electronic patient reported outcome data. In developed countries almost every patient owns or has access to a telephone, making it a potentially ubiquitous portal for interactive data exchange and feedback between mental health service providers and patients. Interactive Voice Response (IVR) is a mode of data collection that uses an automated telephone interview, where a computer controls the administration of pre-recorded questions, and the respondents indicate their answers by pressing one of the keys on their telephone key pad or, as voice-recognition technologies become increasingly sophisticated, by saying out aloud the number corresponding to their answer. Such automated consumer-provider interactions are already commonplace in many business and service applications (e.g., phone banking, airline flight information). The scope of automated information exchange is very flexible. IVR systems for mental health care can be programmed to collect information in three basic modes: interval contingent (e.g., having patients report daily the frequency and intensity of symptoms of a presenting problem), signal contingent (e.g., calling patients on multiple occasions to elicit patient reports for those specific points in time), and event contingent (e.g., patients initiate calls to the system to report their acute status at the moment a particular target event occurs). Conditional branching of IVR administered questions based on decision algorithms acting on patient input can be adapted for many clinical applications such as diagnostic screening, aftercare monitoring, and triggering system-initiated proactive support mechanisms (e.g., automated voice and email messages describing coping strategies). If a patient fails to call the system at the expected times, automated reminder calls can be sent and treatment providers can be electronically notified to asses the need for an in-person follow-up. Likewise, clinicians can be alerted by the system if changes in patient status trigger programmed thresholds for stepped-up risk management or treatment intensity.

There are several advantages of IVR systems that are particularly relevant to mental health care applications. Patient-initiated calls can be recorded and processed at any time of day or night. Provider-initiated calls reach patients in their home without requiring an office visit. IVR systems are ideally suited for providing continuing care to hard-to-reach groups such as the homeless and drug users, or patients living in remote locations. Previous reviews of IVR studies (e.g., Corkrey & Parkinson, 2002) noted that the privacy afforded by interacting with automated, standardized interview protocols facilitates the accurate and honest reporting of potentially stigmatizing behaviors such as drug use or sexually risky behaviors. The automated patient-provider interface and standardization of interviewing formats eliminates interviewer bias and other unintended observer effects (Shaw & Verma, 2007). The verbal nature of IVR-based interviewing benefits patients with low levels of reading ability, including children. Children especially appreciate the high level of confidentiality in IVR communications, because questions presented by the IVR system cannot be overhead by others even within earshot, and the children's responses are keyed in unobtrusively via the touch-tone telephone (Stritzke, Dandy, Durkin, & Houghton, 2005).

Despite these potential advantages of IVR technology in enhancing mental health service delivery, the routine integration of IVR systems in mental health care is yet to be realized. In a review of first-generation IVR studies published in the decade prior to the year 2001, Corkrey & Parkinson (2002) concluded that most patient monitoring studies were uncontrolled and intervention trials produced mostly nonsignificant results. Yet, these reviewers were optimistic that IVR technology would eventually prove its value as an economical and flexible tool in the provision of quality mental health services. More recently, there are promising signs that research in this area is slowly moving from a preponderance of studies demonstrating only feasibility and acceptability of this technology to controlled trials evaluating the efficacy of psychological interventions incorporating IVR protocols (e.g., Brendryen & Kraft, 2008; Mahoney, Tarlow, & Jones, 2003; Mundt, Moore, & Bean, 2006; Greist et al., 2002; Reid, Pipe, Quinlan, & Oda, 2007). While there is still some way to go, there can be little doubt that IVR systems are one of a suite of emerging technologies that will reduce the burden of unrecognized and untreated psychological disorders at the level of primary care (Kobak et al., 1997), while simultaneously increasing the capacity for delivering preventative services. For example, in the U.S., there is a huge gap between the one minute that primary care providers consider the realistic average amount of time they can devote to prevention during a typical office visit, and the 7.5 hours each day they would have to spend on prevention if they delivered all the preventative services recommended by practice guidelines (Glasgow, Bull, Piette, & Steiner, 2004). IVR technology is a partial solution to closing that gap. Just as accurate diagnosis is the cornerstone of effective treatment, reliable monitoring of treatment progress is the foundation of iterative treatment planning and accountability for outcomes (Page & Stritzke, 2006). A number of recent studies demonstrate that IVR systems can be successfully incorporated in (a) assessment and diagnosis of mental disorders, (b) monitoring of behaviors and symptoms during treatment and aftercare, and (c) initiating referral pathways and delivering interventions.

Assessment and Diagnosis

IVR systems can be used prior to the clinic visit to initiate the assessment process. In an early study, Kobak et al. (1997) showed that an IVR version of a standard structured clinical interview administered in primary care settings yielded high diagnostic correspondence between the IVR- and clinician-administered versions. Recent studies have confirmed the feasibility of collecting diagnostic information via IVR technology in community settings. For example, Brody and colleagues (Brody, Rosen, Brodey, Sheetz, & Unutzer, 2005) explored the reliability of an IVR version of the Brief Symptom Inventory (BSI) in a community health centre serving low-income populations including English- and Spanish speaking groups. Results showed that IVR-generated responses on the BSI were not significantly different from a paper-and-pencil version, had high test-retest reliability ($\alpha = .95$), and patients reported similar satisfaction with both modalities. Thus, IVR is well suited to administer standard diagnostic tools of broad psychiatric functioning.

The reliability and validity of IVR versions of specific psychiatric symptom scales have also been examined. For example, a comparison of clinician-administered and IVR-administered versions of the Montgomery-Asberg Depression Scale (MADRS) yielded comparable reliability measures (Mundt et al, 2006), and symptom severity was equivalent for nine of the ten individual items. An interesting feature of the IVR version was that after providing an initial rating for each item of the scale, the system responded with a gender-matched voice to provide the anchoring description of the numerical severity rating spoken in an affective intonation that reflected the severity of the rating provided by the respondents. Patients were allowed to adjust their ratings up or down based on the auditory feedback until they felt the affective tone of the voice matched their own feeling. Whether such features improve the reliability or predictive validity of the rating was not tested in this study. Assessment systems using IVR technology to screen for depressive symptoms have also been used extensively in clinical trials of antidepressant medications (Moore et al., 2006).

Few studies have examined IVR assessment protocols in non-adult samples. A notable exception is a comparison between IVR- and clinician-administered versions of the Teen-Addiction Severity Index (Brodey et al, 2005). The authors reported that reliability indices of the IVR version were equal or superior to those obtained by interview, and IVR-generated responses were reasonable convergent across a range of symptom domains. Importantly, participants claimed that their responses would be more honest using automated systems than during face-to-face assessments, although they preferred an Internet version over the IVR version. However, because this sample was recruited from a highly structured inpatient setting, it is unclear if IVR assessment of addiction severity would yield comparable results in outpatient settings.

IVR assessment protocols have also been evaluated for neuropsychological testing. Mundt and colleagues (Mundt, Kinoshita, Hsu, Yesavage, & Greist, 2007) monitored longitudinally cognitive functioning in three groups of community-dwelling elderly participants, who were either cognitively normal, had mild cognitive impairment, or had mild dementia. Results were promising and showed that the IVR-administered test battery reliably and validly discriminated cognitive functioning between the three groups. However, the reliance on touch-tone inputs proved somewhat difficult for participants with mild dementia, indicating that the generalizability of IVR assessments in this format may be constrained by the severity of cognitive impairments in respondents (Mundt et al., 2007; cf. Block, Bates, & Hall, 2003). This limitation may be overcome in the future as automated speech recognition can provide an alternative to manually keyed-in responses. There is also some preliminary evidence that it may be feasible to use IVR for the administration of *objective* measures of neuropsychological functioning such as choice reaction time tasks (Mundt, Geralts, & Moore, 2006). However, reliability of these measures can be poor as design and functional constraints of the telephone interfaces are still extremely variable posing problems for the standardization of testing conditions (Mundt et al., 2006).

In sum, there is considerable evidence that IVR-administered assessments of psychiatric symptoms can yield reliable and valid diagnostic impressions. In most studies, though, participants received compensation for their participation. It is unclear what the uptake of IVR assessment protocols would be among patients not receiving monetary incentives.

Monitoring

IVR systems are especially well suited for the frequent monitoring of clinically relevant behaviors, thoughts, and feelings over time while keeping reporting burdens at a minimum. For example, daily IVR assessments have been used in a randomized controlled trial to monitor the effect of medication on patients' ratings of emotional and painful symptoms associated with depression (Moore et al., 2007). The daily reporting regimen via IVR was able to show that a dose-related improvement in symptoms was already evident after the first day of treatment. IVR has also been shown to be a valid tool in monitoring the side effects or complications associated with medication. In one recent study examining the onset and chronology of antidepressant-induced sexual dysfunction, assessments of participants at home using IVR identified onset of sexual dysfunction well before it was detected during scheduled office visits (Dunn, Arakawa, Greist, & Clayton, 2007). Thus, frequent assessments via IVR enables more precise evaluation of changes in symptom patterns.

Frequent monitoring of problem behaviors is especially important for chronic, relapsing disorders such as substance use disorders. In two recent studies, Toll and colleagues (Toll Cooney, McKee, & O'Malley, 2005; 2006) compared reports from recently quit smokers on their cigarette and alcohol consumption over a 7-day period using either an IVR system or the traditional timeline follow-up (TLFB) method. Although both methods yielded largely comparable reports, compliance with the IVR system was quite poor despite participants earning extra compensation for completing the telephone questionnaire. As with studies using IVR to collect assessment and diagnostic information discussed earlier, monitoring studies also typically offer a fair amount of monetary incentives to enhance compliance. Little is known about the motivation required for IVR users to bear the burden of frequent interactions with an IVR system under conditions where no monetary incentives are provided. Some have argued, though, that lower rates of IVR reported data entry which is verified by date and time stamping is preferable over higher, but unverifiable, compliance rates achieved with alternative methods (Collins, Kashdan, & Gollnisch, 2003). Moreover, IVR monitoring is superior to other methods in contiguously exploring triggers and contextual variables of problem behaviors. For example, IVR studies have examined the relationship between mood and gambling behavior in real time (Gee, Coventry, & Birkenhead, 2005), environmental and internal triggers of cigarette smoking (Krukowski, Solomon, & Naud, 2005), contextual variables of drinking and abstinence for up to 128 days in resolved untreated community problem drinkers (Tucker, Foushee, Black, & Roth, 2007), changes in alcohol use and comorbid symptoms (Simpson, Kivlahan, Bush, & McFall, 2005), and links between alcohol use and stress (Anderson, Gordh, & Berglund, 2007) and victimization (Neal et al., 2006).

Although the feasibility of IVR monitoring in adult samples is well documented, there is a relative neglect of IVR monitoring research with adolescent samples and children. The feasibility and acceptability of daily IVR monitoring of predictors of alcohol use was recently explored in a small pilot study of adolescents treated for alcohol use disorders (Kaminer, Litt, Burke, & Burleson, 2006). Results were encouraging, but compliance over a 14-day period was moderate (72%) and may have been contingent on the use of generous incentives (up to $100) which are typically not available in general clinical practice. In contrast, in the first studies to investigate the feasibility of using IVR in community samples of children (Ns = 74 and 662; aged 9 – 13 years), compliance rates with daily monitoring of alcohol and tobacco related behaviors and attitudes were high (91% and 92%), with reporting periods of up to 8 weeks and a comparatively modest amount of incentives of up to $15 (Stritzke et al., 2005). Yet, the potential of IVR technology in health promotion and research with non-adult populations still remains largely untapped.

Intervention

Perhaps the greatest clinical utility of IVR technology lies in its capacity to integrate IVR diagnostic and monitoring functions with automated clinical decision-making tools. Systems can be configured for initiating differential referral pathways, delivering brief interventions, enhancing risk management, assessing the need for stepped-up or stepped-down follow-up care, and providing tailored relapse prevention assistance.

In several non-controlled studies, IVR systems have been used for pre-visit screening to direct patients into appropriate referral pathways and interventions. For example, IVR technology has been used to screen for tobacco use prior to scheduled primary care visits in two inner-city clinics (McDaniel, Benson, & Martindale, 2005). Just over half of the patients contacted completed the automated survey, and 39% of those were identified as smokers. Survey information was linked (albeit via manual entry) with the electronic medical record system to generate reminders to primary care providers to initiate smoking cessation interventions. Unfortunately, almost one in three patients reported in a post-visit interview that they did not receive an automated call prior to their appointment, and less than half of the smokers had discussed smoking cessation with their provider. This raises concern about the reliability of the IVR-initiated screening and the utilization of IVR-generated feedback to prompt clinician-guided behavior change. Future refinements of automated patient-provider interfaces need to take into account the potential for "reminder fatigue" in medical personnel (McDaniel et al., 2005), especially if IVR systems do not also incorporate automated brief intervention features that can lessen the response burden on medical staff. The feasibility of IVR screening to initiate referral pathways has also been explored for large, state-wide dementia screening (Mundt, Moore, & Greist, 2005), as well as for automated depression screening of a small convenience sample of disadvantaged pregnant women in an urban obstetric clinic (Kim, Bracha, & Tipnis, 2007). In those studies, of the callers who received a positive screen, 34% to 57% indicated a desire to speak with a health care provider or accessed further information about referral options. These results are encouraging and demonstrate the feasibility of IVR applications in facilitating the automated transfer of patients receiving positive screens into appropriate referral pathways.

Beyond the initiation of referral pathways, feedback from an IVR patient-provider interface can be used to directly prompt the delivery of interventions. In one recent randomized-controlled trial, IVR technology was tested for following and triaging smokers after discharge from a busy tertiary care hospital following treatment for coronary heart disease (Reid et al., 2007). Patients were automatically contacted via telephone to check their smoking status for up to 30 days after discharge. A decision-making algorithm prompted the IVR system to flag any patients who had resumed smoking but were motivated to make another quit attempt. These patients then received additional assistance via three telephone sessions over an 8-week period conducted by the nurse-specialist. The odds of being smoke-free at the 12-month follow-up were more than two-fold for the IVR group compared to a usual care group. Another randomized controlled trial examined outcomes of a 12-month IVR-mediated intervention designed to assist family caregivers managing persons with disruptive behaviors related to Alzheimer's disease (Mahoney et al., 2003). Caregivers were monitored weekly by the automated system and, if distress levels exceeded programmed thresholds, were offered automated assistance. If problems persisted, additional coping strategies were made available, as well as options for stepping up care which allowed caregivers to seek support from an expert panel or other caregivers via personal voice-mail linkage. Caregivers with low levels of mastery and high anxiety at baseline showed a significant intervention effect at 12-months follow-up, reporting reduced distress, depression, and anxiety compared to controls. IVR-mediated positive treatment effects have also been demonstrated in randomized controlled trials of computerized cognitive-behavior therapy for obsessive-compulsive disorder (Tumur, Kaltenthaler, Ferriter, Beverley, & Parry, 2007), and some of these systems have gained approval by government regulatory bodies (Baer, Greist, & Marks, 2007). It appears that randomized controlled trials of systems that combine automated features with some options for clinician-guided care, whether in person or via telephone contacts, show superior treatment outcomes and clinical utility compared to trials of systems where patient contact is limited to the machine (e.g., Mundt, Moore, & Bean, 2006). However, as IVR systems mature and start to utilize 100% automated patient-machine interfaces in *multiple* media, such as text, voice, and graphical images, which are capable of providing real-time feedback and iterative case management, the need for human resources to achieve long-term efficacy of IVR-mediated treatment outcomes may diminish (Brendryen & Kraft, 2008).

Perhaps the greatest advantage of the 24-hour availability of IVR-controlled "duty managers" in mental health case management is its tremendous potential for extending the reach of risk management protocols for outpatients, and thereby improving the safety of patients. For example, IVR systems have been successfully used for detecting, monitoring, and managing suicidality risk in home monitoring programs for patients with chronic illness (Turvey, Willyard, Hickman, Klein, & Kukoyi, 2006), and in large clinical trials involving vulnerable populations of depressed outpatients (Nierenberg et al., 2004).

Similar to diagnostic and monitoring applications of IVR technology, there is almost no research evaluating IVR-based applications to interventions with adolescents, let alone children. A promising start is a recent encouraging report on the feasibility and acceptability of an IVR-controlled behavioral aftercare intervention for youths following a 9-week treatment program for alcohol use disorder (Burleson & Kaminer, 2007).

Future Directions for IVR-Mediated Mental Health Care

The modal conclusion in published reports of IVR applications in mental health service delivery to date is that they are "feasible", and that they are "acceptable" to patients, when compared to alternative methods of information exchange between patients and providers. If the promising potential of IVR technology is to be fully realized in the routine care of mental health patients, future research needs to move beyond simply demonstrating feasibility and attend to several important issues. First, there is a need to extend the body of randomized controlled trials that test the long-term clinical outcomes of IVR-mediated interventions. Second, it is important that such trials are carried out by investigators that do not have a commercial stake in the intervention (Tumur et al., 2007). Third, not only improvements in psychological functioning and well-being are of interest. Equally important is to increase the evidence for cost effectiveness, cost offsets, and reductions in health care utilization associated with IVR-mediated care (e.g., McCrone et al., 2007). Fourth, the dissemination and wide-spread implementation of these innovative treatment tools is likely to require the advocacy and funding infrastructure from macrosystems such as large health care organizations, practice networks, and payers (Glasgow et al., 2004). Fifth, there is a dearth of studies investigating IVR-based interventions in children and adolescents. Given that today's technology-savvy youth in the developed world are born with a 'digital spoon' in their mouth, they are likely to be tomorrow's primary consumers of mobile telephone based interfaces for mental health services delivery. Sixth, compliance with IVR protocols requiring frequent patient-initiated contact with the machine has ranged from very good to poor, and published compliance rates typically were achieved by offering incentives for IVR users. Evaluation data are needed to establish the reliability of the uptake of IVR technology in routine care in the absence of monetary incentives for patients. Finally, medicolegal and ethical challenges associated with automated mental health services require further scrutiny (Koocher, 2007), and there need to be safeguards for monitoring the automated monitors. Especially if interoperation of independent IVR database systems between members of service networks occurs, it is important to ensure that data sources are allowed to interoperate and make their data available to external user interfaces without compromising their autonomy and security (Dawson, Qian, & Samarati, 2000). One can also be safe in the prediction that IVR technology is going to be only one of many drivers of modern mental health service communication interfaces, and it will be seamlessly integrated with other innovations in automated processing of electronic patient reported outcome data. One of these is the use of touchscreen technology to provide treatment staff with a platform to access on demand up-to-date data on a patient's treatment progress and mental health well-being.

TOUCHSCREEN TECHNOLOGY CAN KEEP A MENTAL HEALTH "WELL-BEING THERMOMETER" AT THE CLINICIAN'S FINGER TIPS

The humble thermometer is one of a suite of excellent tools for monitoring a person's health. The measurement is quick, reliable, and elevated temperatures alert staff to the presence of pathology. In contrast to physical medicine, clinical psychological services have lacked a "thermometer" to monitor client progress in real time. There is a need for a mental health measuring instrument that is rapid, reliable, sensitive to change, and can assist clinical decision making in mental health. Fortunately, developments in computing have facilitated rapid and efficient data collection, storage, and management. When this computing power is combined with a valid and psychometrically sound instrument, the promise of being able to provide real-time feedback on progress in treatment becomes a reality. The remainder of the chapter will briefly review the current status of data collection in psychotherapy and describe efforts to automate the real-time data collection in a mental health context. The ultimate aim is that when mental health "thermometers" are available and widely used, positive treatment responses will be identifiable to prevent unnecessarily long service delivery, and potential negative responses will be flagged in a timely manner to trigger a review of treatment options or activation of safety protocols.

The Rationale for a Mental Health Well-Being Thermometer

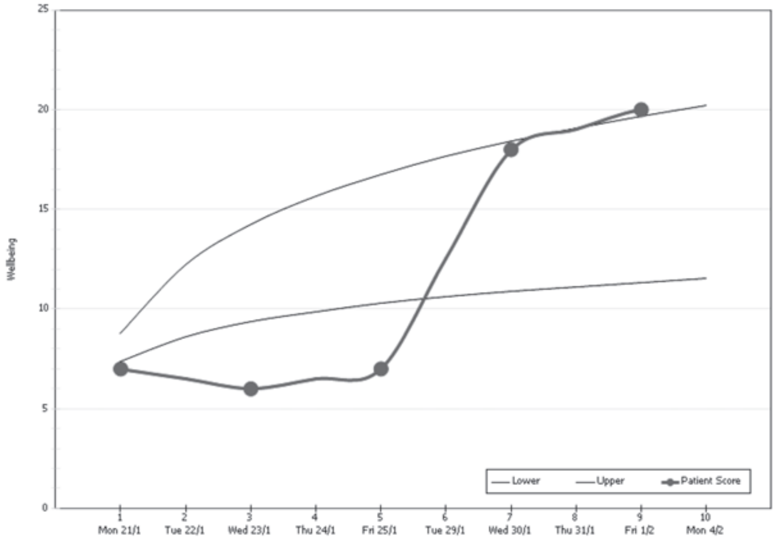
The logic behind the clinical use of a mental health thermometer is straightforward. First, it is necessary to identify and distinguish normal and abnormal 'temperature' readings. In the second step, once cut-off scores are identified, client trajectories can be monitored as they move from the abnormal range and shift towards normal by post-treatment. Clients who fail to follow the anticipated trajectory of improvement can be identified and remedial action instituted. Clients who reach the normal range faster than expected, can be discharged safely from treatment thereby saving on therapy time. The final step is the efficient assimilation into the workflow of a system of data collection and feedback that interferes as little as possible with the core business of therapy.

In psychotherapy, the concept of "clinical significance" was developed to achieve the twin functions of identifying when a change in mental health outcomes was statistically reliable and when it was clinically meaningful. The most commonly used metric (Ogles, Lunnen, & Bonesteel, 2001) is that developed by Jacobson and colleagues (Jacobson, Follette, & Revenstorf, 1984). The Jacobson and Truax (JT) method comprises two components, the first of which is the Reliable Change Index (RCI). The RCI expresses the pre to post difference in standardized units. The units are based on the reliability of the index and conceptually the RCI can be used to determine if the pre-post change is reliable (i.e., beyond that associated with measurement error). The second component assumes that client scores are drawn from one ("unhealthy") population and non-client scores are drawn from another ("healthy") population. A cut-off is established to estimate if a client's post-treatment score has moved from the unhealthy range into that of the healthy population range. Consequently, a client with a post-treatment score that is not reliably different from their pre-treatment score can be classified as "unchanged." Someone who has reliably improved, but failed to move into the healthy range will be classified as "improved" whereas someone who has reliably improved and moved into the healthy range can be classified as "recovered." Finally, clients who exhibit a reliable change in the opposite direction can be classified as "deteriorated." Such a classification allows clinicians to identify a benchmark against which mental health outcomes can be compared (e.g., Newnham, Harwood, & Page, 2007).

In terms of the thermometer analogy, these classifications permit discrimination between 'normal' and 'abnormal' scores on a psychometric instrument. It is then possible to interpret the trajectories of clients as they progress through treatment. Ideally, a client who begins in the abnormal or dysfunctional range will proceed towards the normal or functional range by the end of treatment. When symptom severity is plotted as a function of time in treatment, the average of client trajectories tends to follow a negatively accelerating function. That is, rapid initial progress gives way to a slower progress, which ends in the progress curve reaching an asymptote (Howard, Lueger, Martinovich, & Lutz, 1999; Lutz, Lowry, Kopta, Einstein, & Howard, 2001).

The expected progress trajectories can be used as a benchmark against which to compare each individual's progress. Minimally, clients can be compared against the average score of all clients. Alternatively, rather than a single trajectory, an estimate of measurement error can be placed around the trajectory to acknowledge the variability expected around the average course (Lambert & Archer, 2006). Initial symptom severity can be used to generate a suite of trajectories, so that the expected course of improvement will be different for different clients (Lutz et al., 2006). In addition, different methods of calculating the trajectory and the difference of a client's score from the trajectory can be used (Lutz et al., 2005). However, the common theme is that the progress of an individual client through treatment is evaluated against an expected trajectory. When a desired level of improvement has been achieved or exceeded, client and clinician can begin a discussion about the termination of treatment as well as planning for discharge and relapse prevention. Alternatively, if a client fails to make sufficient progress, a dialogue with the clinician can be initiated and the issues addressed (Harmon, Hawkins, Lambert, Slade, & Whipple, 2005). For instance, in Figure 1, the

Figure 1. An example of a client's scores during treatment being plotted against an expected trajectory (i.e., the area between the upper and lower curves)



client's trajectory, on an instrument where high scores are associated with improvement, shows that the person is failing to improve across the first five days of the inpatient treatment program. The area between the upper and lower curves is the expected trajectory of improvement for a patient with this level of severity. Thus, it was possible to discuss the absence of improvement. In this case, reasons were identified and a remedial plan was able to be put into operation over the weekend. By the Monday, the patient had been able to put into operation the treatment plan and move into the expected course of recovery, and into the healthy range by the end of treatment. Thus, real-time monitoring allowed for a timely adjustment to the treatment plan, which in turn resulted in a rapid improvement in patient well-being over the next couple of days (see Figure 1).

Monitoring Well-Being Trajectories

Lambert (2005) described the development of a monitoring regime within an outpatient setting using a 45-item instrument called the Outcomes Questionnaire (OQ-45). Following the analogy of the thermometer given earlier, Lambert's team repeatedly administered the instrument during treatment. Once sufficient data had been collected, typical expected treatment trajectories could be generated, and ultimately, actual progress could be benchmarked against expected improvement. In outpatient settings, providing staff with feedback from the OQ-45 increased treatment efficiency and effectiveness (e.g., Hannan et al., 2005; e.g., Hawkins, Lambert, Vermeersch, Slade, & Tuttle, 2004; Lambert et al., 2001; Whipple et al., 2003). Specifically, clients who were 'on track' could be treated in fewer sessions when feedback was provided. In contrast, clients who were 'not on track' received more sessions than when feedback was not provided. Since the clients who were 'not on track' were in the minority, there was a net reduction in the amount of treatment. This is a desirable outcome. The consumer is satisfied because they receive an appropriate level of care, and the provider is satisfied because costs are reduced and their time is used efficiently. Furthermore, by predicting treatment outcomes and alerting therapists to clients deemed likely to demonstrate poor outcomes at the termination of treatment, it was possible to halve the number of clients who deteriorated (Lambert et al., 2005).

There are a variety of other questionnaires that are appropriate for evaluating client outcomes (e.g., Miller, Duncan, Sorrell, & Brown, 2005). The Clinical Outcomes in Routine Evaluation (CORE) is a suite of instruments that vary in length (Barkham et al., 2001) from the 18-item short form (Cahill et al., 2006) to the 34-item Outcome Measure. Like the OQ-45, the CORE is able to identify patterns of change and then use these to predict different treatment outcomes and durations (Stulz, Lutz, Leach, Lucock, & Barkham, 2007). However, these initiatives were largely focussed on outpatient settings (where treatment duration is measured in weeks) rather than inpatient settings (where duration is measured in days). The difficulty is that the questionnaires being used in outpatient settings refer to "long" time periods (e.g., the past week). Therefore, we needed to identify a measure potentially suitable for briefer time periods.

Searching for a brief measure that could be administered rapidly and repeatedly, we identified the World Health Organization's 5-item Well-Being Index (WHO-5). It measures psychological health and is suitable in physical (Bech, Gudex, & Staehr Johansen, 1996a, 1996b) and mental health (Henkel et al., 2003). It has high sensitivity and good specificity in identifying health status and good negative predictive value (Henkel et al., 2003). In her doctoral thesis Elizabeth Newnham has shown that the WHO-5 is a valid, highly reliable and sensitive measure when used in a psychiatric setting. Positive correlations between the WHO-5 and various symptom measures suggest it has strong convergent validity. In concert, these findings suggest that the WHO-5 is an appropriate measure of wellbeing in psychiatric settings.

Given that the psychometric properties of the WHO-5 remained strong among inpatient psychiatric samples it appeared a good candidate for monitoring change trajectories in inpatients. Since our purpose was to monitor well-being, we modified the wording to measure well-being over the past day, rather than the past two weeks as it was previously designed. Despite this change, the reliability and validity of the WHO-5 remained high and predictive of future outcome. Previous research (Lambert et al., 2003) revealed that early progress is indicative of final outcome and our results support this view. However, having an appropriate instrument is only one element to the issue of monitoring progress. The second component is a process for the efficient input, processing, and output of the data from each patient. To illustrate, we will describe the process adopted at Perth Clinic; a private psychiatric hospital in Western Australia, funded in part by the health insurer Medibank Private.

Linking the Well-Being Thermometer to a Touchscreen Interface

To address the issues associated with the input of data, it was necessary to find a process that was simple for patients to use, did not place a burden on nursing or administrative staff, minimized data transcription errors, and was readily accessible. To this end touchscreens were introduced into the treatment rooms and quickly adopted into the daily routine. This permitted data collection from both inpatients and daypatients at any time of the day. The touchscreens were acceptable to patients and provided an easy method of completing the questionnaire.

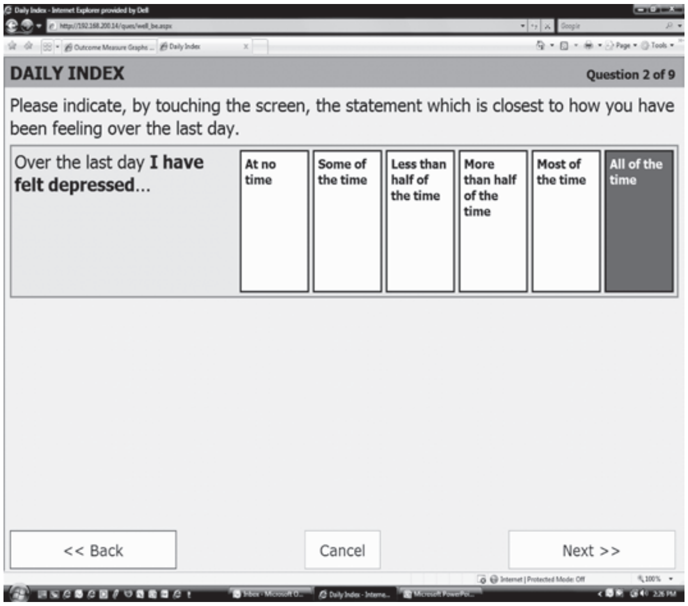
The next problem that needed a solution involved security. First, there was the issue of patient confidentiality. It was necessary to link the patient data to other data within the existing data base without providing a data entry system that disclosed the confidentiality of each person. Second, there was the issue of security of the existing patient data (i.e., it was imperative that people could not use the data entry hardware to access any confidential data held by the hospital). Third, there was the issue of security of the hardware itself. A hospital environment is a busy one and there is a risk of both theft and accidental damage.

Patient confidentiality was assured by requiring each user to enter their initials and date of birth into an entry screen. If a match was found with the hospital database, then patients were asked to confirm that the first name and suburb being used was correct. The patient could then proceed to enter their data (and in the future, view their treatment trajectory plotted against an expected trajectory).

The security of existing data held in the hospital's database was protected by the use of a Wyse "thin client" terminal. A thin client is a computer that relies on a central server for processing activities. They typically are solid state and do not have a hard drive. The hardware is sufficient to manage input and output and may include embedded software with a Web browser. In our context the thin client links to a web page that displays the questionnaire to the screen. Logging on opens a session and as patients enter their data, these are transferred to the server (for an example of a touchscreen data entry page, see Figure 2). Since no application data reside on the thin client, patient data is secure against loss or theft.

A variety of other benefits accrue from the adoption of a thin client to manage the data entry rather than a personal computer. The absence of moving parts and dependence on the remote server mean that the thin client is sufficiently robust to function in a busy ward environment. Since the thin client has no moving parts, overheating is less of a problem and so the hardware could be mounted securely and safely in a cabinet. From the perspective of the hospital's IT Department, the programming (in .NET) was relatively straightforward and thin clients are efficient because software upgrades and modifications can be made centrally on the server.

Figure 2. A screenshot of the touchscreen of the "well-being thermometer"



DAILY INDEX

Question 2 of 9

Please indicate, by touching the screen, the statement which is closest to how you have been feeling over the last day.

Over the last day **I have felt depressed**...

In sum, we have found that the development of a "wellbeing thermometer" has been well-received by patients and staff. To date, the responses from patients to the touchscreen technology has been anecdotal, and more systematic evaluations of this novel patient-provider interface are needed. They indicate that they are willing to participate because they can see that their data are relevant to their treatment progress. The main limitation seems to be that some level of management is required to oversee the process to ensure that patients are compliant with the data entry. In the past, when paper-and-pencil versions were used, it was obvious to staff which patients had been provided with and completed the questionnaires but now these data are stored on a central database. Therefore, a feedback process is required to alert staff which patients needed to be invited to complete the questionnaire on a given day. Nonetheless, these difficulties seem to be offset by the advantage that missing data (which occurred with paper-and-pencil versions) no longer occur, because progress through the questionnaire requires completion of previous items. Thus, the use of touchscreens to manage data entry (and ultimately feedback) has been achieved in a cost-effective manner that permits timely monitoring of mental health well-being in a psychiatric in-patient setting by providing relevant data to the clinical staff.

CONCLUSION

Among the emerging technologies in mental health service delivery, IVR and touchscreen technologies are poised to change the way mental health practitioners interact with their patients and deliver services. There is consistent evidence that these technologies can produce reliable patient reported outcome data, and level of acceptance of these innovations among patients is satisfactory. More controlled studies are needed to bolster the evidence base for the long-term efficacy of IVR- and touchscreen-mediated interventions. There is little doubt, though, that integrating these technologies in mental health care is feasible and holds great potential for improving the quality of care. However, routine and wide-spread adoption of automated patient-provider interfaces has significant implications for the funding infrastructure of mental health services and poses considerable challenges for the training of veteran and new members of the mental health work force. To the extent that these challenges are successfully met, the impact of IVR- and touchscreen-mediated interventions on the quality, continuity, and responsiveness of mental health care will be immense.

ACKNOWLEDGMENT

Completion of this chapter was in part supported by Western Australian Health Promotion Foundation (Healthway) Grants 7688 and 9354 to the first author, and a grant from the Medibank Private Safety and Clinical Improvement Incentive Pool to the second author. Correspondence concerning this chapter should be addressed to Werner G. K. Stritzke, School of Psychology, M304, University of Western Australia, 35 Stirling Highway, Crawley 6009, Australia (e-mail: werner@psy.uwa.edu.au).

REFERENCES

Andersson, C., Gordh, A. H. V. S., & Berglund, M. (2007). Use of real-time interactive voice response in a study of stress and alcohol consumption. *Alcoholism, Clinical and Experimental Research*, *31*, 1908–1912. doi:10.1111/j.1530-0277.2007.00520.x

Baer, L., Greist, J., & Marks, I. M. (2007). Computer-aided cognitive behaviour therapy. *Psychotherapy and Psychosomatics*, *76*, 193–195.

Barkham, M., Margison, F., Leach, C., Lucock, M., Mellor-Clark, J., & Evans, C. (2001). Service profiling and outcomes benchmarking using the CORE-OM: Toward practice-based evidence in the psychological therapies. *Journal of Consulting and Clinical Psychology*, *69*, 184–196. doi:10.1037/0022-006X.69.2.184

Bech, P., Gudex, C., & Staehr Johansen, K. (1996a). The WHO (ten) well-being index: A reply concerning the soundness of its development and the perspectives of its use. *Psychotherapy and Psychosomatics*, *65*, 334–336.

Bech, P., Gudex, C., & Staehr Johansen, K. (1996b). The WHO (ten) well-being index: Validation in diabetes. *Psychotherapy and Psychosomatics*, *65*, 183–190.

Block, R. I., Bates, M. E., & Hall, J. A. (2003). Relation of premorbid cognitive abilities to substance users' problems at treatment intake and improvements with substance abuse treatment and case management. *The American Journal of Drug and Alcohol Abuse*, *29*, 515–538. doi:10.1081/ADA-120023456

Brendryen, H., & Kraft, P. (2008). Happy ending: A randomized controlled trial of a digital multimedia smoking cessation intervention. *Addiction (Abingdon, England)*, *103*, 478–484. doi:10.1111/j.1360-0443.2007.02119.x

Brodey, B. B., Rosen, C. S., Brodey, I. S., Sheetz, B., & Unutzer, J. (2005). Reliability and acceptability of automated telephone surveys among Spanish- and English-speaking mental health service recipients. *Mental Health Services Research*, *7*, 181–184. doi:10.1007/s11020-005-5786-1

Brodey, B. B., Rosen, C. S., Winters, K. C., Brodey, I. S., Sheetz, B. M., Steinfeld, R. R., & Kaminer, Y. (2005). Conversion and validation of the teen-addiction severity index (T-ASI) for Internet and automated-telephone self-report administration. *Psychology of Addictive Behaviors*, *19*, 54–61. doi:10.1037/0893-164X.19.1.54

Burleson, J. A., & Kaminer, Y. (2007). Aftercare for adolescent alcohol use disorder: Feasibility and acceptability of a phone intervention. *The American Journal on Addictions*, *16*, 202–205. doi:10.1080/10550490701375251

Cahill, J., Barkham, M., Stiles, W. B., Twigg, E., Hardy, G. E., Rees, A., & Evans, C. (2006). Convergent validity of the CORE measures with measures of depression for clients in cognitive therapy for depression. *Journal of Counseling Psychology*, *53*, 253–259. doi:10.1037/0022-0167.53.2.253

Collins, R. L., Kashdan, T. B., & Gollnisch, G. (2003). The feasibility of using cellular phones to collect ecological momentary assessment data: Application to alcohol consumption. *Experimental and Clinical Psychopharmacology*, *11*, 73–78. doi:10.1037/1064-1297.11.1.73

Corkrey, R., & Parkinson, L. (2002). Interactive voice response: Review of studies 1989-2000. *Behavior Research Methods, Instruments, & Computers*, *34*, 342–353.

Dawson, S., Qian, S., & Samarati, P. (2000). Providing security and interoperation of heterogeneous systems. *Distributed and Parallel Databases*, *8*, 119–145. doi:10.1023/A:1008787317852

Dunn, J. A., Arakawa, R., Greist, J. H., & Clayton, A. H. (2007). Assessing the onset of antidepressant-induced sexual dysfunction using interactive voice response technology. *The Journal of Clinical Psychiatry*, *68*, 525–532.

Gee, P., Coventry, K. R., & Birkenhead, D. (2005). Mood states and gambling: Using mobile telephones to track emotions. *The British Journal of Psychology*, *96*, 53–66. doi:10.1348/000712604X15536

Glasgow, R. E., Bull, S. S., Piette, J. D., & Steiner, J. F. (2004). Interactive behavior change technology: A partial solution to the competing demands of primary care. *American Journal of Preventive Medicine*, *27*(2S), 80–87. doi:10.1016/j.amepre.2004.04.026

Greist, J. H., Marks, I. M., Baer, L., Kobak, K. A., Wenzel, K. W., & Hirsch, M. J. (2002). Behaviour therapy for obsessive compulsive disorder guided by a computer or by a clinician compared with relaxation as a control. *The Journal of Clinical Psychiatry*, *63*, 138–145.

Hannan, C., Lambert, M. J., Harmon, C., Nielsen, S. L., Smart, D. W., Shimokawa, K., & Sutton, S. W. (2005). A lab test and algorithms for identifying clients at risk for treatment failure. *Journal of Clinical Psychology*, *61*, 155–163. doi:10.1002/jclp.20108

Harmon, C., Hawkins, E. J., Lambert, M. J., Slade, K., & Whipple, J. L. (2005). Improving outcomes for poorly responding clients: The use of clinical support tools and feedback to clients. *Journal of Clinical Psychology*, *61*, 175–185. doi:10.1002/jclp.20109

Hawkins, E. J., Lambert, M. J., Vermeersch, D. A., Slade, K. L., & Tuttle, K. C. (2004). The therapeutic effects of providing patient progress information to therapists and patients. *Psychotherapy Research*, *14*, 308–327. doi:10.1093/ptr/kph027

Henkel, V., Mergl, R., Kohnen, R., Maier, W., Moller, H.-J., & Hegerl, U. (2003). Identifying depression in primary care: A comparison of different methods. *BMJ: British Medical Journal*, *326*, 200–201. doi:10.1136/bmj.326.7382.200

Howard, K. I., Lueger, R. J., Martinovich, Z., & Lutz, W. (1999). The cost-effectiveness of psychotherapy: Dose-response and phase models. In N.E. Miller & K.M. Magruder (Eds.), *Cost-effectiveness of psychotherapy: A guide for practitioners, researchers, and policymakers* (pp. 143-152). New York: Oxford University Press.

Jacobson, N. S., Follette, W. C., & Revenstorf, D. (1984). Psychotherapy outcome research: Methods for reporting variability and evaluating clinical significance. *Behavior Therapy*, *15*, 336–352. doi:10.1016/S0005-7894(84)80002-7

Kaminer, Y., Litt, M. D., Burke, R. H., & Burleson, J. A. (2006). An interactive voice response (IVR) system for adolescents with alcohol use disorders: A pilot study. *The American Journal on Addictions*, *15*, 122–125. doi:10.1080/10550490601006121

Kim, H., Bracha, Y., & Tipnis, A. (2007). Automated depression screening in disadvantaged pregnant women in an urban obstetric clinic. *Archives of Women's Mental Health*, *10*, 163–169. doi:10.1007/s00737-007-0189-5

Kobak, K. A., Taylor, L. V. H., Dottle, S. L., Greist, J. H., Jefferson, J. W., & Burroughs, D. (1997)... *Journal of the American Medical Association*, *278*, 905–910. doi:10.1001/jama.278.11.905

Koocher, G. P. (2007). 21st century ethical challenges for psychology. *The American Psychologist*, *62*, 375–384. doi:10.1037/0003-066X.62.5.375

Krukowski, R. A., Solomon, L. J., & Naud, S. (2005). Triggers of heavier and lighter cigarette smoking in college students. *Journal of Behavioral Medicine*, *28*, 335–345. doi:10.1007/s10865-005-9003-x

Lambert, M. J. (2005). Emerging methods for providing clinicians with timely feedback on treatment effectiveness: An introduction. *Journal of Clinical Psychology*, *61*, 141–144. doi:10.1002/jclp.20106

Lambert, M. J., & Archer, A. (2006). Research findings on the effects of psychotherapy and their implications for practice. In C.D. Goodheart, A.E. Kazdin & R.J. Sternberg (Eds.), *Evidence-based psychotherapy: Where practice and research meet* (pp. 111-130). Washington, DC: American Psychological Association.

Lambert, M. J., Harmon, C., Slade, K., Whipple, J. L., & Hawkins, E. J. (2005). Providing feedback to psychotherapists on their patients' progress: Clinical results and practice suggestions. *Journal of Clinical Psychology*, *61*, 165–174. doi:10.1002/jclp.20113

Lambert, M. J., Whipple, J. L., Hawkins, E. J., Vermeersch, D. A., Nielsen, S. L., & Smart, D. W. (2003). Is it time for clinicians to routinely track patient outcome? A meta-analysis. *Clinical Psychology: Science and Practice*, *10*, 288–301. doi:10.1093/clipsy/bpg025

Lambert, M. J., Whipple, J. L., Smart, D. W., Vermeersch, D. A., Nielsen, S. L., & Hawkins, E. J. (2001). The effects of providing therapists with feedback on patient progress during psychotherapy: Are outcomes enhanced? *Psychotherapy Research*, *11*, 49–68.

Lutz, W., Leach, C., Barkham, M., Lucock, M., Stiles, W. B., & Evans, C. (2005). Predicting change for individual psychotherapy clients on the basis of their nearest neighbors. *Journal of Consulting and Clinical Psychology*, *73*, 904–913. doi:10.1037/0022-006X.73.5.904

Lutz, W., Lowry, J., Kopta, S., Einstein, D. A., & Howard, K. I. (2001). Prediction of dose-response relations based on patient characteristics. *Journal of Clinical Psychology*, *57*, 889–900. doi:10.1002/jclp.1057

Lutz, W., Martinovich, Z., Howard, K. I., & Leon, S. C. (2002). Outcomes management, expected treatment response, and severity-adjusted provider profiling in outpatient psychotherapy. *Journal of Clinical Psychology*, *58*, 1291–1304. doi:10.1002/jclp.10070

Lutz, W., Saunders, S. M., Leon, S. C., Martinovich, Z., Kosfelder, J., & Schulte, D. (2006). Empirically and clinically useful decision making in psychotherapy: Differential predictions with treatment response models. *Psychological Assessment*, *18*, 133–141. doi:10.1037/1040-3590.18.2.133

Mahoney, D. F., Tarlow, B. J., & Jones, R. N. (2003). Effects of an automated telephone support system on caregiver burden and anxiety: Findings from the REACH for TLC intervention study. *The Gerontologist*, *43*, 556–567.

McCrone, P., Marks, I.M., Greist, J.H., Baer, L., & Kobak, K.A., Wenzel, & Hirsch, M.J. (2007). Cost-effectiveness of computer-aided behaviour therapy for obsessive-compulsive disorder. *Psychotherapy and Psychosomatics*, *76*, 249–250.

McDaniel, A. M., Benson, P. L., Roesener, G. H., & Martindale, J. (2005). An integrated computer-based system to support nicotine dependence treatment in primary care. *Nicotine & Tobacco Research*, *7*(Suppl. 1), S57–S66. doi:10.1080/14622200500078139

Miller, S. D., Duncan, B. L., Sorrell, R., & Brown, G. S. (2005). The partners for change outcome management system. *Journal of Clinical Psychology*, *61*, 199–208. doi:10.1002/jclp.20111

Moore, H. K., Mundt, J. C., Modell, J. G., Rodrigues, H. E., DeBrota, D. J., Jefferson, J. J., & Greist, J. H. (2006). An examination of 26,168 Hamilton depression rating scale scores administered via interactive voice response across 17 randomized clinical trials. *Journal of Clinical Psychopharmacology*, *26*, 321–324. doi:10.1097/01.jcp.0000219918.96434.4d

Moore, H. K., Wohlreich, M. M., Wilson, M. G., Mundt, J. C., Maurizio, F., Mallinckrodt, C. H., & Greist, J. H. (2007). Using daily interactive voice response assessments to measure onset of symptom improvement with duloxetine. *Psychiatry*, *4*, 30–37.

Mundt, J.C., Geralts, D.S., & Moore, H.K. (2006). Dial “T” for testing: Technological flexibility in neuropsychological assessment. *Telemedicine and e-Health, 12*, 317-323.

Mundt, J. C., Katzelnick, D. J., Kennedy, S. H., Eisfeld, B. S., Bouffard, B. B., & Greist, J. H. (2006). Validation of an IVRS version of the MADRS. *Journal of Psychiatric Research*, *40*, 243–246. doi:10.1016/j.jpsychires.2005.05.002

Mundt, J. C., Kinoshita, L. M., Hsu, S., Yesavage, J. A., & Greist, J. H. (2007). Telephonic remote evaluation of neuropsychological deficits (TREND): Longitudinal monitoring of elderly community-dwelling volunteers using touch-tone telephones. *Alzheimer Disease and Associated Disorders*, *21*, 218–224. doi:10.1097/WAD.0b013e31811ff2c9

Mundt, J. C., Moore, H. K., & Bean, P. (2006). An interactive voice response program to reduce drinking relapse: A feasibility study. *Journal of Substance Abuse Treatment*, *30*, 21–29. doi:10.1016/j.jsat.2005.08.010

Mundt, J. C., Moore, H. K., & Greist, J. H. (2005). A novel interactive voice response (IVR) system for dementia screening, education, and referral: One-year summary. *Alzheimer Disease and Associated Disorders*, *19*, 143–147. doi:10.1097/01.wad.0000174992.68332.0d

Neal, D. J., Fromme, K., Del Boca, F. K., Parks, K. A., King, L. P., & Pardi, A. M. (2006). Capturing the moment: Innovative approaches to daily alcohol assessment. *Alcoholism, Clinical and Experimental Research*, *30*, 282–291. doi:10.1111/j.1530-0277.2006.00025.x

Newnham, E. A., Harwood, K. E., & Page, A. C. (2007). Evaluating the clinical significance of responses by psychiatric inpatients to the mental health subscales of the SF-36. *Journal of Affective Disorders*, *98*, 91–97. doi:10.1016/j.jad.2006.07.001

Nierenberg, A. A., Trivedi, M. H., Ritz, L., Burroughs, D., Greist, J., & Sackeim, H. (2004). Suicide risk management for the sequenced treatment alternatives to relieve depression study: Applied NIMH guidelines. *Journal of Psychiatric Research*, *38*, 583–589. doi:10.1016/j.jpsychires.2004.03.004

Ogles, B. M., Lunnen, K. M., & Bonesteel, K. (2001). Clinical significance: History, application, and current practice. *Clinical Psychology Review*, *21*, 421–446. doi:10.1016/S0272-7358(99)00058-6

Page, A. C., & Stritzke, W. G. K. (2006). *Clinical psychology for trainees: Foundations of science-informed practice.* Cambridge University Press.

Reid, R. D., Pipe, A. L., Quinlan, B., & Oda, J. (2007). Interactive voice response telephony to promote smoking cessation in patients with heart disease: A pilot study. *Patient Education and Counseling*, *66*, 319–326. doi:10.1016/j.pec.2007.01.005

Shaw, W. S., & Verma, S. K. (2007). Data equivalency of an interactive voice response system for home assessment of back pain and function. *Pain Research & Management*, *12*, 23–30.

Simpson, T. L., Kivlahan, D. R., Bush, K. R., & McFall, M. E. (2005). Telephone self-monitoring among alcohol use disorder patients in early recovery: A randomized study of feasibility and measurement reactivity. *Drug and Alcohol Dependence*, *79*, 241–250. doi:10.1016/j.drugalcdep.2005.02.001

Stritzke, W. G. K., Dandy, J., Durkin, K., & Houghton, S. (2005). Use of interactive voice response (IVR) technology in health research with children. *Behavior Research Methods*, *37*, 119–126.

Stulz, N., Lutz, W., Leach, C., Lucock, M., & Barkham, M. (2007). Shapes of early change in psychotherapy under routine outpatient conditions. *Journal of Consulting and Clinical Psychology*, *75*, 864–874. doi:10.1037/0022-006X.75.6.864

Toll, B. A., Cooney, N. L., McKee, S. A., & O'Malley, S. S. (2005). Do daily interactive voice response reports of smoking behavior correspond with retrospective reports? *Psychology of Addictive Behaviors*, *19*, 291–295. doi:10.1037/0893-164X.19.3.291

Toll, B. A., Cooney, N. L., McKee, S. A., & O'Malley, S. S. (2006). Correspondence between interactive voice response (IVR) and Timeline Followback (TLFB) reports of drinking behavior. *Addictive Behaviors*, *31*, 726–731. doi:10.1016/j.addbeh.2005.05.044

Tucker, J. A., Foushee, H. R., Black, B. C., & Roth, D. L. (2007). Agreement between prospective interactive voice response self-monitoring and structured retrospective reports of drinking and contextual variables during natural resolution attempts. *Journal of Studies on Alcohol and Drugs*, *68*, 538–542.

Tumur, I., Kaltenthaler, E., Ferriter, M., Beverly, C., & Parry, G. (2007). Computerised cognitive behaviour therapy for obsessive-compulsive disorder: A systematic review. *Psychotherapy and Psychosomatics*, *76*, 196–202.

Turvey, C.L., Willyard, D., Hickman, D.H., Klein, D.M., & Kukoyi, O. (2007). Telehealth screen for depression in a chronic illness care management program. *Telemedicine and e-Health, 13*, 51-56.

Whipple, J. L., Lambert, M. J., Vermeersch, D. A., Smart, D. W., Nielsen, S. L., & Hawkins, E. J. (2003). Improving the effects of psychotherapy: The use of early identification of treatment and problem-solving strategies in routine practice. *Journal of Counseling Psychology*, *50*, 59–68. doi:10.1037/0022-0167.50.1.59

This work was previously published in Handbook of Research on Information Technology Management and Clinical Data Administration in Healthcare, edited by A. Dwivedi, pp. 87-103, copyright 2009 by Medical Information Science Reference (an imprint of IGI Global).

Chapter 3.11

Using Object Oriented Technologies to Build Collaborative Applications in Healthcare and Medical Information Systems

A. Dwivedi
University of Hull, UK

R.K. Bali
BIOCORE, Coventry University, UK

Nilmini Wickramasinghe
Illinois Institute of Technology, USA

R.N.G. Naguib
BIOCORE, Coventry University, UK

INTRODUCTION

The adoption and diffusion of e-health and the application of IT in healthcare is increasing at a rapid rate. Both European and U.S. governments are making e-health a priority on their agendas. The technical infrastructure required to support initiatives such as community healthcare integrated networks (CHINs) and telemedicine efforts is often dependent upon connecting different types of computer networks, each running on different types of technologies so as to present to the user the image of a single virtual electronic health highway. It is generally agreed that current software development technology cannot deliver this due to limitations of restricted scalability, fragmented management, and inflexibility in providing business support.

One of the potential solutions may be the use of Object Oriented (OO) technology. This article explores the feasibility of combining OO technologies with healthcare based workflow management systems (WFMS). We introduce the concept of workflow technologies and discuss the main advantages and limitations of WFMS. We detail the circumstances in which the use of WFMS could be considered and the technological factors necessary for its successful implementation.

DOI: 10.4018/978-1-59904-889-5.ch168

We also present an Object Management Group (OMG) model, analysing it in the context of the support offered for WFMS. The main advantages and disadvantages of the model are discussed. A workflow management coalition (WFMC) model is then contrasted with the OMG management model in order to identify the architectural differences between them. We focus on the relationship between workflow concepts and the position of the two reference models (WFMC and OMG) and on the use of UML in the design of information systems. We conclude by summarizing our findings on the extent to which OO technology can be used to build collaborative applications in healthcare and medical information systems.

BACKGROUND

During his State of the Union Address in January 2004, President George Bush affirmed the intention of the government to emphasize the role of technology in administration and delivery of healthcare in the United States (Bush, 2004). Similar sentiments have been voiced by the European leaders (Global Medical Forum Foundation, 2005; The Oslo Declaration on Health, 2003), and the World health organization ("E-Health in Eastern Mediterranean," 2005; A Health Telematics Policy, 1997). Both European and U.S. authorities define their initiatives primarily in terms of medical information technology centering on computerized patient record (CPR) or, in more acceptable parlance, the electronic health record (EHR). See Brailer and Terasawa (2003).

WHO's platform statement (A Health Telematics Policy, 1997) speaks of "health telematics policy," an all inclusive term that incorporates not only EHR but essentially all healthcare services provided at a distance and based on the use IT.

While implementation of these concepts is preeminently realistic in the context of EU and the U.S.A., the WHO plan appears, for many reasons, a combination of a list of good ideas and delineation of significant obstacles that make the good ideas seem almost futuristic. In response to the inefficiency of the highly fragmented programs to address even the most urgent aspects of healthcare across the globe, a demand for the development of a new rule set (Banjeri, 2004; Barnett, 2004; Olutimayin, 2002; Onen, 2004) governing the future actions began to emerge—the quest for the "doctrine of global health."

To address this void, von Lubitz and Wickramasinghe developed the doctrine of "networkcentric healthcare" (von Lubitz & Wickramasinghe, 2006a, 2006b, 2006c), which calls for the development of interconnected information grids that, together, constitute a powerful and well-structured network that facilitates information sharing among all participants within the operational continuum (Cebrowski & Garstka, 1998; Stein, 1998). Consequent to improved information sharing is the enhancement of its quality and integrity which, in turn, escalates the level of situational awareness that is the foundation for efficient, real-time collaboration among the involved entities, their self-synchronization, and operational sustainability which leads to a dramatic increase in mission effectiveness (Cebrowski & Garstka, 1998).

As described by von Lubitz and Wickramasinghe (2006a, 2006b, 2006c), networkcentric healthcare operations must be conducted within the intersecting territory of three mutually interconnected and functionally related domains (Garstka, 2000):

- The *physical domain* which encompasses the structure of the entire environment healthcare operations intend to influence directly or indirectly, for example, elimination of disease, fiscal operations, political environment, patient and personnel education, and so forth.
- The *information domain* which contains all elements required for generation, storage, manipulation, dissemination/sharing of information, and its transformation and

dissemination/sharing as knowledge in all its forms. It is here that all aspects of command and control are communicated and all sensory inputs gathered.

- The *cognitive domain* relates to all human factors that affect operations, such as education, training, experience, political inclinations, personal engagement (motivation), "open-mindedness," or even intuition of individuals involved in the relevant activities. Difficulties in metrics relevant to the cognitive domain notwithstanding, a body of experimental studies begins to emerge that will, ultimately, provide close quantitative relationships to other domains that govern healthcare operations space (Abel-Smith, 1989; Back & Oppenheim, 2001; Bodner et al., 1986; Newby, 2001; Roberts & Clifton, 1992; Wetherell et al., 2002).

The essential and enabling technology element of NCHO is the Worldwide Healthcare Information Grid (WHIG) that allows full and unhindered sharing of information among individual domains, their constituents, and among constituents across the domains (von Lubitz & Wickramasinghe, 2006a, 2006b, 2006c). In order to perform such a function, the WHIG must consist of an interconnected matrix of ICT systems and capabilities (including communication platforms, data collection, storage, manipulation/dissemination, and sharing), associated processes (such as information and knowledge storage and retrieval, management and their dissemination/sharing), people (e.g., healthcare providers/investigators, administrators, economists, politicians, lawyers, ICT personnel), and agencies (governmental and Non-Governmental Organizations or NGSs) at local/national/international level.

However, von Lubitz and Wickramasinghe have not detailed the technological make up of the WHIG which is the backbone of NCHO. We contend that the ultimate use of Object Oriented (OO) technologies as we discuss in this article will be to provide the technological backbone to such initiatives as NCHO or smaller scale initiatives such as community healthcare integrated networks (CHINs) or e-health and telemedicine applications. To fully appreciate the power and benefits that OO technologies bring to effecting superior healthcare delivery, it is necessary first to understand the evolution of IT applications in healthcare and the key challenges to date.

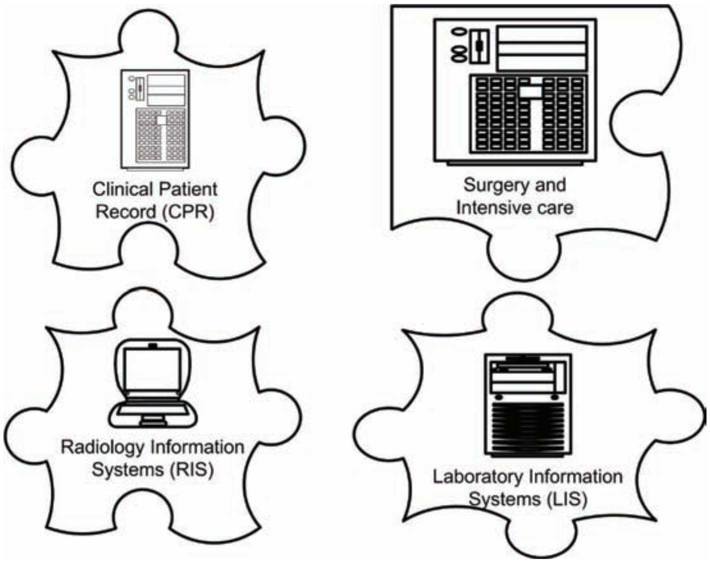
EVOLUTION OF IT APPLICATIONS IN HEALTHCARE

In the 1970s, the focus of IT applications in healthcare was to facilitate better healthcare administration, particularly in routine administrative tasks such as the calculation of patient charges for reimbursement . In the 1980s, the focus shifted to the development of clinical systems to aid in patient diagnosis and treatment (Johns, 1997; Rao, 2001). This trend continued until the late 1990s. A distinguishing feature of this trend was that most of the IT applications in healthcare were developed for very specific uses such as standalone software applications (Rao, 2001). This lack of interoperability has today become a significant challenge for the healthcare sector.

Simultaneously, in the last 40 years, there has been a significant evolution in system architectures that form the substrate of IT applications. Organizations have evolved from a centralised to a distributed computing architecture (Ganti & Brayman, 1995). This change of emphasis in system architectures has been accompanied by the emergence of client/server and object oriented (OO) technologies. By the 1990s, these two technologies had signalled the coming of age of the distributed computing architecture (Ganti & Brayman, 1995).

Modern IT applications have evolved to provide basic support for services to aid knowledge processing, problem-solving, and coordination by incorporating concepts such as intelligent design

Figure 1. Limited interfaces between IT healthcare apps



systems, workflow management, and intelligent agents (Ganti & Brayman, 1995). These changes (i.e., evolution from a centralised to a distributed computing architecture technologies) have had implications on the healthcare sector. Even IT applications in healthcare have undergone a drastic change (Ohe, 1998; Pollard & Hammond, 1998; Rao, 2001).

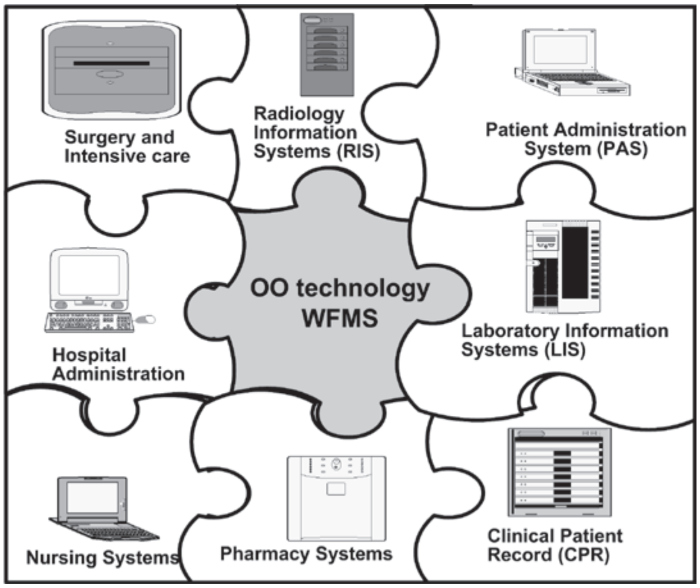
In the centralised computing architecture, IT applications in healthcare were characterised by being written in a proprietary language, specifically made to function on a particular hardware platform, and, most importantly, had very limited interfaces (connections, ability to communicate) with other healthcare information systems (clinical, diagnostic, etc.) (see Figure 1). Moreover, they did not have to ability to interconnect with common desktop applications (word processing, etc.).

This lack of interoperability between different but related healthcare systems (see Figure 1) has been cited as one of the main challenges facing the healthcare sector (Ferrara, 1998; Greenberg & Welcker, 1998; Harrington, 1993). This problem has been further aggravated by the advent of modern IT applications in healthcare that are centred on the power of the Internet (Egger, 2000; Weber, 1999).

The use of OO technologies in conjunction with protocols such as the HyperText Transport Protocol (HTTP) and the Wireless Application Protocol (WAP), with devices such as Personal Digital Assistant (PDA), have allowed patients and doctors to remain in close contact (Dwivedi, Bali, James, & Naguib, 2001; Farkas, 1999; Pollard & Hammond, 1998). These new technologies (OO, HTTP, and WAP) have collectively triggered the connectivity revolution in healthcare. Simultaneously, these new technologies have been accompanied by a revolution in medical electronics and human genome research. It is estimated that in the next 10 years, more then 100,000 medical devices will be launched in the healthcare sector (Egger, 2000).

Advances in the application of computer technology have largely driven the biomedicine revolution in the healthcare industry. As a result of the above revolution, modern day healthcare industry is witnessing "the emergence and proliferation of entire new scientific disciplines—

Figure 2. Vision of an integrated healthcare system in the new millennium



molecular biology, economics, bioinformatics and proteomics—which are revealing the secrets of genes, proteins and their functions" (Watanabe, 1999, p. 27). This has implications for the healthcare process.

Advances in pharmaceutical developments will in turn be driven largely by these new scientific disciplines. Our understanding of the human genome could result in the discovery of new treatments based on new pharmaceutical compounds. It has been estimated that in the near future new pharmaceutical compounds could replace 50% of today's in-patient services (Egger, 2000). It is clear that the healthcare system of the new millennium will be computing based and would revolve around Information Technology (Egger, 2000).

The benchmark for survival for healthcare institutions in the future will shift from the current emphasis on "facilities, range of services,or clinicians associated with the organization" to the "experience that the healthcare institution has in providing that care" (Egger, 2000, p. 22), which in turn would require an effective integration of all the different systems associated with healthcare treatment, diagnosis, and delivery. The vision of the healthcare system of the new millennium is one where all the different information systems relating to healthcare delivery are connected seamlessly and appear to the user as a virtual system, see Figure 2 (Johns, 1997; Mercer, 2001).

Object Oriented Technology (OOT) and Workflow Management Systems (WFMS) are the two most promising technologies that stand out from the entire set of all the technologies that can provide a seamless integration for a virtual healthcare system for the future (see Figure 2). We contend that these two technologies, in combination, hold the potential of transforming the vision of the healthcare system of the new millennium into a reality. As mentioned earlier, one of the biggest paradigm shifts in computing was the evolution of system architectures from centralised computing architecture to a distributed computing architecture. This paradigm shift brought out to the forefront the enabling power of client/server computing (Khanna, 1994).

Table 1. Evolution of client/server with OOT

<table>
<tr><th></th><th>1982</th><th>1986</th><th>1990</th><th>1995</th><th>1998 +</th></tr>
<tr><td>First Wave</td><td colspan="2">File Servers</td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">Second Wave</td><td></td><td colspan="3">Database Servers</td><td></td></tr>
<tr><td></td><td></td><td colspan="2">Groupware</td><td></td></tr>
<tr><td>Third Wave</td><td></td><td></td><td></td><td colspan="2">Distributed Objects</td></tr>
</table>

EVOLUTION OF OOT

One of the main reasons for the popularity of the client/server revolution is the sharing of data, applications, and the processing power between different clients and the server, thereby improving the efficiency of the system. OOT, and in particular distributed objects, are likely to be the driving force that will transform the vision of an integrated distributed computing architecture into reality; see Table 1 (Orfali, Harkey, & Edwards, 1996).

OOT is a software development methodology that uses a commonly accepted body of knowledge that includes notation diagrams to represent the design of a software application. One of the main advantages of adopting the OO methodology is that it reduces the software development cycle; it offers support in extending the application further by allowing reuse of existent software components.

In addition to the above, OO methodology offers more flexibility in building and interfacing the proposed /existing application with other applications. This not only makes it easier to maintain software applications produced under the OO methodology, but also substantially reduces the cost of software development (Athwall & Moreton, 1995).

Prior to the mid 1980s, all the major types of Hospital Information Systems (HIS) were based on the centralized computing architecture (Khanna, 1994; Ohe, 1998). These legacy HIS used to consist of a number of powerful mainframes which were linked to a very large number of dumb terminals (Ohe, 1998).

One of the main problems in the 1990s was how to utilise these legacy systems with the modern HIS. This gave impetus to the need for having a computing architecture that enabled coordination between different resources (hardware and software) that was available on a network, and the concept of the distributed computing architecture that could enable the above to become a reality (Khanna, 1994).

DISTRIBUTED COMPUTING BASED CLIENT/SERVER ARCHITECTURE

One of the main disadvantages of early client/server technologies was that there was a clear separation between the two, resulting in the creation of two monoliths instead of one (Orfali et al., 1996). Any vision of a healthcare system in the new millennium would feature knowledge-intensive applications. These applications would evolve from a convergence of digital and multimedia technologies and all of which are likely to run a large number of heterogeneous, autonomous, and distributed information systems (Tsiknakis, Chronaki, Kapidakis, Nikolaoul, & Orphanoudakis, 1997).

This poses severe limitations for existing client/server applications, most of which are based on old technologies (see Table 1). Distributed objects are being regarded as a technology that holds a lot of potential in empowering client/server applications to deal with the challenge of repeatedly integrating a large amount of multimedia clinical data from a wide number of heterogeneous, autonomous, and distributed HIS within a very limited time span (Orfali et al., 1996; Tsiknakis et al., 1997).

Distributed objects through the use of components can achieve the above by subdividing today's monolithic client/server applications into self-managing components that can interact with each other and move across networks and operating systems (Orfali et al., 1996). Distributed objects take full advantage of having the data and business logic which is encapsulated within them to interact with other (old) legacy applications via object wrappers (Orfali et al., 1996). This makes the system more flexible as it takes full advantage of the concept of modularity in software development.

DEFINITION AND INTERRELATIONSHIP BETWEEN DISTRIBUTED OBJECTS AND COMPONENTS

Distributed objects can be defined as an independent piece of created code that is visible to other remote clients irrespective of the language and compiler used to create it. It has the ability to be accessed by other remote clients via method invocation. To put it in simple terms, a distributed object is a blob of intelligence that can live anywhere on the network and which can message each other transparently (Orfali et al., 1996).

There is no precise definition of the term component as it represents diverse features depending upon the perspective taken. However, any definition of components must include the fact that it is a reusable piece of software that is independent of any application (Orfali et al., 1996). Components can be a black box (i.e., they support polymorphism and encapsulation but not inheritance) or white box that supports all three mentioned concepts of traditional objects (Orfali et al., 1996).

A broad overview of the relationship between components and objects could be verbalised to state that each component is an object that is not bound to a particular program, computer language, or implementation (Orfali et al., 1996). The interrelationship between distributed objects and components is that all distributed objects are components but not all components are objects or distributed objects, for example, OLE and black box components (Orfali et al., 1996). This is because components have synergistically evolved from three paradigms (1) the distributed computing architecture, (2) the client/server revolution, and (3) the OO revolution.

Components are different from traditional objects in the sense that components are standalone objects that can plug-and-play across networks, applications, languages, tools, and operating systems (Orfali et al., 1996). As each component has its own intelligence and data, the use of components would allow developers and users to create applications on the fly very easily. Moreover, by using components based on distributed objects on a client/server platform, it is possible to very simply build a large number of customised software applications. The use of components represents the ultimate form of client/server distribution and in the near future almost all desktops would be using client/server distribution (Orfali et al., 1996).

If we look at the evolution of database management systems (DBMS) in the context of their suitability for multi-user support whilst handling complex data types, the following picture emerges (see Table 2) (Connolly & Begg, 1998).

A previous study has noted that almost all modern day HIS are based on traditional relational database systems. However, it has been acknowledged that relational database systems cannot deal with the large volumes of clinical data that come in different formats (audio, video, images, and multimedia) (Farkas, 1999). This study examined both extended relational and object relational databases (see Table 2) and on their ability to

Table 2. Evolution of DBMS

Search capabilities/multi-user support.	Relational DBMS	Object Relational DBMS
	File Systems	Object Oriented DBMS
	Data complexity/ extensibility	

store and access clinical data that is multimedia in nature, and come to the conclusion that in a HIS context, object-oriented databases is the best solution (Farkas, 1999). All the existing HIS use client/server technology with the server running a traditional relational database that cannot store and supply multimedia data (X-ray images, etc.) effectively, while their client side often uses peculiar user interfaces that are difficult to govern and are usually not platform independent (Farkas, 1999). The main rationale behind a relational database application is that it establishes modularity between data—modularity which is not established not because it is an essential requisite, but only because it makes the system easier to implement and manage (Farkas, 1999).

WFMS

A Workflow Management System (WFMS) is an ideal software application that assists in the processing of tasks. At a basic level, workflow can be thought of as a series of actions that help in the automation of tasks.

Since workflow refers to a series of tasks, it implicitly refers to scheduling or routing (i.e., which is the best possible way of performing a particular group of tasks). Since it refers to tasks which have to be performed, it would require responsibility at a basic level. Thus a workflow model can be thought to be a value adding process which is carried out in an efficient and effective manner with clear responsibilities for each of the participants in the process (Workflow Management Coalition, 1995). The WFMS uses process instances to instantiate each business process, and each process instantiation represents a workflow. This gives the WFMS the facility of having several workflows of the identical business process, at the same time. This means that each of them (each process instantiation) can act in a different manner. The advantages here are comparable to the advantages given by multitasking and object orientation (Workflow Management Coalition, 1999).

The Workflow Management Coalition (WFMC) (1995) have provided a Workflow Reference Model (WRM) that has the following five main interfaces:

1. **Process definition tools:** This interface provides specifications for process definition data and interchange.
2. **Other workflow enhancement services:** This interface provides support for interoperability between different workflow systems.
3. **Invoked applications:** This interface provides support for interaction with a variety of IT application types.
4. **Workflow client applications:** This interface provides support for interaction with the user via desktop functions.
5. **Administration and specifications for process definition and data interchange:** This interface provides support for system monitoring and metric functions to facilitate the management of composite workflow application environments.

One of the main weaknesses of the WRM model recommended by the WFMC is that it does not support workflow implementation "across a heterogeneous, distributed infrastructure" (Santanu, Edwin, & Jarir, 2001).

This drawback forces the workflow system architecture to be a client/server system architecture where all the main workflow services are run from the workflow server and, as such, it becomes "monolithic" and "centralised." The main disadvantage of the centralised workflow system architecture is that it "does not address the needs of distributed workflows on a WAN" and thereby prevents the workflow to function in a distributed manner (Santanu et al., 2001). This is a very serious drawback, particularly considering that the future of workflows is connected with the Web or, at minimum, across multiple sites.

The Object Management Group (OMG) is an international body whose objective is "to promote the theory and practice of OOT" by establishing industry standards (Athwall & Moreton, 1995). OMG has challenged the WRM by providing its own version of workflow systems.

The OMG architecture uses CORBA as middleware (a software that helps in assuring client/server communications) that enables distributed objects to cooperate. The OMG architecture uses Object Request Brokers (ORBs) to provide the basic functionality for establishing communication between objects.

This is achieved via two interfaces: (1) the application specific interface and/or (2) the Domain interface. All the CORBA facilities given by the OMG can be classified into: (1) Object services (OSs), which are families of system services, that are universal and have standardised interfaces, and (2) Common Facilities (CFs), which specify the specific services for a particular application domain (e.g., healthcare) (Pollard & Hammond, 1998). In the OMG model, workflow is a part of its CORBA facilities and falls under common facilities (Leymann & Roller, 2000).

The main difference between these two models is that, under the WFMC model, the workflow engine has a centralist character, while in the OMG architecture workflows are just objects. The WFMC model uses five interfaces whilst the OMG model uses just objects, thus fully exploiting the CORBA facilities (both object services and common facilities).

FUTURE TRENDS

Modern day healthcare organizations have realised that in the future their survival would depend upon their ability to give the caregiver access to such information that would enable the caregiver to deliver personalised clinical diagnosis and treatment in real-time in very specific clinical contexts (a process termed as Information Therapy). Information therapy is defined as the "prescription of specific, evidence-based medical information to a specific patient, caregiver, or consumer just in time to help someone make a specific health decision or behaviour change" (Kemper & Mettler, 2002, p. 17). This vision has been translated into concepts like Integrated Delivery System (IDS) and Community Health Information Networks (CHIN) (Lang, 1997; Mercer, 2001; Morrissey, 2000).

IDS refers to a HIS that is a business model based on computing technologies such as OO "to share key data, with partners and providers, that will allow faster and more accurate decision making… to deliver care to a broader population with fewer requirements for expensive and scarce resources" (Lang, 1997, p. 18). CHINs are integrated HIS based upon a combination of different technology platforms that are connected to enable support for data sharing amongst different healthcare providers (Mercer, 2001).

Both IDS and CHIN are very similar in nature and both refer to an integrated network for allowing the delivery of personalised healthcare. We argue that in the near future component technology would be the driving force behind all HIS as it would support new ways of combing islands of knowledge, and present the knowledge acquired to the user as an integrated whole. In addition to the above, component technology would also provide support for the use of modern computer techniques (such as Intelligent Data Mining tools, WFMS) to discovering previously undiscovered patterns on a case-to-case basis, thereby bringing to the fore a truly integrated healthcare system that supports delivery of personalised healthcare.

On a grander, global scale, such component technology and the integral role for the OO-platform we have discussed is essential in supporting networkcentric healthcare operations (NCHO) as outlined by von Lubitz and Wickramasinghe (2006a, 2006b, 2006c). The constructing of NCHO is clearly a large task that requires to coordination of several players at a global level. However, the WHIG (as discussed earlier), the world healthcare information grid and backbone of NCHO, cannot be constructed without utilising these component technologies and OO platform. To date actualising the structure of the WHIG has not been discussed.

We contend that the ultimate use of Object Oriented technologies for healthcare as we have discussed in this article will be to provide the technological backbone to such initiatives as NCHO. NCHO represents the new paradigm for healthcare delivery while the OO technologies coupled with the WFMC model is an essential enabling criterion and critical success factor fore realising superior healthcare delivery.

CONCLUSION

Old legacy HIS were predominantly used to allow computerization of information to aid in providing financial information and to assist the healthcare managers in having centralized control over different healthcare activities (Lang, 1997).

Healthcare institutions in the 1990s have realized that the old model does not work as the nature of information required is different. Contemporary healthcare institutions are under ever-increasing pressure to find new ways of reducing healthcare costs whilst simultaneously increasing administrative and clinical efficiency to provide a superior level of quality relating to patient care (Carlos & Comaford, 1998). Modern day HIS have a number of clinical information systems each of which is committed to diverse healthcare providers (nurses, doctors, etc.) in different clinical disciplines (radiology, surgery, etc.) to effectively ensure coordination among these necessitates the integration of hospital-wide available information (Tsiknakis et al., 1997).

There is an increasing realization that an integrated HIS is an infrastructure prerequisite if healthcare institutions are to successfully meet the above mentioned challenge (Farkas, 1999; Ohe, 1998; Pollard & Hammond, 1998; Tsiknakis et al., 1997). The old model of HIS cannot meet the above challenge as the old legacy HIS running monolithic computing applications based upon centralized computing architecture cannot ensure an integrated HIS (Lang, 1997; Tsiknakis et al., 1997).

The distributed computing architecture is the only means of providing the integration between different heterogeneous systems that are autonomous and distributed (Lang, 1997; Pollard & Hammond, 1998; Tsiknakis et al., 1997). Another factor which holds a lot of potential in ensuring that the vision of an integrated HIS becomes a reality is the Unified Modelling Language (UML). Developed by the OMG, UML is a graphical and object-oriented notation methodology for describing processes in a form that helps both developers and users (Botelho, 2000a, 2000b). The advent and acceptance of UML as the defacto industry standard has made possible a standard way to depict graphically the design of an information system that can be understood by all the stakeholders at any stage of the software development cycle (Botelho, 2000b). Despite being of OMG specification, UML is independent of any middleware technology, that is, OMG's-CORBA, Microsoft's Component Object Model (COM), and Sun's Enterprises JavaBeans (EJB) (Sutherland, 1998). It is clear that, in the new millennium, an innovative approach would have to be adopted to ensure that the vision of a virtual integrated HIS becomes a reality. We conclude by reiterating that the current gap between different islands of heterogeneous HIS can be bridged if the technologies discussed above (OO, Component Technology, Distributed Computing, WFMS, and UML) are concurrently adopted.

REFERENCES

Abel-Smith, B. (1989). Health economies in developing countries. *The Journal of Tropical Medicine and Hygiene*, *92*, 229–241.

Athwall, A. K., & Moreton, R. (1995). Use of object-oriented technology in healthcare. In B. Richard (Ed.), *Current perspective in healthcare computing* (Vol. 2, pp. 583-584).

Back, J., & Oppenheim, C. (2001). A model of cognitive load for IR: Implications for user relevance feedback interaction. *Information Res.*, *2*. Retrieved from http://InformationR.net/ir/6-2/ws2.html

Banjeri, D. (2004). The people and health service development in India: A brief overview. *International Journal of Health Services*, *34*, 123–142. doi:10.2190/9N5U-4NFK-FQDH-J46W

Barnett, T. P. M. (2004). *The Pentagon's new map*. New York: G.P. Putnam (pp. 1-435).

Bodner, G. M., & McMillen, T. L. B. (1986). Cognitive restructuring as an early stage in problem solving. *Journal of Research in Science Teaching*, *23*, 727–737. doi:10.1002/tea.3660230807

Botelho, J. (2000a). The latest look in systems management. *Telephony*, *238*(23), 252–258.

Botelho, J. (2000b). The object-ive viewpoint. *Telephony*, *239*(19), 74–80.

Brailer, D. J., & Terasawa, A. B. (2003). *Use and adoption of computer-based patient records.* California Healthcare Foundation (pp. 1-42).

Bush, G. (2004). State of the Union Address, The White House. Retrieved February 4, 2008, from http://www.whitehouse.gov/news/release/2004/01/20040120-7.html

Carlos, L. G., & Comaford, K. M. (1998). *Future trends in healthcare enterprise-wide knowledge distribution.* Paper presented at the Annual Conference of Healthcare Information and Management Systems Society (pp. 231-242).

Cebrowski, A. K., & Garstka, J. J. (1998). Network-centric warfare: Its origin and future. *U.S. Nav. Inst. Proc.*, *1*, 28–35.

Connolly, T. M., & Begg, C. E. (1998). *Database systems: A practical approach to design, implementation, and management.* Harlow: Addison-Wesley.

Dwivedi, A., Bali, R. K., James, A. E., & Naguib, R. N. G. (2001). *Workflow management systems: The healthcare technology of the future?* Paper presented at the 23rd Annual International Conference of the IEEE - Engineering in Medicine and Biology Society (EMBS), Istanbul, Turkey (pp. 3887-3890).

E-health in the eastern Mediterranean, WHO-EMRO. (2005). Retrieved February 4, 2008, from http://www.emro.who.int/his/ehealth/ehealthPlan.htm

Egger, E. (2000). Market memo: How technology is changing the healthcare system. *Health Care Strategic Management*, *18*(1), 1, 20–23.

Farkas, Z. (1999). Internet technologies in hospital information systems. *Internet Research*, *9*(2), 3.

Ferrara, F. M. (1998). The CEN healthcare information systems architecture standard and the DHE middleware. A practical support to the integration and evolution of healthcare systems. *International Journal of Medical Informatics*, *48*(1-3), 173–182. doi:10.1016/S1386-5056(97)00123-8

Ganti, N., & Brayman, W. (1995). *The transition of legacy systems to a distributed architecture.* New York: Wiley.

Garstka, J. J. (2000). Network centric warfare: an overview of emerging theory. *Phalanx*, *4*, 28–33.

Global Medical Forum Foundation. (2005, April 4-6). *GMF IV: New frontiers in healthcare.* Retrieved February 4, 2008, from http://www.globalmedicalforum.org/gmf_iv/session3.asp

Greenberg, D. S., & Welcker, B. (1998). Active X based standards for healthcare integration. *International Journal of Medical Informatics*, *48*(1-3), 183–190. doi:10.1016/S1386-5056(97)00124-X

Harrington, J. (1993). *Recommendations for an object oriented healthcare information model.* Paper presented at the Progress in Standardization in Healthcare Informatics (pp. 52-59).

A health telematics policy in support of WHO's health-for-all strategy for global health development: Report of the WHO group consultation on health telematics. (1997, December 11-16). World Health Organization, Geneva, 1998

Johns, P. M. (1997). Integrating information systems and healthcare. *Logistics Information Management*, *10*(4), 140–145. doi:10.1108/09576059710187555

Kemper, D. W., & Mettler, M. (2002). Information therapy: A tale. *Health Forum Journal*, *45*(1), 16–20.

Khanna, R. (1994). *Distributed computing: Implementation and management strategies*. Englewood Cliffs, NJ: Prentice Hall.

Lang, R. D. (1997). The promise of object technology: What's in it for healthcare? *Journal of Healthcare Resource Management*, *15*(10), 18–21.

Leymann, F., & Roller, D. (2000). *Production workflow: Concepts and techniques*: Prentice-Hall International.

Mercer, K. (2001). Examining the impact of health information networks on health system integration in Canada. *Leadership in Health Services*, *14*(3), 1–30. doi:10.1108/13660750110399928

Morrissey, J. (2000). The evolution of a CHIN. *Modern Healthcare*, 42.

Newby, G. B. (2001). Cognitive space and information space. *Journal of the American Society for Information Science and Technology*, *12*, 1026–1048. doi:10.1002/asi.1172

Ohe, K. (1998). *A hospital information system based on common object request broker architecture (CORBA) for exchanging distributed medical objects - an approach to future environment of sharing healthcare information.* Paper presented at the MEDINFO 98, Amsterdam.

Olutimayin, J. (2002). Communication in healthcare delivery in developing countries: Which way out? *Pacific Health Dialog*, *9*, 237–241.

Onen, C. L. (2004). Medicine in resource-poor settings: Time for a paradigm shift? *Clinical Medicine (London, England)*, *4*, 355–360.

Orfali, R., Harkey, D., & Edwards, J. (1996). *The essential distributed objects survival guide.* New York: Wiley.

Pollard, D. L., & Hammond, W. E. (1998). *Object technology: Raising the standards for healthcare information systems.* Paper presented at the MED-INFO 98, Amsterdam (pp. 217-221).

Rao, S. S. (2001). Integrated healthcare and telemedicine. *Work Study*, *50*(6), 222–228. doi:10.1108/EUM0000000006034

Roberts, L. W., & Clifton, R. A. (1992). Measuring the cognitive domain of the quality of student life: An instrument for faculties of education. *Canadian Journal of Education*, *2*, 176–191. doi:10.2307/1495319

Santanu, P., Edwin, P., & Jarir, C. (2001). *Essential requirements for a workflow standard*. Retrieved February 4, 2008, from http://www.jeffsutherland.org/oopsla97/santanu.html

Stein, P. (1998). *Observations on the emergence of network centric warfare*. Retrieved February 4, 2008, from http://www.dodccrp.org/research/ncw/stein/_ observations/steincw.htm

Sutherland, J. (1998). Why I love the OMG: Emergence of a business object component architecture. *ACM StandardView*, *6*(1), 4–13. doi:10.1145/293376.293382

The Oslo declaration on health, dignity and human rights. (2003). 7th Conference of European Health Ministers, Oslo, Norway, June 12-13, 2003. Retrieved February 4, 2008, from http://odin.dep.no/hod/norsk/aktuelt/taler/monister/042071-990209/dpk-bn.html

Tsiknakis, M., Chronaki, C. E., Kapidakis, S., Nikolaoul, C., & Orphanoudakis, S. C. (1997). An integrated architecture for the provision of health telematic services based on digital library technologies [Special issue on digital libraries in medicine]. *International Journal on Digital Libraries*, *1*(3), 257–277. doi:10.1007/s007990050021

von Lubitz, D., & Wickramasinghe, N. (2006a). Healthcare and technology: The doctrine of networkcentric healthcare. [IJEH]. *International Journal of Electronic Healthcare*, *4*, 322–344.

von Lubitz, D., & Wickramasinghe, N. (2006b). Networkcentric healthcare: Outline of the entry portal concept. *International Journal of Electronic Business*, *1*(1), 16–28.

von Lubitz, D., & Wickramasinghe, N. (2006c). Networkcentric Healthcare and bioinformatics. *Intl J. Expert Systems*, *30*, 11–23. doi:10.1016/j.eswa.2005.09.069

Watanabe, A. M. (1999). Living with innovation: Issues for medicine in the 21st century. *Executive Speeches*, *14*(3), 26–31.

Weber, D. O. (1999). Web sites of tomorrow: How the Internet will transform healthcare. *Health Forum Journal*, *42*(3), 40–45.

Wetherell, J. L., Reynolds, C. A., Gatz, M., & Pedersen, N. L. (2002). Anxiety, cognitive performance, and cognitive decline in normal aging. *J. Gerontol (B) . Psych. Sci. and Soc. Sci.*, *57*, 246–255.

Workflow Management Coalition. (1995). *The workflow reference model*. Retrieved February 4, 2008, from http://www.wfmc.org/standards/docs/tc003v11.pdf

Workflow Management Coalition. (1999). *The workflow management coalition terminology & glossary* (Document No. WFMC-TC-1011). Retrieved February 4, 2008, from http://www.wfmc.org/standards/docs/TC-1011_term_glossary_v3.pdf

KEY TERMS

CHINs: Community healthcare integrated networks.

E-Health: The use of Internet-based technologies to facilitate healthcare delivery.

Object Oriented (OO) Technology: Technologies that support/utilise object oriented programming.

Telemedicine: The aiding of medical support from a distance via technology.

Workflow Management System (WFMS): Systems that support effective and efficient workflow.

This work was previously published in Encyclopedia of Healthcare Information Systems, edited by N. Wickramasinghe; E. Geisler, pp. 1338-1348, copyright 2008 by Medical Information Science Reference (an imprint of IGI Global).

Chapter 3.12

Collaborative Virtual Environments and Multimedia Communication Technologies in Healthcare

Maria Andréia F. Rodrigues
Universidade de Fortaleza, Brazil

Raimir Holanda Filho
Universidade de Fortaleza, Brazil

ABSTRACT

This chapter shows how recent computing technologies such as collaborative virtual environments, high speed networks and mobile devices can be used for training and learning in healthcare providing an environment with security and quality of service. A number of studies have been conducted so far in these research areas. However, the development of integrated care has proven to be a difficult task. Therefore, we aim also to discuss the promising directions of the current work and growing importance on these subjects. This includes comparative analysis of the most relevant computer systems and applications developed so far that integrate modern computing technologies and health care. We believe this work is considered to be primarily for the benefit of those who are working in the field of computer science and health care, as well academic community, practitioners, and those involved in the development, implementation and study of integrated care using new computing technologies.

DOI: 10.4018/978-1-60566-002-8.ch028

INTRODUCTION

In this chapter, we investigate how recent computing technologies such as collaborative virtual environments (CVEs), high speed networks and mobile devices can be used for training and learning in healthcare providing an environment with security and quality of service (QoS).

In our view, there is a considerable gap between the promises that the new computing technologies hold, and the expectations that they cause in the medical area, particularly, in the simulation and training of surgical procedures. The evidences indicate that these expectations should be fulfilled in the next few years. This partnership will require the improvement of several computational technologies (storage devices, high-speed networks, distributed systems for mobile environments, etc), as well as changes in the background of health professionals before their routine adoption. New areas of interdisciplinary research can emerge, such as multimedia surgical support, interventional radiology, and even less invasive surgical procedures. The development of system architectures utilizing new computing technologies that support interactive computer graphics and CVEs is another growing necessity. Examples are computer systems developed to support virtual training and learning, which are becoming more and more realistic (Blezek et al., 2000; Hosseini & Geordanas, 2001; Dev et al., 2002; Gunn et al., 2005a; DiMaio & Salcudean, 2005; Lee et al., 2006; Rodrigues et al., 2007). Some of these systems are used to construct a virtual world where users (trainer and trainees) can interact with one another and the environment in which they preside when performing training exercises.

Nowadays, geographically distributed computing technologies can be interconnected to create an integrated computing environment. Healthcare professionals in different places can collaborate using this environment. Collaborative virtual environments involve several participants working in a network, using a shared virtual environment to analyze the same object from different points of view, and in which the action of any participant is viewed by all others sharing the environment. In order to make communications more realistic the environment must supply voice, video and data multimedia applications. This will favor comprehension of the actual intent of each participant, thus improving the collaborative environment.

Networked computers and corresponding applications facilitate collaboration activities through a constellation of various tools (such as shared spaces, whiteboards, etc) having appropriate approaches to collaboration and social interactions. A World Wide Web tem proporcionado uma plataforma comum para que pessoas em qualquer parte do mundo possam interagir. Com o incremento do uso de dispositivos móveis, abre-se um vasto campo para novas pesquisas especialmente nas áreas de redes sem fio e colaboração distribuída. O aumento da disponibilidade de facilidades de comunicação tem provocado uma mudança no conceito de utilização de inúmeras aplicações, uma vez que dispositivos móveis possuem um comportamento diferente e oferecem possibilidades de interação diferentes, dependendo do contexto em que a aplicação está sendo usada. Para analisar estes diferentes cenários, muito esforço tem sido direcionado em pesquisas para mitigar possíveis ataques e para prover padrões mínimos de qualidade de serviço.

The World Wide Web has provided a collective platform where people in any part of the globe can interact. The increasing number of mobile devices in use has opened a vast field for new research, especially in the areas of wireless networks and distributed collaboration. The increase in availability of communications facilities has brought about changes in the concept of use of many applications, considering that mobile devices have a different behavior and offer different possibilities of interaction, depending on the context in which the application is being used. In order to analyze these different settings, a lot of effort has been directed to researches in mitigating possible attacks, and providing minimum standards of QoS.

Our discussion will also focus on recent wireless network technologies (Sharma & Nakamura, 2004) and mobility facilities (Pesch et al., 2007) that are highly recommended for the development of CVEs. One of the benefits of wireless data communication is the possibility of exchanging real-time messages among patients and medical staff. Wireless handhelds are becoming simple, direct and efficient communication paths with great potential for facilitating the access and flow of information. These new computing technologies are also important to be taken into account to provide better working conditions in the health area.

Finally, as consequence of the use of patient data, further attention is important to provide a secure network environment, specifically in the cases where wireless connections are used. In this scenario, authentication, authorization and cryptography procedures (Stallings, 2005) are mandatory to mitigate unauthorized users to get access to information, and to hinder data capture in promiscuous mode. Another relevant topic is to supply a network environment with minimum QoS guarantees for voice and video traffic (Ash, 2006). In this case, some network parameters such as delay and jitter are very important to assure QoS. Moreover, the traffic of huge image files should also be controlled in order not to affect real-time traffic classes.

Hence, the key to achieving all these requirements on current technology is to pay more attention to applications that aim at assisting in bridging the gap between theoretical workers in the medical field and those scientists involved in handling and simulating true life problems. In so doing, the former should be able to better identify the objective towards which future developments should be directed, and the latter will be provided with an insight of the possibilities and limitations of existing theoretical work. Our utmost interest is then to investigate the extent to which present computer technologies can contribute to training and learning in healthcare.

CVES IN HEALTHCARE

Although no attempt was made to be comprehensive, we have investigated the CVEs developed so far for training and learning in healthcare.

Many researchers have reported that Virtual Reality (VR) technology has proved to be an invaluable approach in Computer Graphics to represent real life problems within an interactive three-dimensional representation of an environment. Based upon these grounds, we can consider that VR technology is increasingly becoming an important component for simulation in surgical training, although it brings with it educational issues and practical implications. Further, qualitative findings reported in the literature, present that simulators can provide safe, realistic learning environments for repeated practice, underpinned by feedback and objective metrics of performance (Kneebone, 2003).

Some researchers have concentrated on the development of CVEs that have proved beneficial when groups or individuals need to share visual (graphics) or textual information. The most representative simulation-oriented learning environments support interaction, collaboration, and active learning. In general, the topics of training and learning are anatomy and basic surgical manipulations which involve a visual-haptic-audio experience. According to Dev et al. (2002), "while books, lectures, and multimedia are important routes to learning, the acts of touching, feeling, and cutting are believed to be essential in the training of surgeons". Therefore, simulated environments that deliver this experience with simultaneous viewing of the virtual world by all users are expected to form the next generation of technology-enhanced training and learning environments.

In some CVEs, haptic feedback devices are also used to improve the perceived virtual presence in these environments. In fact, they have been useful in building realistic computer based training systems in which users interact with virtual objects. In these systems, Web-based technology can be used to set the model parameters and run the simulation on a remote machine, while visualizing results on a low cost local machine. A library of objects, such as patients and medical devices, can then be created, and used to provide the component parts for a variety of virtual environments (VEs) that may be shared, simulated, analyzed, touched, and visualized by the virtual world of trainee and instructor.

In the last few years, implementation of shared virtual environments has been particularly active.

As a result, distributed, multi-user simulations have been implemented, which generally allow the interactions of users with the virtual scenario by clicking on objects to carry out functions to reproduce typical tasks and conditions commonly available in a physical training environment (e.g., a surgical) or educational environment (e.g., a classroom). These actions can be shared and transmitted through the Internet to other participants to have the impression of being involved in a training exercise. One example is the work presented in (Gunn et al., 2005b).

Essentially, the main focus in implementing shared VEs that use haptic devices is to reduce delay in processing force information. Actually, touch is central in expertise in surgery. During surgery procedures, the surgeon should have the feeling in his hands of directly holding the medical instruments interacting with the patient. In addition, the integration of VR technologies and experiences with VR-based approaches for clinical assessment, treatment and rehabilitation offers powerful options that could revolutionize standard practices in these fields (Rose et al., 2005; Rizzo et al., 2006). There is a series of studies involving haptic devices which can display virtual textures, which are useful to perceive objects (tactile sensing). The haptic devices have potential for simulating real world objects and helping in the navigation of VEs, mainly for simulating minimally invasive procedures (to operate remotely and interactively) and assisting people with disabilities. The great importance of minimally invasive surgery resides in the fact that it has revolutionized many surgical procedures over the last few decades (Basdogan et al., 2004). One of the most important aspects of surgical simulation is to provide the user with estimated reaction forces that arise from surgical instrument and soft tissue interactions.

The advantages of using VR in the medical area through simulations (that could replace the process of building physical mock-ups of functional environments needed for human performance testing, training, and learning) have already been recognized by many research groups. These joint efforts point to a promising future for CVEs. As the field of VR matures, our expectations are indeed that CVEs can deliver substantial benefits to the healthcare area.

MOBILITY

CVEs in healthcare increase the needs for privacy of data. This is tightly linked to security. If data about patients are to be processed, the level of security should match the sensibility of the data with personal information (e.g. address, phone number etc.) calling for lower security, and secret information (like names, exams, test results, etc) requiring highest security and more access restrictions. Enhanced privacy and security furthermore result in added trust in the system. This should in turn increase usage and acceptance, whereas low security will almost certainly have detrimental effects.

Hence, the system needs to be secure. The necessity and the level of security depend on the data processed. Patient images and other medical content could be secured in a way that only authorized users (health staff) have access to them. This might be desirable from a medical point of view when the documents should not be widely distributed, for example, because they contain confidential information.

Recently, security concerns have been emphasized due to mobility issues, and due to access through wireless networks. Introduction of these new technologies have associated greater difficulties to these kinds of communications, demanding mechanisms, for example, to prevent attacks.

In order to provide mobility, wireless network technologies have expanded rapidly in the past few years, becoming accessible to the ordinary user, which may revolutionize the computing and learning environments. This concept affords the emergence of numerous possibilities, like the development of real-time, distributed collaborative applications in mobile devices.

The concept of mobility in CVEs is not entirely new. For example, a system was proposed in Satchel (Lamming et al., 2000) to provide access to any document, at any time from anywhere. Although this is not a Mobile-CVE, it requires sharing of resources from anywhere at any time. The scenario proposed in Satchel involved a worker outside his workplace, who needed remote access to documents, but couldn't do so effectively due to the high transmission times provoked by mobility. Satchel's scenario (Lamming et al., 2000) demonstrates the importance of resource (e.g. documents) sharing during the mobile process, and that it is even more important to diffuse the collaboration of not only resources, but also of information in the more ample sense of the word (such as chats, messages, etc.).

The new "computing anywhere, at any time" paradigm is generating a movement towards mobile services. In this case the concepts of e-commerce are being extended to m-commerce, and e-learning now includes m-learning. With mobility, advantages in the quality of education, and improved results in learning are both expected. M-learning is, therefore, the next step in the evolution of e-learning.

The need for mobile users to use mobile devices for collaborative purposes does not arise from the fact that they are mobile, but from the implication of mobility, that is, they do not have access to conventional means of collaboration through their desktop computers. As mobile devices and access networks become more adequate and trustworthy, people feel increasingly attracted to use collaborative computing on several types of platforms. These changes have brought about a transition from the traditional model of computing to an ubiquitous one, which enables the entire environment to be available to the user from wherever it may be required.

The use of mobile devices is also justified in emergency situations, where a worker (or team of workers) must be located to establish collaboration, but is presently outside the normal work environment, and therefore unable to access his (their) desktop computers. Therefore, it is necessary to evaluate the impact of transferring the use of a desktop computer to a mobile device, mainly in the issues related to QoS (quality of service) and security. Now we present some situations in the medical field where mobile devices can be employed: requests for a second opinion, remote attendance of surgical procedures, and the transmission of warnings concerning the state of patients.

New computing technologies have provided some tools to overcome some limitations, creating virtual environments that can bring people closer together. A fairly common procedure, nowadays, is the concept of a "second opinion". This procedure has progressed from the use of asynchronous communications (e-mails) to synchronous communications, by means of instant messages to relay information. More recently, this communication has progressed even further with the development of CVEs that allow healthcare workers to interact in real time with audio, video and data transfer based on Web standard interfaces. All of these concepts may obviously be available also in PDA (Personal Digital Assistant) type mobile devices, and the collaborators can be located anywhere, at any time. This has been made possible through the creation of an access infrastructure based on wireless networks. It was recently established that part of the resistance of healthcare professionals to working in remote areas originates from the feeling of isolation and not being able to share diagnoses.

In the case of transmission of patient data warnings, the idea is not limited to the use of Short Message Services (SMS) provided by cellular phone networks, but also the transmission of a warning followed by the relay of information that can be monitored at a given moment, allowing a physician to evaluate the gravity of the warning and issue procedures adequate for each case.

QUALITY OF SERVICE AND STABILITY

Present Internet network architecture was designed to relay information using a Best Effort service model, with no guarantees concerning QoS (quality of service) requirements. In the event of a congestion packets are discarded and there is a certain downgrade in the transmission rate, which does not guarantee that the application will be executed effectively. These problems result from the increase of traffic over the Internet, and the type of information carried over the network.

QoS is defined as a set of techniques used to provide differentiated treatments to the flow of data, according to the application. The requirements for each flow can be characterized by four main parameters: Delay – the time necessary for a packet to travel through he network, measured from the moment of transmission to the moment of arrival; Jitter - is the variation in delay, and is defined by consecutive pairs of packets (if D_i is the delay of the i_{th} packet, then the jitter of the pair of packets is defined as $D_i - D_{(i-1)}$); Reliability - is associated to the packet loss rate, which is the relation between the number of packets lost and the number transmitted, measured at the receiving end (this loss occurs when the router buffer is overloaded and no longer allows storage of packets); Bandwidth – represents the speed of the environment, in other words, the maximum transmission rate available at a given moment for communication between two knots of the network (Ash, 2006).

In a multimedia environment different types of traffic (viedo, voice, data, etc.) compete for the use of the same resources. Therefore it is important to understand the network requirements needed to provide satisfactory QoS performance. The introduction of QoS management mechanisms is necessary, as a measure to guarantee that applications sensitive to delay, jitter and packet loss are not affected.

Furthermore, to guarantee the continuous use of a mobile system, stability must be a premise. Stability, in the technical sense, means that the services must be carried out obeying parameters of speed and availability. This is a fundamental point when the link to the mobile device has low speed. Instability, in this case, such as connection losses and application interruptions, will cause loss of user data. If the system is functioning devoid of interesting information, users will lose interest in the system. Lastly, stability is also connected to maintenance. Programming errors may never be fully solved, thus the need for someone who is responsible for receiving bug reports and suggestions that should be incorporated to the system, in order to guarantee good acceptance.

MOBILE LEARNING

The premise of Mobile-education is based on the idea by Pascoe et al. (2000): “Using While Moving”, which is basically what users need from a mobile computer system. Mobile-education affords distributed collaboration over wireless devices to generate learning opportunities. This is, therefore, a new approach that uses a virtual wireless community to facilitate learning activities through collaboration in a distributed environment. Mobile-Education is significantly different from traditional learning systems. In this new model collaborative activities are based on virtual communities, and offer a wide range of collaboration opportunities, such as synchronous and asynchronous peer-to-peer interactivity, allowing data visualization. All of this interaction will be possible from handheld devices.

MAIN CHALLENGES

Some challenges facing the CVEs and Multimedia Communication Technologies are briefly outlined in this section.

High performance computing and networking technology promise to offer great potential to link many medical centers and universities to each other. An interesting point to note regarding this fact, is that virtual anatomical models of the human body will be able then to be shared and used systematically, for various surgical simulation and learning applications through the Web. As a result, we believe that these applications will be able to generate immersive and highly adaptable VEs that will allow individual participants or teams to train and learn simultaneously. However, we need also to take into account the fact that CVEs are typically associated with high-performance computers and specialized input/output haptic devices, with high costs involved, which make operating them on a large scale still prohibitively expensive. Also, related to this issue is the problem of ensuring that each participant sharing an entity in the CVE has a consistent view of the environment. The consequences of differing state can be detrimental to the application as each user's perception of the interaction being performed would differ, thus, leading to a breakdown in the collaboration (Glencross & Chalmers, 2005).

Other important issues in typical CVEs are the most complex types of interactions possible, which are collisions (detection and response) and touch. Collisions are often the bottleneck of simulation applications in terms of calculation time, directly related to the geometric complexity of the VE, and sometimes involves a huge number of geometrical tests for determining which elements are colliding (Ericson, 2005). Colliding virtual bodies can be deformable or rigid. During their movements, a point located anywhere in space (centre of rotation) is associated with the surfaces. Rotational and translational velocities around that point define the instantaneous motion. These velocities are integrated forward in time to define the motion of the surfaces. It is appropriate to certify always during the collisions whether the surfaces are still both physically continuous and topologically contiguous. From a rendering point of view, for graphical display of VEs that support interactions between objects, such as collisions, one of the most important considerations is maintaining suitably high frame rates to guarantee the quality of the simulation.

In some CVEs, participants may change attributes of entities (with complex behavior), which have physical characteristics allowing them to deform or flow (Glencross & Chalmers, 2005). This type of interaction impacts upon the values provided to the algorithms used to compute the state and/or the geometric structure of the entities. Haptic feedback is one of the important stimuli that can be used to provide richer response for physical interaction with VEs by touch. However, simply adding haptic feedback to CVEs does not lead to usable medical applications. It is also essential to consider how to combine suitable force models to support correct perception of surface details (e.g, textures), entity-entity collisions, and motion during interactions.

As medical devices are becoming increasingly networked, ensuring the same level of existing health safety become crucial (Lee et al., 2006), especially considering that interactions in VEs still suffer from problems of accuracy. In addition, networked virtual reality (NVR) services with integrated multimedia components (and perceived "real-time" interactivity) impose certain QoS requirements at the user/application level as well on the underlying network (Skorin-Kapov et al., 2004).

IP technology, in its original conception, does not offer any type of guarantee of QoS. Also, in order for an IP network to support voice services with strict delay and jitter requirements, it is necessary to implement some functionalities to this protocol. The IETF (Internet Engineering Task Force) standardized two specific architectures to supply QoS in the IP environment: IntServ – Integrated Services, and DiffServ – Differentiated Services. The big challenge, however, consists of implementing an infrastructure capable of supporting these architectures.

Further, as devices become increasingly smaller in physical terms, but larger in software terms, they bring capabilities that are sufficient to provide the basis for mobile use. Equipped with small health applications these PDAs can be given out to a number of health agents, thus providing a higher coverage by giving many agents access to a computing device. Therefore, as mobility in collaboration is emerging as a research topic in itself, it is imperative that researchers in this field explore new methods of interaction and novel applications (Perry et al., 2001).

The type of device which can be used for a service is basically unrestricted as long as it is wireless. However, wireless does not mean that a constant connection to a server or network is required. A PDA that holds notes which were transmitted during synchronization using a personal computer is a mobile device just as is a mobile phone with a Wireless Application Protocol (WAP) browser, or a PDA with a Wireless Local Area Network (WLAN) connection.

The need for privacy and confidentiality is giving rise to increased expectations about data storage and transmission security, as data on demand emerges as a viable concept in healthcare. Regarding security, it is important to emphasize that unrestricted admittance is only possible with a valid user identity, which is controlled by the system. Adequate security is ensured by encrypting all data at 128 bit. For mobile admittance the user has to enter an identifier. When the infrastructure supports Wireless Identification Module (WIM), additional security can be established by unambiguously identifying a user.

CONCLUSION AND FUTURE WORK

The medical field has been one of the most appealing areas for computer graphics and VR research. Further, we believe that CVEs can provide novice physicians, residents and students with a natural training and learning environment that may increase understanding of the anatomic relationships of the human body and improve healthcare, minimizing the risks to patients, thereby their ultimate safety. The advantage is that the novice, for example, will be introduced to uncommon conditions that would only arise rarely in clinical practice.

We also observe that while a range of VR medical applications do contain simulation and rich behavior to varying degrees, it is still very hard to quantify the realism of the computer models, since the human body is a system of complex interactions between organs and tissues. These interactions are particularly intricate in the case of soft tissues (very little information is currently known regarding their deformable behavior). In addition, there are ethical problems involved and the need of volunteers. Last, but not least, there is still the fact that collecting medical data takes time. Beyond these issues are also the psychological and sociological barriers to implementation that any new technology should overcome. Crossing these barriers among professionals in Education, Training, Healthcare Delivery, Engineering, and Computer Science will require an integrated and collaborative approach. Actually, over the past few years, a movement characterized by increased collaboration among these professionals has started to take shape.

QoS makes it possible to offer better guarantees and security for Internet applications, once the traffic of advanced applications (such as voice, videoconference, etc.) is being given greater priority, while users of traditional applications continue to use the Best Effort approach.

Finally, we hope that CVEs and recent computer technologies can contribute not only to the advance and improvement of healthcare delivery, but also to do it more safely.

ACKNOWLEDGMENT

The research was partly supported by The National Council for Scientific and Technological Development of Brazil (CNPq) under grant No. 303046/2006-6.

REFERENCES

Ash, G. (2006). *Traffic engineering and QoS optimization of integrated voice & data networks*. Morgan Kaufmann Series in Networking.

Basdogan, C., De, S., Kim., J., Munivandi, M., & Srinivasan, M.A. (2004). Haptics in minimally invasive surgical simulation and training. *IEEE Computer Graphics and Applications (special issue on Haptic Rendering – Beyond Visual Computing), 24*(2), 56-64.

Blezek, D. J., Robb, R. A., & Martin, D. P. (2000). Virtual reality simulation of regional anesthesia for training of residentes. *Presented at the 33rd Hawaii International Conference on System Sciences*, (pp. 1-8). IEEE CS Press.

Burdea, G. (1999). Haptic feedback for virtual reality. *Presented at the Virtual Reality and Prototyping Workshop*, (pp. 87-96).

Dev, P., Montgomery, K., Senger, S., Heinrichs, W. L., Srivastana, S., & Waldron, K. (2002). Simulated medical learning environment on the Internet. *Journal of the American Medical Informatics Association*, *9*(5). doi:10.1197/jamia.M1089

DiMaio, S. P., & Salcudean, S. E. (2005). Interactive simulation of needle insertion models. [IEEE CS Press.]. *IEEE Transactions on Bio-Medical Engineering*, *52*(7), 1167–1179. doi:10.1109/TBME.2005.847548

Ericson, C. (2005). *Real time collision detection*. Morgan Kaufmann. Elsevier.

Glencross, M., & Chalmers, A. (2005). High fidelity collaborative virtual environments. *Presented at the 4th International Conference on Virtual Reality, Computer Graphics, Visualization and Interaction in Africa (tutorial notes)*. AFRIGRAPH.

Gunn, C., Hutchins, M., & Adcock, M. (2005b). Combating latency in haptic collaborative virtual environments. *Presence (Cambridge, Mass.)*, *14*(3), 313–328. doi:10.1162/105474605323384663

Gunn, C., Hutchins, M., Stevenson, D., Adcock, M., & Youngblood, P. (2005a). Using collaborative haptics in remote surgical training. *Presented at the Eurohaptics Conference and Symposium on Haptic Interfaces for Virtual Environment and Teleoperator Systems*, (pp. 481-482).

Hosseini, M., & Georganas, N. D. (2001). Collaborative virtual environments for training. *In the ACM Multimedia*. Ottawa, ON, Canada.

Kneebone, R. (2003)... *Medical Education*, *3*, 267–277. doi:10.1046/j.1365-2923.2003.01440.x

Lamming, M., Eldridge, M., Flynn, M., Jones, C., & Pendleburry, D. (2000). Satchel: providing access to any document, any time, anywhere. *ACM Transactions on Computer-Human Interaction*, *7*(3), 322–352. doi:10.1145/355324.355326

Lee, I., Pappas, G. J., Cleaveland, R., Hatcliff, J., Krog, B. H., & Lee, P. (2006). High-confidence medical device software and systems. [special issue on Clinical Software Engineering]. *Computer*, *39*(4), 33–38. doi:10.1109/MC.2006.180

Pascoe, J., Ryan, N., & Morse, D. (2000). Using while moving: HCI issues in fieldwork environments. *ACM Transactions on Computer-Human Interaction*, *7*(3), 417–437. doi:10.1145/355324.355329

Perry, M., O'Hara, K., Sellen, A., Brown, B., & Harper, R. (2001). Dealing with mobility: understanding access anytime, anywhere. *ACM Transactions TOCHI, 8*(4).

Pesch, D., Irvine, J., & Klepal, M. (2007). *Mobile communication systems and networks*. John Wiley & Sons.

Rizzo, A.A., Klimchuk, D., Mitura, R., & Bowerly, T., Buckwalter, Parsons, TD & Yeh, S.C. (2006). A virtual reality scenario for all seasons: the virtual classroom. *CNS Spectrums*, *11*(1), 35–44.

Rodrigues, M.A.F., Silva, W.B., Barbosa-Neto, M.E., Gillies, D.F., Ribeiro, I.M.M.P. (2007). An interactive simulation system for training and treatment planning in orthodontics (article in press, doi: 10.1016/j.cag.2007.04.010). *Computers & Graphics*, Elsevier.

Rose, F. D., Brooks, B. M., & Rizzo, A. A. (2005). Virtual reality in brain damage rehabilitation: a review. *Cyberpsychology & Behavior*, *8*(3), 241–262. doi:10.1089/cpb.2005.8.241

Sharma, C., & Nakamura, Y. (2004). *Wireless data services: Technologies, business models and global markets*. Cambridge University Press.

Skorin-Kapov, L., Vilendečić, D., & Mikić, D. (2004). Experimental performance evaluation of networked virtual reality services. *Presented at the IEEE MELECON*, (pp. 661-664). IEEE CS Press.

Stallings, W. (2005). *Cryptography and network security*. Prentice Hall.

KEY TERMS

Collaborative Virtual Environments (CVEs): CVEs are used to construct a virtual world where users can interact with one another and the environment in which they preside in order to perform, for example, a training exercise.

Distributed Collaboration: VR has been employed to allow geographically distributed people to do more than simply hear and see each other. For instance, VR technology is being used to develop highly interactive shared virtual environments, graphically orientated, for local and distance training and learning.

Haptics: It refers to technology which interfaces the user via the sense of touch by applying forces, vibrations and/or motions to the user.

Haptic Feedback: A crucial sensorial modality in VR applications. Haptics means both *force feedback* (simulating object hardness, weight, inertia, etc) and *tactile feedback* (simulating surface contact geometry, smoothness, slippage, and temperature) (Burdea, 1999).

Mobility: It is the ability of mobile devices to move or change the position.

Quality of Service (QoS): QoS refers to control mechanisms that can provide different priority to different users or data flows, or guarantee a certain level of performance to a data flow in accordance with requests from the application program.

Security: It is the practice of protecting and preserving private resources and information on the network from unauthorized modification or destruction.

Virtual Reality (VR): VR entails the use of advanced technologies, including computers and multimedia peripherals, to produce "virtual" environments that users perceive as comparable to real world objects. It offers great potential as a technology for computer-based training and simulation. It may be delivered to the user via a variety of input/output devices such as screen monitors, head-mounted displays, data gloves, etc.

Virtual Environments (VEs): VEs can be used to simulate aspects of the real world which are not physically available to the users of the application.

Wireless: Communication or transfer of information over a distance without the use of wires. It is generally used for mobile devices.

This work was previously published in Handbook of Research on Distributed Medical Informatics and E-Health, edited by A. Lazakidou; K. Siassiakos, pp. 399-409-, copyright 2009 by Medical Information Science Reference (an imprint of IGI Global).

Chapter 3.13

HealthGrids in Health Informatics:

A Taxonomy

Aisha Naseer
Brunel University, UK

Lampros K. Stergioulas
Brunel University, UK

ABSTRACT

Healthcare is a vast domain encapsulating not only multiple sub-domains or sub-sectors but also many diverse operations and logistics within each sub-sector. This diversity needs to be handled in a systematic and well-characterized manner in order to maintain consistency of various healthcare tasks. Integration of health information systems within each healthcare sub-sectors is crucial for ubiquitous access and sharing of information. The emerging technology of HealthGrids holds the promise to successfully integrate health information systems and various healthcare entities onto a common, globally shared and easily accessible platform. Many different types of HealthGrids exist but there lacks a taxonomy to classify them into a hierarchical order. This chapter presents a well-characterized taxonomy of different types of HealthGrid and classifies them into four major types, namely BioGrid, MediGrid, PharmaGrid and CareGrid. Each of these HealthGrids possesses dedicated features and functionalities. The proposed taxonomy serves to better understand the realtionship among various HealthGrid types and would lay a basis for future research.

DOI: 10.4018/978-1-60566-030-1.ch008

INTRODUCTION

Healthcare is currently going through a series of technological advancements and modifications. Health information has always been of great importance to society and has a strong impact on various social aspects. Due to its nature, health information has to be dealt with great care and confidentiality. At the same time, it has to be shared and exchanged across various organizations or individuals to provide improved healthcare service. Two of the most important disciplines in Health Informatics today are bioinformatics and medical informatics. As Computer Science and Biotechnology communities join forces to create new technologies for the advancement of medical science and improvement of medical service delivery (Stewart, 2004), this might prove to be promising for enabling people to lead normal, healthy lives.

It is widely recognised today that the healthcare industry requires customized solutions with respect to information integration. The information sharing techniques currently available are not sufficient to meet the requirements of an integrated health care system. The state of electronic information integration in healthcare lags noticeably behind other business domains such as banking, insurance and electronic commerce (Bilykh et al., 2003). There is a need for health information systems to be fully integrated with each other and provide interoperability across various organizational domains for ubiquitous access and sharing. Moreover, due to rapid progress of biotechnology an increasing number of life science databases are becoming available that are being operated and managed individually (Tohsato et al., 2005). Many existing solutions still do not offer the desired levels of utility/functionality or sophistication that a health information system demands.

The emerging Grid technologies hold out the promise of a global information channel that is far more powerful and uniquely distinct from the existing internet framework (Naseer and Stergioulas, 2006b). By definition:

"Grid is a large-scale, high-performance, always-on and dynamic, although geographically distributed yet networked, infrastructure that comprises and seamlessly unifies a variety of autonomous, heterogeneous components such as processes, resources, network layers, interfaces, protocols and services, with strong, consistent and controlled relationships among them." (Naseer and Stergioulas, 2006b)

HealthGrid is a Grid used in the context of healthcare. HealthGrids are expected to successfully integrate health information systems and various healthcare entities, including humans and non-humans, such as scientists, scientific tools, medical instruments, physicians, patients and all types of healthcare data or medical information, onto a common (global) platform that would be shared and easily accessible (Breton et al., 2005). In such a scenario, each health information system is composed of various distinct components, which are integrated in a way that each component has its well-defined semantics and ontology and is well-aware of all other components.

Considering the vast nature of the heathcare domain (Alexopoulos et al., 2007), it can not be assumed that only one HealthGrid would be sufficient for the entire healthcare domain. However, many small HealthGrids could be combined together to form a giant HealthGrid infrastructure in order to facilitate collaborative work and resource sharing. There are several existing medical classifications, terminologies and taxonomies (Alexopoulos et al., 2007) but such a taxonomy that illustrates how the various HealthGrids could be classified does not exist yet. Therefore a taxonomy is needed that classifies various types of HealthGrids and lays-out a hierarchical structure that is simple to understand but is yet systematic & well-characterized. Such a taxonomy would be beneficial for understanding, in detail, the realtionship among various HealthGrid types and would lay a basis for the future research.

This chapter offers a systematic taxonomy of the HealthGrids. It first outlines the characteristic features and functionalities of HealthGrids, and reflects on the need for Grid technology in healthcare. The taxonomy of HealthGrids is proposed, based on their functionality, purpose, and application area. Finally, this chapter reflects on the future of HealthGrids in Health Informatics and draws some conclusions.

HEALTHCARE NEEDS GRID TECHNOLOGY

The case for the use of Grid technology in healthcare arises mainly from the need to improve, safeguard and effectively exploit the available *life-significant medical information*, the need to protect the privacy of *personal, life-sensitive health information*, and the need to provide *integrated healthcare services* and have in place effective, global *channels of collaboration*.

Health-related information is important for the well-being of society and has to be accurate and consistent. Medical information provided over the internet often suffers from ambiguity and contradiction that would increase the complexity and confusion of medical issues instead of solving them. Moreover, anyone can publish or post material of their choice over the internet without any peer review or checking, which makes open internet an unreliable source of healthcare information.

Information available on HealthGrids can initially be peer reviewed once before uploading, but even more importantly, it can be constantly and continuously checked and revised appropriately, thus making HealthGrids an accurate and reliable source of health information that can be accessed any time from any place.

Blake and Bult (2006) stated: "One of the major challenges faced by the biomedical research community is how to access, analyse, and visualize heterogeneous data in ways that lead to novel insights into biological processes or that lead to the formulation of a hypothesis that can be tested experimentally". In order to exploit effectively the wealth of medical information, there is an urgent need to *integrate, manipulate, process, and analyse* huge heterogeneous datasets from disparate sources. More systematic use of Grid technology in healthcare will not only help meet the current needs for data processing, but will ensure that future demand for even more capacity to deal with far larger volumes of data can be met (Breton et al., 2005).

Moreover, whenever *confidential medical information* is shared among health organizations, security and privacy are critical issues (Bilykh et al., 2003), since HealthGrids contain 'life sensitive data'. The information content in a healthcare system is related to various entities, such as hospitals and their staff, stakeholder organisations and their members, medical equipment/devices, medicines, diseases, patient information records and healthcare operations (pathways). Amongst all the entities, the *patient record* is the most prominent, since it encapsulates information on most other entities (some of which is personal, and should be kept private to the patient).

On another level, HealthGrids can prove to be an *effective channel for international collaborations* where the world's scientific minds can collectively work, such as to conduct a group-wise analysis, and might produce solutions that would effectively address complex medical problems (for instance, a disease or remedy).

There are many *other reasons* why the healthcare industry needs Grid technology, such as to:

1. provide more computational power
2. make network resources readily available
3. better utilise system resources, and reduce wastage by eliminating idle resources
4. create new business opportunities and exploit economies of scale
5. enable faster problem solving
6. support multiple operations by concurrent and ubiquitous access
7. provide the massive data storage spaces required in healthcare
8. make healthcare solutions/systems more efficient
9. facilitate collaborations and integration among various healthcare resources and stakeholders

All of the above and many more emerging issues demand to be addressed in a sophisticated manner by an advanced and reliable solution and a systematic, well-characterized taxonomy of different types of HealthGrids is expected to facilitate these operations. A study by Estrella et al. (2007) discusses that Grid computing holds the promise of harnessing extensive computing resources located at geographically dispersed locations that can be used by a dynamically configured group of collaborating institutions. It defines a suitable platform on which distributed medical informatics applications could be based. Particularly, HealthGrids are expected to address issues such as data distribution, data processing, data analysis, data sharing, data security, resource heterogeneity and interoperability.

HealthGrids might prove to be a good way to address these needs and provide reasonable solutions the challenges of modern healthcare. A study by Piggott et al. (2004) explores the potential use of Grid technology in Healthcare, such as integration of heterogeneous data sets from multiple diverse sources systems. Thus, if successfully implemented, the HealthGrid will have a high impact towards lower costs and greater benefits for healthcare in the long run. In this respect, the HealthGrid could be the driver of Health Informatics and which is the next generation of healthcare IT and a taxonomy of various HealthGrid types would be of significance at this stage in order to have a better idea of how the various types are classified in order of their hierarchy.

TAXONOMY OF HEALTHGRIDS TYPES

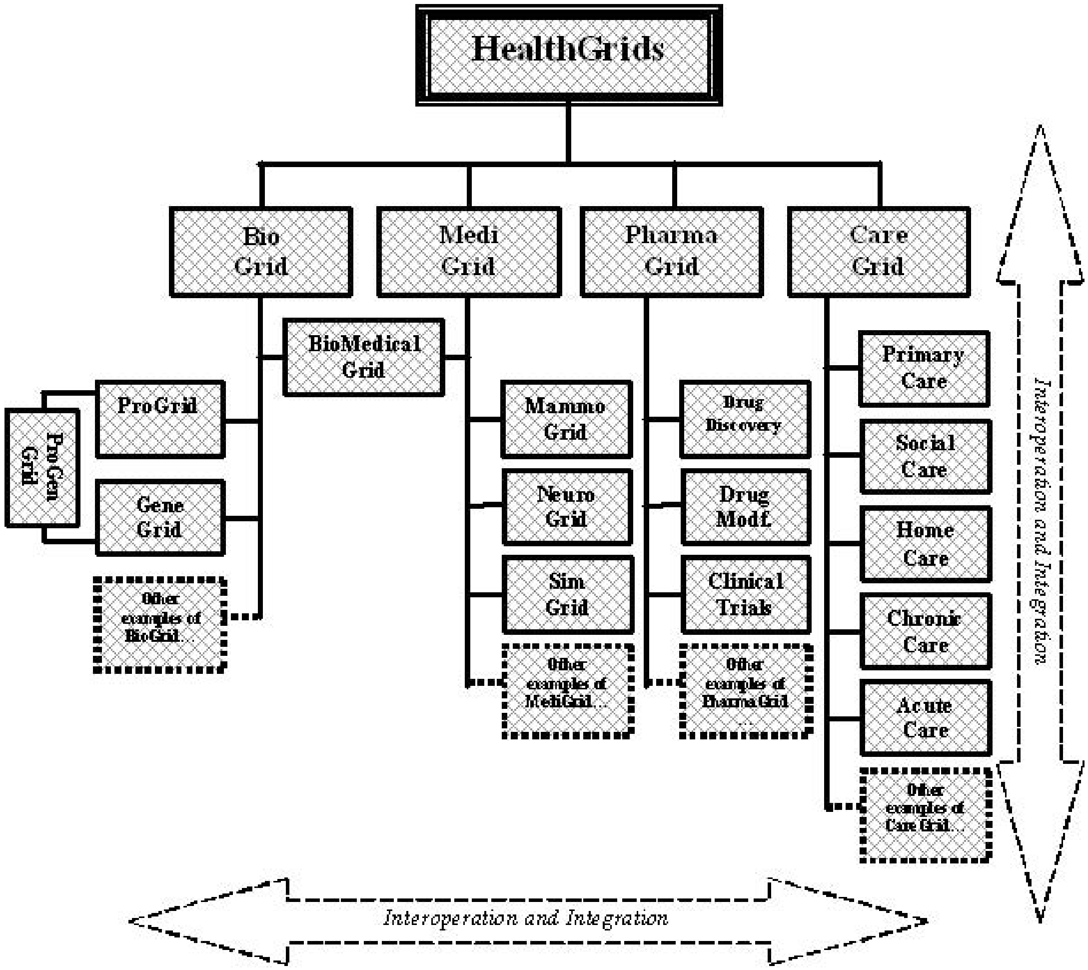
There are various types of HealthGrids defined in the healthcare sector. Each has been devised for a dedicated purpose, so as to provide special services and to support the performance monitoring of specialized tasks in a particular healthcare sector. A taxonomy of HealthGrids types is proposed based on their functionality, purpose, and application area. This must be kept in mind that all HealthGrids are mainly DataGrids.

Considering the vast nature of the heathcare domain (Alexopoulos et al., 2007), it can not be assumed that only one HealthGrid would be sufficient for the entire healthcare domain. However, many small HealthGrids could be combined together to form a giant HealthGrid infrastructure in order to facilitate collaborative work and resource sharing. There are several existing medical classifications, terminologies and taxonomies (Alexopoulos et al., 2007) but such a taxonomy that illustrates how various HealthGrids could be classified doesnot exist yet.

This chapter presents a taxonomy of HealthGrids (Figure 1) and classifies them into four major types, namely BioGrid, MediGrid, PharmaGrid and CareGrid, where the BioGrid and the MediGrid merge into the BioMedicalGrid, which combines the features and functionalities of both Bio and Medi Grids. The BioGrid is sub-categorized into representative examples such as ProGrid for Proteomics and GeneGrid for Genomics, both of which merge into the ProGenGrid. The MediGrid is also further sub-categorized into typical implementations, such as Medical Imaging (Visual) grids (e.g. MammoGrid) for the management and processing of medical images, scans or DICOM (Digital Imaging and Communications in Medicine) files, NeuroGrid for neurologists and SimGrid for medical simulations and modelling (another example of a Visual Grid). There is a need for the HealthGrids to be integrated and possess strong interactions among themselves in order to facilitate data sharing. For example, although GeneGrid does not have a direct link with the CareGrid as shown in Figure 1, however, data from both these domains could be made available for accessing & sharing over these Grids, if needed.

The various types of HealthGrids, along with characteristic applications, are examined and discussed further in this section. Each of the HealthGrids described in this section is effectively a DataGrid and could also be a SemanticGrid (Semantic grid project, 2007) if it is based on semantic principles. For example, in a similar fashion to NeuroGrid, there can be a dedicated HealthGrid for each medical domain, such as Car-

Figure 1. **Taxonomy of HealthGrids types**



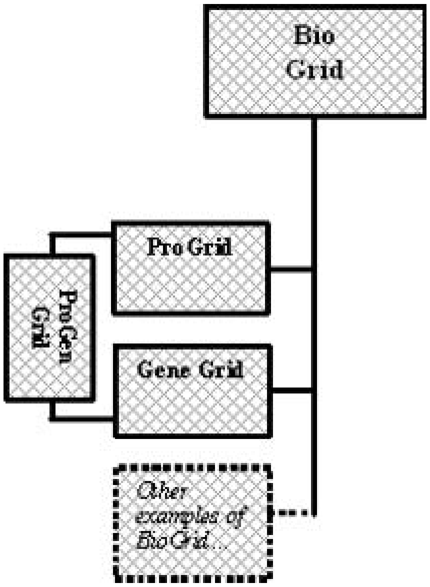
dioGrid, OptiGrid, OrthoGrid, GynaecologyGrid or OtolaryngologyGrid and many others.

BioGrid

BioGrid is a type of HealthGrid designed specifically for accessing and sharing biological information, often around the globe, by authorized individuals and/or organizations. Information related to biological components at the molecular level such as genes, proteins, DNA, RNA, chromosomes and other molecular biological structures need to be critically analysed for further biological research purposes. BioGrids are increasingly important in the development of new computing applications for the life sciences and in providing immediate medical benefits to individual patients. They have significant potential to support the offering of personalised medical care and to be able to target only those at risk (Ellisman et al., 2004). Examples of BioGrid are shown in Figure 2.

OGSA-DAI (Open Grid Service Architecture Data Access and Integration) have been used in ChemBioGrid by bringing Data Management tools into collaborative environment. The mechanism has been studied, for supporting Digital Libraries in High-Performance Computing environment based on Grid technology. OGSA-DAI have been

Figure 2. Examples of BioGrid



implemented to provide abilities to assemble heterogeneous data from distributed sources into integrated virtual collections (Zhuchkov et al., 2006). The BioGrid is sub-categorized into the ProGrid and the GeneGrid, which are also the applicable examples of BioGrids and are described below:

a. ProGrid

ProGrid is a practical example of BioGrid that is specialized in the management of all types of information related to proteins, such as proteomic and proteo-type data, protein structures, protein identification, protein analysis, protein expression level, protein mutation, protein screening and classification.

The human body is incredibly complex and consists of roughly 50 trillion cells, each consisting of an enormous number of components (of the order of 10^{13}), many of which are proteins. It normally takes months on a Peta-flop class computer (one capable of performing 10^{15} calculations per second) to simulate the activity of a single protein, taking into account each atom in the protein. No such computer systems exist today, and designing one remains a formidable challenge (Stewart, 2004).

The ProGrid will be able to address this issue by making available enormous computation resources for highly complex computational operations. A recent study (Cannataro et al., 2005) presents MS-Analyzer, a tool for the management processing and analysis of proteomic Mass Spectrometry data. It is a specialized version of PROTEUS (Cannataro et al., 2004), which is a Grid-based Problem Solving Environment for bioinformatics applications that uses (a) domain ontologies to design complex in silico experiments by modelling basic software tools, data sources and workflow techniques and (b) data mining software tools to provide proteomics facilities. Its main requirements include interfacing with proteomics facilities, storing and managing proteomic Mass Spectrometry data, and interfacing with off-the-shelf data mining and visualization software tools.

An architecture combining the use of OGSA-DAI, Grid distributed querying (OGSA-DQP) and data integration software tools to support distributed data analysis has been proposed (Zamboulis et al., 2006), for the integration of several autonomous proteomics data resources.

b. GeneGrid

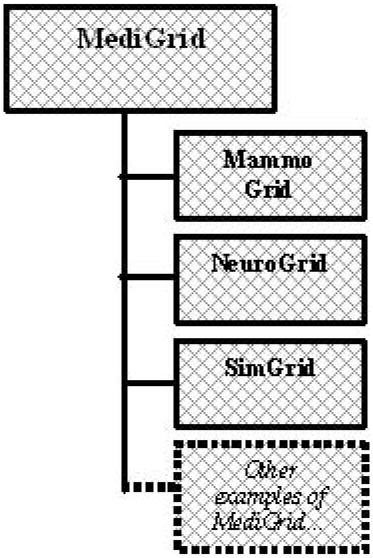
GeneGrid is another practical example of BioGrid that is specialized in the management of all types of information related to genes and of relevance to genomic studies, such as information on genomes & genotype, genetic structures, genetic sequences, genetic mutations, genetic diseases, genetic epidemiology, gene therapy, gene naming, genetic analysis, gene screening, genetic variation and genetic classification. For the purposes of genetic epidemiology GeneGrid can support the unified naming of phenotypes and standardised acquisition and recording of clinical parameters. In genetic epidemiology studies, a clinical annotation service is one of the central services in a Grid for clinical phenotype descriptions (Breton et al., 2005). The GeneGrid project (Jithesh et al., 2005) integrates numerous bioinformatics programs and databases available on different resources across various sites allowing scientists to easily access the diverse applications and data sources without having to visit many web servers. This reduces the overall time for executing the experiment. The Grid services developed in the GeneGrid project are based on the Open Grid Services Architecture (Foster et al. 2003) and provide scheduled access to resources, data, and applications, using XML-based messages.

The need to have a dedicated GeneGrid arises due to the ever-increasing volumes of genomic data and ever more demanding complex computations for genetic operations.

c. ProGenGrid

The ProGrid and GeneGrid merge into the ProGenGrid which is dedicated to perform management of data related to the sequence and structure of both the genome and proteins. Operations carried out on a ProGenGrid could include the aggregation, selection, retrieval, analysis, filtration and sharing of proteomic and genomic data for concurrent access and collaboration. The ProGenGrid, developed at the University of Lecce (Aloisio et al., 2005a), is intended to provide a practical solution to specific HealthGrid problems. This Grid aims at providing a virtual laboratory where e-scientists can simulate biological experiments, compose existing analysis and visualization tools, monitor their execution, store the intermediate and final output and finally save the model of the experiment for updating or reproducing it. Another study (Aloisio et al., 2005b) introduces the ProGenGrid workflow that comprises a semantic editor for discovering, selecting and composing bioinformatics tools available in a Grid environment, and a workflow scheduler for running the composed applications. The workflow editor uses an ontology of tools for the bioinformatics domain and employs the Unified Modeling Language (UML) for modelling the workflow. The UML graphical notation is stored as an XML file. On running the application, the workflow scheduler takes activities from the XML file and runs them, taking into account the state and availability of Grid resources and relevant bioinformatics tools. The system also allows monitoring of the job flows.

Figure 3. Examples of MediGrid



MediGrid

The MediGrid (Medical Grid) is a type of HealthGrid designed specifically for accessing and sharing medical information around the globe by authorized individuals/organizations. Examples of MediGrid are shown in Figure 3.

It is expected to contain all levels of medical information from tissue, organ, and patient to population and public health, including various types of scans, mammograms, simulations and models of different body organs and other medical domains. All this information needs to be shared and critically analysed for further medical research purposes. A paper proposes a MediGrid (Boccia et al., 2005) which has been designed specifically for the aggregation and integration, analysis and visualization, and processing and management of biomedical images for nuclear doctors. It is a distributed, user friendly GUI-based application that uses the First In First Out (FIFO) algorithm for job scheduling and follows the Grid Application Development Software (GrADs) Project workflow (Berman et al., 2001), (Vadhiyar and Dongarra, 2005). It focuses on complex Grid-enabling parallel algorithms for the examination of medical images.

Amongst others, the MediGrid can be subcategorized in terms of its practical application; representative examples include the MammoGrid, the NeuroGrid and the SimGrid, which are next described:

a. MammoGrid

The MammoGrid (Mammography Grid) (MammoGrid, 2007) is one of the most important practical examples of a MediGrid designed particularly for the access, storage, retrieval, analysis, management, manipulation and sharing of various types of digital images, medical scans, or DICOM (Digital Imaging and Communications in Medicine) files. Some computationally intensive image analysis algorithms often devised to assist clinicians to make decisions in diagnosis and therapy are known to produce better results, but are not used in practice due to the lack of computing power (Breton et al., 2005). The MammoGrid is expected to provide enormous computing and storage resources so as to make feasible and to support distributed image analysis.

A recent study (Scheres et al., 2005) presents an interface between Grid computing middleware and a three-dimensional electron microscopy (3D-EM) image processing package ("Xmipp") (Sorzano et al., 2004). Results showed clearly that 3D-EM image processing can greatly benefit from the resources offered by Grid computing. Another study (Glatard et al., 2005) produced a generic, Grid-enabled workflow framework, to be deployed on the computational Grid infrastructure provided by the EGEE European project (EGEE, 2008). It encompasses image registration algorithms wrapped in standard Web-Services, a Grid enabled workflow manager, and Grid middleware for performing the distributed computations. The framework developed could easily be adapted to a wide variety of medical applications. However, one of the limitations stems from the *stateless nature* of Web Services.

e-Diamond, a UK e-Science project (Brady et al., 2003), is a Grid-enabled prototype system (medical image database) that aims at supporting breast cancer screening by maintaining a national database for digital mammograms. In the development of e-Diamond, an object-relational approach to the storage of DICOM files has been taken (Power et al., 2004). Other work carried out within the context of the e-Diamond research project (Power et al., 2005), (Simpson et al., 2005) addresses the challenges of patients' data security and confidentiality via employing query modification. Query modification is also used in GIMI (Simpson et al., 2005) to restrict access to the data in Grid-enabled medical research databases for the sake of patients' data security.

A MIP-Grid (Grid-enabled Medical Image Processing Application System) is presented (Huang et al., 2006), that is based on OGSA-DAI middleware. It aims at providing high performance medical image process services in a large distributed grid computing environment. OGSA-DAI allow uniform access to and integration of data held in heterogeneous data resources.

b. NeuroGrid

The NeuroGrid (Neurology Grid) is another example of a MediGrid that is designed to support neurologists worldwide in their collaborative work. A recent study (Geddes et al., 2005) has proposed the implementation of a NeuroGrid, i.e. a Grid dedicated to neuro-scientific studies. It is intended to be built on the experience of other UK e-science projects aiming to assemble a Grid infrastructure, and apply this to three exemplar areas: (a) stroke, (b) dementia and psychosis, and (c) generic collaborative neuroscience research. Grid-enabled sharing of data, experience and expertise will facilitate the archiving, curation, retrieval and analysis of imaging data from multiple sites and enable large-scale clinical studies in neurology. To achieve this goal, the NeuroGrid seems to be built upon existing Grid technologies and tools (developed within the UK e-Science programme), aiming to integrate image acquisition, storage and analysis, and to support collaborative working within and between neuro-imaging medical centres. Moreover, the Biomedical Information Research Network (BIRN) (Ellisman and Peltier, 2004) is devoted to neurology and is exploring the use of Virtual Data Grid (VDG) to support multiscale brain mapping. BIRN currently participates in three testbed projects; namely Function BIRN, Morphometry BIRN and Mouse BIRN (Stewart, 2004).

In the not too distant future, a dedicated NeuroGrid will address the need to support the computation and monitoring of various neurological functions, for both humans and animals, such as brain histology, MRI (Magnetic Resonance Imaging), neurological disorders, electron microscopy and brain imaging.

c. SimGrid

The SimGrid (Simulation Grid) is also an example of MediGrid designed specifically for providing special simulation and modelling services for various types of medical treatments and analysis such as surgery, radiotherapy, chemotherapy, endoscopy, electrocardiography, osteotomy and bio-fluids simulation. Thus SimGrid encapsulates all simulation levels from Proteomics and Genomics up to overall body-level simulation. The SimGrid can be of importance not only in planning surgeries but also in training surgeons (Breton et al., 2005). The simulation process is quite time consuming and might require millions (or even billions) of computation cycles and terabytes of storage space, depending upon the nature of the specific simulation task. However, using Grids for this purpose could resolve the problem of computation speed to a considerable extent.

A recent study (Gonzalez-Velez and Gonzalez-Velez, 2005) presents a stochastic simulation of L-type Ca^{2+} current assuming thousands of calcium channels on the membrane of a spherical cell. The simulation runs on a dedicated Grid and employs structured parallelism techniques. Results showed hours of time saved using a computational Grid for simulation (compared to single-machine simulation runs).

GEMSS (Grid-enabled Medical Simulation Services) (Jones et al. 2004), (Benkner et al. 2005) that is concerned with the Grid-provision of advanced medical simulation applications and aims to provide a transparently accessible health computing resource suited to solving problems of large magnitude. The viability of this approach is currently being evaluated through six diverse medical applications, including maxillo-facial surgery planning, neuro-surgery support, medical image reconstruction, radiosurgery planning and fluid simulation of the airways and cardiovascular system. Without using a Grid, an accurate nonlinear simulation takes a considerably longer time (up to several hours), whereas, by allowing access to high performance computing through the Grid, the simulation time can be reduced to a level acceptable for clinical implementation (less than one hour), with the potential to improve the outcome of the surgical procedure. The GEMSS Grid infrastructure is based on standard Web Services technology with an anticipated future transition path towards the OGSA (Foster et al. 2003) standard proposed by the Global Grid Forum.

A new execution and simulation procedure for two dental applications, namely Computational Fluid Dynamics (CFD) and Computational Aero Acoustics (CAA) is proposed in (Nozaki et al., 2005), which can reduce the implementation time via Grid-enabled parallel processing. The study also reports on the design, implementation and performance evaluation of the optimal CPU resource allocation based on the total computation time of the dental application, which combines CFD and CAA as a part of a DentGrid system. The data for both the simulations is obtained by Magnetic Resonance Imaging (MRI). This DentGrid system aims to be a computation and storage power supplier for dental clinics and hospitals. Simulating dentistry operations is highly beneficial, in the sense that dentists can examine visually the post-effects of dental surgery.

The modelling of individuals is an ongoing research topic and involves the complete simulation of the human body, which is a computationally intensive task. In the field of modelling and simulation, Grid computing has the capability to accelerate the pace of the analysis/discovery process and to deliver the new results quickly and efficiently to the medical user community (Berti et al., 2003).

The application of OGSA-DAI in Simulation Grids has been discussed (Xing et al., 2006), to address the issues of integrating, controlling and accessing the different types of distributed data resources in the simulation. The databases in the simulation grid system supported the dynamic distribution of the data and model resources in the simulation environment.

OGSA-DAI has been used also as a middleware in the BioSimGrid project (Wu et al., 2004), that aims to exploit the Grid infrastructure to enable comparative analysis of the results of biomolecular simulations.

BioMedicalGrid

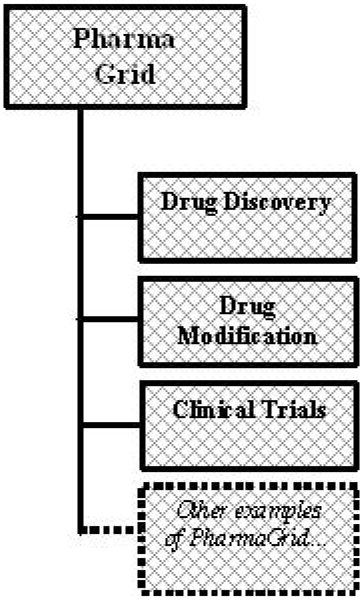
The BioGrid and MediGrid merge into the BioMedicalGrid which encapsulates features of both the Bio and Medi Grids. The main challenge faced in biomedical informatics is the development and maintenance of an infrastructure for the storage, access, transfer and simulation of biomedical information and processes. Moreover, BiomedicalGrids must be able to produce, use and deploy knowledge as a basic element of advanced applications and to achieve this, they are mainly based on Knowledge Grids and Semantic Grids (Breton et al., 2005). BiomedicalGrids will thus provide a universally accessible platform for the sharing of ever-increasing biomedical data pertaining to all the levels of healthcare such as molecule, cell, tissue, organ, patient and public health. They are expected to provide interoperability and sharing/collaboration to both the Biological and Medical domains of healthcare.

Recent research (Tirado-Ramos et al., 2005) has used *on-line application monitoring* for improved computational resource selection and application optimization. A number of user-defined performance metrics within the European CrossGrid Project's G-PM tool (CrossGrid.org, 2008), (Stevens et al., 2004) have been used to run a blood flow simulation application (solver) based on the lattice Boltzmann method for fluid dynamics. Results showed that online monitoring gives a more accurate view of computational resource status than the regular resource information provided by standard information services to resource brokers. Moreover, on-line monitoring has good potential for optimizing biomedical applications for more efficient computational runs. Other work (Alonso et al., 2005), (Tirado-Ramos et al., 2005) has shown how a BioMedicalGrid can enhance the processing of a biomedical application as well as the respective image analysis. The integration of a bio-physical model into a clinical augmented reality system is another challenging task, where Grid technology could be the key (Breton et al., 2005).

PharmaGrid

Another important type of HealthGrid is the PharmaGrid (Pharmaceutical Grid), which focuses on the management and sharing of drug-related data to support operations such as clinical trials, dose

Figure 4. Examples of PharmaGrid



computation, drug discovery, drug development, drug interactions, pathology and genomics that could be carried out in a collaborative environment to advance the quality of healthcare. Examples of PharmaGrid are shown in Figure 4.

The pharmaceutical industry is a distinct domain with specific operations and processes, and is currently faced with many challenges. There is an increasing need for more innovative products that can target more effectively today's critical diseases. At the same time, there is a growing pressure for personalised medication (by using both phenotype and genotype), a move which will increase both the effectiveness and safety of medicines, but which will eventually shrink the scale of economy and create a much more fragmented market. Furthermore, the data produced by the pharmaceutical industry is of the order of terabytes or petabytes in size and needs massive storage capacity. Moreover, various operations to do with the manufacturing of drugs and the dissemination of drug information need huge numbers of computational cycles. The results obtained from various drug experiments and clinical trials are of crucial importance and need to be delivered in a consistent and timely manner to the healthcare professionals and patients.

One of the key challenges of the pharmaceutical sector today is to manage, share and understand the medicines information in a way that facilitates and accelerates the Research & Development process. This progress suffers from poor information management due to inflexible, closed, heterogeneous, unconnected and segregated sources of information. It has now been widely recognised that Grid technology holds out the promise for a more effective means of sharing and managing information and enhancing knowledge-based processes in the Pharma R&D environment. The emerging PharmaGrid is a powerful new technology set to revolutionise the way medicines-related ("Pharma") information is used. The PharmaGrid has the potential to address the "information" problem, with many benefits for the industry, in terms of boosting innovation in drug discovery, shaping clinical trials, reducing time to market, and reducing costs. (see Figure 4)

Furthermore, Grid technologies have the potential to provide transparency and integration of information, break communication barriers, enhance communication and collaboration between the various actors (industry, regulators, healthcare and insurance providers, doctors and patients), and as a result to accelerate a large number of healthcare processes to do with pharmaceutical therapies.

Other benefits from the use of PharmaGrids include (Houghton, 2002):

- substitution of in silico for in vitro and in vivo testing;
- operation and management of clinical trials;
- monitoring post-launch usage and outcomes;
- marketing and distribution of medicines;
- e-commerce and total quality management in healthcare supplies and procurement;

- regulatory and watchdog activities;
- financial planning and cost efficiency in healthcare;
- health information services for all stakeholders;
- electronic prescription and clinical decision support tools.

Even more crucially, the Pharma industry and researchers are faced with a continuously growing amount of distributed heterogeneous information, a real explosion of experimental data, documents, article, patents, with rapidly changing terminology and analysis approaches. In order to adequately fulfil such requirements, the PharmaGrids have to meet the following challenges:

- Intelligent middleware that facilitates the user transparent access to many services and execution tasks
- High quality security features, enabling large databases to be accessed via Grid solutions
- Sophisticated semantic and contextual systems to enable diverse sources of data to be related to knowledge discovery

Thus PharmaGrids are expected to deal with all types of drug-related information such as drug features, design specifications, safety, success rate, purpose and usage, and complex operations such as clinical trials, evaluation process, experimental results, treatment, and effective trails. This information should be shared across various organizational boundaries and manipulated online.

The development of PharmaGrids is instrumental in meeting the current industry challenges, as it will provide an efficient way of exchanging and managing knowledge in a shared environment in the areas of discovery, development, manufacturing, marketing and sales of new drug therapies. Grid infrastructures are currently built upon different architectures, designs, technologies, open standards, and operating systems. PharmaGrid development is a highly complex and technically challenging activity and it should address many different problems to do with Pharma information, including knowledge-representation and integration, distributed architectures, search and access controls, data mining and knowledge management, real-time modelling and simulations, algorithm development and computational complexity. PharmaGrids will need to be scale-independent/scalable, adaptive, secure and dependable Grid infrastructures that enable the management of large networked distributed resources across different platforms of stakeholders, such as pharmaceutical companies, policy makers, R&D development companies. The required enabling technologies include amongst others semantic web and agent-mediated approaches, peer-to-peer technologies and self-organising architectures.

PharmaGrids can be part of or closely integrated with other HealthGrids. For reasons of competitiveness and intellectual property protection, PharmaGrids are predominantly private, enterprise IntraGrids with strict access and authentication controls, but there is a recognised need for cross-industry platforms (InterGrids), whereby the resulting integration will lead to more efficient coordination of activities.

Moreover, PharmaGrids open up the perspective of cheaper and faster drug development and may enable parallel processes in drug development, away from the traditional approach where the full cycle of target discovery, target validation, lead discovery, lead optimization and transition to development takes on average 12 years (Breton et al., 2005). PharmaGrids hold the promise to provide improved and efficient drug design and better control of diseases and to improve *patient safety* and *quality of healthcare*. Examples of PharmaGrids could include dedicated Grids for Drug Discovery, Drug Modification, Management and/or Running of Clinical Trials.

Another study (Tohsato et al., 2005), uses Globus Toolkit 3 and OGSA-DAI, for the federation of heterogeneous databases, for supporting a drug discovery process. Due to the rapid progress of biotechnology, there are an increasing number of life sciences databases, which need to be shared in order to conduct research collaborations, and OGSA-DAI could make this feasible.

CareGrid

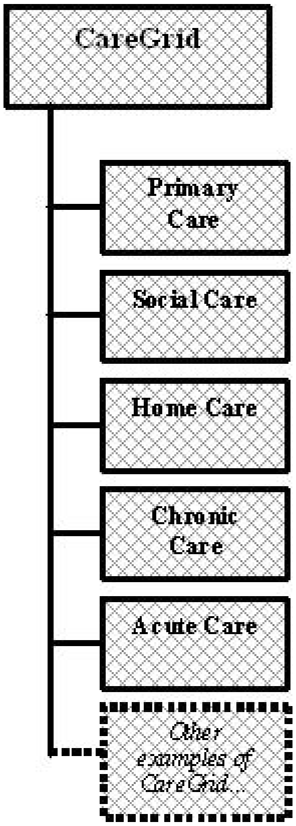
The CareGrid is designed specifically for the general public healthcare services such as patient-centred or virtual healthcare services, dose computation, self-assessment, and online health management. Services on the CareGrid could be customized according to the individual patient needs so as to provide personalized healthcare services. Moreover, the CareGrid aims to provide data management facilities and improved diagnosis.

A typical example of CareGrid is a recently implemented prototype for HealthInfoGrid (Bilykh et al., 2003). The HealthInfoGrid can also be viewed as a Service Grid and its services are designed for sharing and distributing medical information, at times of critical importance and under strict privacy and security regulations. Formalization of the interaction semantics of the HealthInfoGrid components is based on coloured Petri-nets (Jensen 1997). HealthInfoGrid has various components such as organization, staging area, initiator, translator, and merger/adder. Examples of CareGrid are shown in Figure 5.

CareGrids represent a new facet of advanced and improved healthcare that can provide personalized healthcare services at a cost-effective price. Patients can access the CareGrid to retrieve information about their own health, such as clinical tests and diagnosis, dose composition and recommendation, precautions and preventions. This would save them the time and effort spent in waiting to book appointments and all the hassle that goes with such processes.

Examples of CareGrids could include dedicated Grids for Primary Care, Social Care, Home Care, and Chronic Care.

Figure 5. Examples of CareGrid



WHAT'S NEXT IN HEALTH INFORMATICS WITH HEALTHGRIDS?

As we have seen, HealthGrids can be used to support many kinds of healthcare operations and tasks. As such, they can be made to adapt to the lifestyle choices of the patients. Patients should be more and more able to choose their living styles, keeping in mind their persistent health conditions. The future of Health Informatics with HealthGrids implementations would allow patients to take control of their own health by personalized healthcare or illness management programs, thus improving healthcare provisioning quality while lowering the costs. Particularly, future HealthGrid applications will:

- provide secure access to medical data/information distributed globally
- free-up doctors' time and provide healthcare to patients at their doorsteps
- enhance the use of various health monitoring devices, which can be plugged together via Grids to provide better quality of care
- provide active interoperability & collaboration among the various healthcare stakeholders, which is needed for the success of Health Informatics
- facilitate resource sharing

The main problems with medical information or healthcare data are that it is:

- difficult to access
- not always available
- lacks integrity & interoperability
- difficult to understand or data being obscure
- lacks sharing of distributed resources (including healthcare data)

These problems are magnified due to the dynamic nature of healthcare data which is always being modified, and changes to one part are not updated or reflected onto other parts of the system. Moreover, in Health Informatics massive datasets and heavy computation make things even more complicated. Also the health information systems need to be inter-connected. As HealthGrids are mainly DataGrids, they provide platform for data integration and facilitate interoperability among various healthcare data sources. Thus changes to one would automatically be reflected in other and healthcare information would be accessed in a timely and seamless manner.

The case for the use of Grid technology in healthcare arises mainly from the need to improve, safeguard and effectively exploit the available *life-significant medical information*, the need to protect the privacy of *personal, life-sensitive health information*, and the need to provide *integrated healthcare services* and have in place effective, global *channels of collaboration*. To do all this effectively, different types (the most suitable ones) of HealthGrids should be employed to perform different dedicated tasks with specialized features and functionalities and for this purpose a taxonomy of various HealthGrid types, described earlier in this chapter, would prove to be very useful. For long-term future, there is a need for designing various Grid-enabled applications specifically for HealthGrids. Moreover, there is a diverse range of many other services (Naseer and Stergioulas, 2006a), which can be provided on HealthGrids.

Future of Health Informatics lies in the integration, not only among various types of HealthGrids but also among the various healthcare stakeholders, in order to conduct collaborative research. It also lies in constructing new types of specialized HealthGrids, i.e. HealthGrids dedicated for specialized tasks such as anatomy, morphology, and epidemiology. Integration among various HealthGrids would allow information sharing at an advanced level where information related to one classified domain would be accessible by other domains. Future trends also follow that Grid technologies get tightly integrated with Web Services technologies (Naseer and Stergioulas, 2007).

However, the case for HealthGrid implementation in Health Informatics is not that obvious. Learning new Grid-enabled techniques, procedures, and know how about the HealthGrids applications and confidentiality of the medical data remains a challenge. Thus, if HealthGrids can take-on this challenge and provide easy and secure accessibility to the physically distributed heterogeneous data sources with simple user-friendly interfaces, then the future of Health Informatics is secure and very promising through the implementation of specialized HealthGrids.

CONCLUSION

In order to fully benefit from Health Informatics there is a need for the Healthcare data to be available, accessible, readable, understandable and most importantly reliable. Moreover, Healthcare information needs to be interoperable and shared by integrated channels of collaboration and healthcare stakeholders.

This chapter has reviewed current implementations of HealthGrids, and offered a systematic taxonomy of the HealthGrids. It has outlined the characteristic features and functionalities of HealthGrids and reflected on the need for Grid technology in healthcare. Based on their functionality, purpose, and application area, a taxonomy of HealthGrid types has been proposed constituting of four major categories. It has been shown that each serves a dedicated purpose, so as to provide the required services and to support the performance monitoring of the specified/desired tasks. Furthermore, the various types of HealthGrids have been examined on an individual basis and their representative implementations have been reviewed. In summary, this chapter gives some suggestions about the future of Health Informatics with HealthGrids.

To exploit effectively the wealth of medical information, there is an urgent need to integrate, manipulate, process, and analyse huge heterogeneous datasets from disparate sources. More systematic use of Grid technology in healthcare will not only help meet the current needs for data processing, but will ensure that future demand for even more capacity to deal with far larger volumes of data can be met.

Data security is another major issue, as healthcare data has to be protected through ethical firewalls to ensure the privacy, confidentiality and integrity of patients' data. HealthGrids deal with 'life sensitive data' and patient record is the most sensitive data resource that encompasses many critical elements related to personalized healthcare. As patient record encapsulates instances of various other entities, HealthGrids can help achieve the required levels of robustness and consistency of the patient record by provision of secure access to:

- patient's medical history
- medical images (e.g. mammograms)
- library of examples for training & diagnosis
- health support services
- drug details & clinical trials
- health information systems
- standard formats of files & information for comparative analysis

As HealthGrids can also serve as an effective channel for international collaborations, in order to incur long-term economic benefits from the implementation of HealthGrids, there is a need for interoperation and integration among various HealthGrids as shown in Figure 1. Also constructing new types of specialized HealthGrids dedicated for specific tasks would strengthen the future implementation of Health Informatics. Moreover, it has been witnessed from the study that contemporary Grid technologies such as OGSA-DAI and can prove to be a candidate solution to the problem of data federation or integration. However, work is still going on and efforts are being made towards a modernized facet of future healthcare by using HealthGrids as depicted in a prognosis for year 2013 (Silva and Ball, 2002).

As a final remark, HealthGrids hold the promise to offer accurate and reliable sources of health information that can be accessed at any time and from any place. They can and should become a major driver in the race towards successful e-Health and an important ingredient of Health Informatics which is the next generation of healthcare IT. A successfully implemented HealthGrid infrastructure could support all the facets of healthcare sector, and help realise the vision of personalized healthcare. Successful implementation of HealthGrids will have a high impact towards lower costs and greater benefits for healthcare in the long run, thus facilitating the provision of quality healthcare services cost-effectively.

REFERENCES

Alexopoulos, P., Benetou, X., Tagaris, T., Georgolios, P., & Kafentzis, K. (2007). An ontological approach for fraud detection in the healthcare domain. *In Proceedings of the International Conference on Information Technologies (InfoTech - 2007)*, Vol. 1, Bulgaria.

Aloisio, G., Cafaro, M., Fiore, S., & Mirto, M. (2005a). ProGenGrid: a grid-enabled platform for bioinformatics. *Studies in Health Technology and Informatics*, *112*, 113–126.

Aloisio, G., Cafaro, M., Fiore, S., & Mirto, M. (2005b). ProGenGrid: a workflow service infrastructure for composing and executing bioinformatics grid services. In *Proceedings of the 18th IEEE symposium on computer-based medical systems*, (pp. 555-560). Washington, DC: IEEE Computer Society.

Alonso, J. M., Hernandez, V., & Molto, G. (2005). Experiences on a large scale grid deployment with a computationally intensive biomedical application. In *Proceedings of the 18th IEEE symposium on computer-based medical systems*, (pp. 567-569). Washington, DC: IEEE Computer Society.

Benkner, S., Berti, G., Engelbrecht, G., Fingberg, J., Kohring, G., Middleton, S. E., & Schmidt, R. (2005). GEMSS: Grid-infrastructure for medical service provision. *Methods of Information in Medicine*, *44*(2), 177–181.

Berman, F., Chien, A., Cooper, K., Dongarra, J., Foster, I., & Gannon, D. (2001). The GrADS project: Software support for high-level grid application development. *International Journal of High Performance Computing Applications*, *15*(4), 327–344. doi:10.1177/109434200101500401

Berti, G., Benker, S., Fenner, J. W., Fingberg, J., Lonsdale, G., Middleton, S. E., et al. (2003). Medical simulation services via the Grid. In *Proceedings of HealthGrid Workshop 2003*. Retrieved February 1st, 2008 from http://www.ccrl-nece.de/gemss/Presentations/healthgrid.pdf

Bilykh, I., Bychkov, Y., Dahlem, D., Jahnke, J. H., McCallum, G., et al. (2003). Can grid services provide answers to the challenges of national health information sharing? In *Proceedings of the 2003 conference of the Centre for Advanced Studies on Collaborative research (CASCON '03)*, (pp. 39-53). IBM Press.

Blake, J. A., & Bult, C. J. (2006). Beyond the data deluge: Data integration and bio-ontologies. *Journal of Biomedical Informatics*, *39*(3), 314–320. doi:10.1016/j.jbi.2006.01.003

Boccia, V., Guarracino, M. R., D'Amore, L., & Laccetti, G. (2005). A grid enabled PSE for medical imaging: experiences on MedIGrid. In *Proceedings of the 18th IEEE Symposium on computer-based medical systems*, (pp. 529-536). Washington, DC: IEEE Computer Society.

Brady, J. M., Gavaghan, D. J., Simpson, A. C., Parada, M. M., & Highnam, R. P. (2003). eDiaMoND: A grid-enabled federated database of annotated mammograms. In Berman, F., Fox, G. C. and Hey, A. J. C. (eds.), *Grid computing: making the global infrastructure a reality*, (3rd Ed., pp. 923-943). Hoboken, NJ: Wiley.

Breton, V., Dean, K., & Solomonides, T. (2005). The healthgrid white paper. *Studies in Health Technology and Informatics*, *112*, 249–321.

Cannataro, M., Comito, C., Congiusta, A., & Veltri, P. (2004). PROTEUS: a bioinformatics problem solving environment on grids. *Parallel Processing Letters*, *14*(2), 217–237. doi:10.1142/S0129626404001842

Cannataro, M., Guzzi, P. H., Mazza, T., Tradigo, G., & Veltri, P. (2005). Preprocessing of mass spectrometry proteomics data on the grid. In *Proceedings of the 18th international symposium on computer-based medical systems*, (pp.549-554). Washington, DC: IEEE Computer Society.

CrossGrid.org. (2008). *CrossGrid project homepage*. Retrieved February 1st, 2008 from http://www.crossgrid.org/main.html

EGEE. (2008). *Enabling grids for e-science project*. Retrieved February 1st, 2008 from http://www.eu-egee.org/

Ellisman, M., Brady, M., Hart, D., Lin, F., Muller, M., & Smarr, L. (2004). The emerging role of biogrids. *Communications of the ACM*, *47*(11), 52–57. doi:10.1145/1029496.1029526

Ellisman, M., & Peltier, S. (2004). Medical data federation: the biomedical informatics research network. In I. Foster, and C. Kesselman, (Eds.), *The Grid: Blueprint for a New Computing Infrastructure* (2nd Ed.). San Francisco, CA: Morgan Kaufmann.

Estrella, F., Hauer, T., McClatchey, R., Odeh, M., Rogulin, D., & Solomonides, T. (2007). Experiences of engineering Grid-based medical software. *International Journal of Medical Informatics*, *76*(8), 621–632. doi:10.1016/j.ijmedinf.2006.05.005

Foster, I., Kesselman, C., Nick, J. M., & Tuecke, S. (2003). The physiology of the grid. In F. Berman, G. Fox, and T. Hey, (eds.), *Grid Computing: Making the Global Infrastructure a Reality* (pp. 217-249). New York: John Wiley & Sons.

Geddes, J., Lloyd, S., Simpson, A., Rossor, M., Fox, N., Hill, D., et al. (2005). NeuroGrid: using grid technology to advance neuroscience. In *Proceedings of the 18th IEEE symposium on computer-based medical systems*, (pp. 570-572). Washington, DC: IEEE Computer Society.

Glatard, T., Montagnat, J., & Pennec, X. (2005). Grid-enabled workflows for data intensive medical applications, pp. 537-542. In *Proceedings of the 18th IEEE symposium on computer-based medical systems*, (pp. 570-572). Washington, DC: IEEE Computer Society.

Gonzalez-Velez, V., & Gonzalez-Velez, H. (2005). A grid-based stochastic simulation of unitary and membrane Ca/sup 2+/ currents in spherical cells. In *Proceedings of the 18th IEEE symposium on computer-based medical systems*, (pp. 171-176). Washington, DC: IEEE Computer Society.

Houghton, J. (2002). Information Technology and the Revolution in Healthcare. Working paper 4, Centre for Strategic Economic Studies, Victoria University of Technology, Australia. Retrieved February 1, 2008 from http://www.cfses.com/documents/pharma/04-IT_and_Healthcare.pdfHuang, X., Huang, L. & Li, M. (2006). Grid-enabled medical image processing application system based on OGSA-DAI techniques. In *Proceedings of the International workshops on advanced Web, network technologies and Applications*, (pp. 460-464). In Shen, H. T., Li, J., Li, M., Ni, J. & Wang, W. (eds.). (LNCS, Vol. 3842). Berlin, Germany: Springer-Verlag.

Jensen, K. (1997). A brief introduction to coloured Petri Nets, pp. 203-208. (LNCS Vol. 1217).Berlin, Germany: Springer-Verlag.

Jithesh, P. V., Kelly, N., Donachy, P., Harmer, T., Perrott, R., McCurley, M., et al. (2005). GeneGrid: grid based solution for bioinformatics application integration and experiment execution. In *Proceedings of the 18th IEEE symposium on computer-based medical systems*, pp. 523-528. Washington, DC: IEEE Computer Society.

Jones, D. M., Fenner, J. W., Berti, G., Kruggel, F., Mehrem, R. A., Backfrieder, W., et al. (2004). The GEMSS Grid: An evolving HPC environment for medical applications. In *Proceedings of HealthGrid 2004*. Retrieved February 1, 2008 from http://www.ccrl-nece.de/gemss/Reports/Jones-healthgrid2004.pdf

MammoGrid. (2008). European federated mammogram database implemented on a grid structure. Retrieved February 1st, 2008 from http://mammogrid.vitamib.com

Naseer, A., & Stergioulas, L. K. (2006a). Discovering healthgrid services. In *Proceedings of the IEEE International Conference on Services Computing (SCC'06)*, (pp. 301-306). Washington, DC: IEEE Computer Society

Naseer, A., & Stergioulas, L. K. (2006b). Resource discovery in grids and other distributed environments: States of the art. *Multiagent and Grid Systems - . International Journal (Toronto, Ont.)*, *2*(2), 163–182.

Naseer, A., & Stergioulas, L. K. (2007). Combining web services and grid services: practical approaches and implications to resource discovery. In Periorellis, P. (Ed.), *Securing Web Services: Practical Usage of Standards and Specifications* (pp. 298-317). Hershey, PA: IGI Global.

National Digital Mammography Archive. (2008). Retrieved February 1, 2008 from http://www.hoise.com/primeur/05/articles/monthly/AE-PR-02-05-1.html

Nozaki, K., Akiyama, T., Shimojo, S., Maeda, S., & Tamagawa, H. (2005). Integration of computational fluid dynamics and computational aero acoustics on grid for dental applications. In *Proceedings of the 18th IEEE Symposium on Computer-Based Medical Systems*, (pp. 517-522). Washington, DC: IEEE Computer Society.

Piggott, D., Teljeur, C., & Kelly, A. (2004). Exploring the potential for using the grid to support health impact assessment modelling. *Parallel Computing*, *30*(9-10), 1073–1091. doi:10.1016/j.parco.2004.07.012

Power, D., Politou, E., Slaymaker, M., Harris, S., & Simpson, A. (2004). A relational approach to the capture of DICOM files for Grid-enabled medical imaging databases. In *Proceedings of the 2004 ACM symposium on applied computing*, (pp.272-279). New York: ACM Press.

Power, D., Slaymaker, M., Politou, E., & Simpson, A. (2005). Protecting sensitive patient data via query modification. In *Proceedings of the 2005 ACM symposium on applied computing*, pp.224-230. New York: ACM Press.

Scheres, S. H. W., Merino, A. J., Sorzano, C. O. S., & Carazo, J. M. (2005). Grid computing in 3D-EM image processing using Xmipp. In *Proceedings of the 18th symposium on computer-based medical system*, (pp. 561-563). Washington, DC: IEEE Computer Society.

Semantic grid project. (2008). Retrieved February 1, 2008 from http://www.semanticgrid.org/

Silva, J. S., & Ball, M. J. (2002). Prognosis for year 2013. *International Journal of Medical Informatics*, *66*(1-3), 45–49. doi:10.1016/S1386-5056(02)00035-7

Simpson, A., Power, D., Slaymaker, M., & Politou, E. (2005). GIMI: generic infrastructure for medical informatics. In *Proceedings of the 18th symposium on computer-based medical system*, (pp. 564-566). Washington, DC: IEEE Computer Society.

Sorzano, C. O. S., Marabini, R., Velázquez-Muriel, J., Bilbao-Castro, J. R., Scheres, S. H. W., Carazo, J. M., & Pascual-Montano, A. (2004). XMIPP: A new generation of an open-source image processing package for electron microscopy. *Journal of Structural Biology*, *148*(2), 194–204. doi:10.1016/j.jsb.2004.06.006

Stevens, R., McEntire, R., Goble, C., Greenwood, M., Zhao, J., Wipat, A., & Li, P. (2004). myGrid and the drug discovery process. *Drug Discovery Today: BIOSILICO*, *2*(4), 140–148. doi:10.1016/S1741-8364(04)02412-6

Stewart, C. A. (2004). Introduction to the edition. *Communications of the ACM*, *47*(11), 30–33. doi:10.1145/1029496.1029522

Tirado-Ramos, A., Groen, D., & Sloot, P. (2005). On-line application performance monitoring of blood flow simulation in computational grid architectures. In *Proceedings of the 18th symposium on computer-based medical system*, (pp. 511-516). Washington, DC: IEEE Computer Society.

Tohsato, Y., Kosaka, T., Date, S., Shimojo, S., & Matsuda, H. (2005). *Heterogeneous database federation using grid technology for drug discovery process*, (pp. 43-52). (LNCS Vol. 3370). Berlin, Germany: Springer-Verlag.

Vadhiyar, S. S., & Dongarra, J. J. (2005). Self adaptivity in grid computing. *Concurrency and Computation*, *17*(2-4), 235–257. doi:10.1002/cpe.927

Wu, B., Dovey, M., Ng, M. H., Tai, K., Murdock, S., Jeffreys, P., et al. (2004). A web / grid portal implementation of BioSimGrid: A biomolecular simulation database. In *Proceedings of the Information Technology: Coding and Computing*, (pp. 50-54).

Xing, L., Wang, J., & Zhou, B. (2006). Integration and access of data resources in simulation grid system. *Journal of System Simulation*, *18*(2), 369–372.

Zamboulis, L., Fan, H., Belhajjame, K., Siepen, J., Jones, A., Martin, N., et al. *Data access and integration in the ISPIDER proteomics Grid.* Retrieved February 1, 2008 from http://www.cs.man.ac.uk/~norm/papers/dils06.pdf

Zhuchkov, A., Tverdokhlebov, N., & Kravchenko, A. (2006). Advancing of Russian ChemBioGrid by bringing data management tools into collaborative environment. *Studies in Health Technology and Informatics*, *120*, 179–186.

KEY TERMS AND DEFINITIONS

Grid: a large-scale, high-performance, always-on and dynamic, although geographically distributed yet networked, infrastructure that comprises and seamlessly unifies a variety of autonomous, heterogeneous components such as processes, resources, network layers, interfaces, protocols and services, with strong, consistent and controlled relationships among them

Grid Services: a type of Grid resource (service resource) with special capabilities and features to get tasks successfully accomplished on Grid networks. These are used to access other types of Grid resources

HealthGrid: a type of Grid. It is a Grid infrastructure dedicated to the management of healthcare resources that encompasses and integrates the various Grid components and healthcare components with consistent, compatible and meaningful coordination among them, to facilitate provision of the healthcare services

Heterogeneity: a difference in format, platform, semantics or ontology

Integration or Interoperability: a link or connection that enables communication among two or more resource types

OGSA-DAI: Open Grid Service Architecture Data Access and Integration, it is a powerful technology that possesses strong features for providing interfaces to heterogeneous data sources on Grids in order to integrate them

Resource or Grid Resource: a Grid resource can be any real or conceptual object that is needed to be accessed by other entities, such as human users of the system or programmes that generate requests for accessing particular resources

Taxonomy: a classification

Web Services: considered as the most efficient and reliable communicators of messages from one place to another regardless of geographical or technological heterogeneity

This work was previously published in Handbook of Research on Advances in Health Informatics and Electronic Healthcare Applications: Global Adoption and Impact of Information Communication Technologies, edited by K. Khoumbati; Y.K. Dwivedi; A. Srivastava; B. Lal, pp. 124-143, copyright 2010 by Medical Information Science Reference (an imprint of IGI Global)

Chapter 3.14

An Evaluation of the RFID Security Benefits of the APF System:

Hospital Patient Data Protection

John Ayoade
American University of Nigeria, Nigeria

Judith Symonds
Auckland University of Technology, New Zealand

ABSTRACT

The main features of RFID are the ability to identify objects without a line of sight between reader and tag, read/write capability and ability of readers to read many tags at the same time. The read/write capability allows information to be stored in the tags embedded in the objects as it travels through a system. Some applications require information to be stored in the tag and be retrieved by the readers. This paper discusses the security and privacy challenges involve in such applications and how the proposed and implemented prototype system Authentication Processing Framework (APF) would be a solution to protect hospital patient data. The deployment of the APF provides mutual authentication for both tags and readers and the mutual authentication process in the APF provides security for the information stored in the tags. A prototype solution for hospital patient data protection for information stored on RFID bracelets is offered.

INTRODUCTION

Radio Frequency Identification (RFID) refers to an Auto-Identification system comprised of RFID tags, RFID readers and the requisite RFID middleware that interprets tag information and communicates it to the application software. RFID tags contain specific object information in their memory, accessed via radio signal of an RFID reader. RFID tags contain a microchip capable of holding stored information, plus a small coiled antenna or transponder (Psion, 2004).

In the APF (Authentication Processing Framework) implementation (Ayoade 2005) an Omron's RFID tag "V720S-D13P01" was used. It is a passive tag that has read and write tag memory capability. The memory capacity of this tag is 112 bytes (user area). This means it has EEPROM/RAM memory capability. The reader used was manufactured by FEIG electronic (ID ISC MR 100). It has a frequency of 13.56 MHZ. This type of RFID system was used because its frequency has the widest application scope and it is the most widely available high frequency tag world-wide. Its typical read range is approximately 1m.

APF is a system that could allow many readers to read from and write to the RFID tags and it prevents unauthorized readers from reading information from the tags without the knowledge of the tags.

In a nutshell, APF prevents privacy violation of information in the RFID system. The APF system was developed based on the existing typical RFID system and will therefore work with the existing system.

In the RFID system, many proposals have been presented to solve common privacy and security problems, however, these proposals face one disadvantage or another, making them insufficient to completely address the problems in question. We agreed that a simple approach for dealing with the problem of privacy is to prevent readers from receiving data coming from tags (Avoine, 2004). However, as mentioned earlier, all the propositions to date have one disadvantage or another.

RFID technology can be used to collect a lot of data related to persons, objects or animals, thus there are data protection concerns. The first type of risks arises when the deployment of RFID is used to collect information that is directly or indirectly linked to personal data. In a digital world, collecting and analyzing personal data is a task that computers and agents can do diligently. This is an issue connected to ICT in general, rather than to RFID specifically. It is mainly the widespread use of RFID, and its use in mobile situations accompanying persons that could lead to unpredictable situations – and thus unpredictable threats (ECISM 2006).

A second type of privacy implication arises where personal data is stored in RFID tags. Examples of this type of use can be found in passports or RFID-based health records. The relative openness of the area where the application is deployed will greatly influence the options to illicitly access the data (ECISM 2006).

A third type of data protection implication arises from uses of RFID technology which entail individual tracking. As soon as a RFID-profile is known (because the tags are linked to personal data) the comings and goings of people could be followed. This is possible for company-level applications (e.g. by using access cards), but could theoretically also be used in tracking where you are. This could be in your car (if the car or clothes are tagged, as also indicated in the example), or in person, in public locations (ECISM, 2006). This could have implications for people who could come to harm if their health records were to be accessed such as in the case of HIV/AIDS, mental illness, past medical history or even pregnancy.

THE PROPOSED CONCEPT OF THE AUTHENTICATION PROCESSING FRAMEWORK

A framework that will authenticate readers before they can access the information stored in tags was proposed in (Ayoade, 2004). The proposed procedure is called Authentication Processing Framework - APF. The main concept of this framework is that tags and readers will register with the APF database which will authenticate readers prior to reading data stored on RFID tag. Implementing this kind of framework in the RFID system will alleviate security and privacy concerns.

Overview of the APF System

The APF was proposed to deter the data security problem in the RFID system.

APF is a framework that makes it compulsory for readers to authenticate themselves with the APF database before they can read the information in the registered tags.

Figure 1, shows that APF system comprises of four application segments:

i. The Tag Writer's (writer application) is the part of the APF that encrypts the information in the tag and produces the decryption key which will be submitted along with its identification number, to the APF database.
ii. The Reader's Application queries the tag and registers readers' identification number with the APF database. This is also the part of the system that uses the decryption key to decrypt the information after it has been authenticated by the APF database.
iii. The Authentication's Application is the part of the system that integrates both the reader application and the APF database maintenance application.
iv. The Maintenance's Application is the part of the system that maintains the APF database.

APF System Operation and Methods

The tag writer (writer application) subsystem reads tags in its vicinity and then generates a randomized encryption key. The next step is to input and encrypt the information into the tag for security purposes. The next paragraph explains how the authentic tag reader (reader application) subsystem reads the encrypted information in the tag.

The reader subsystem sends a "challenge" command to the tag in its vicinity (just as any typical RFID reader will read the information in the tag within its vicinity) and the tag responds with its unique identification and the content of the information in it. However, in case of the APF system, the content of the information stored in the tags is encrypted. This means the reader can not decrypt the information in the tag without the decryption key which is kept in the APF database system.

The next stage of the operation is that the reader will submit its ID to the APF database subsystem. Then, the APF key inquiry subsystem will check whether or not the reader is authorised to be granted the decryption key to have access to a particular tag. If it is authorised, the decryption

Figure 1. The functional diagram of the APF

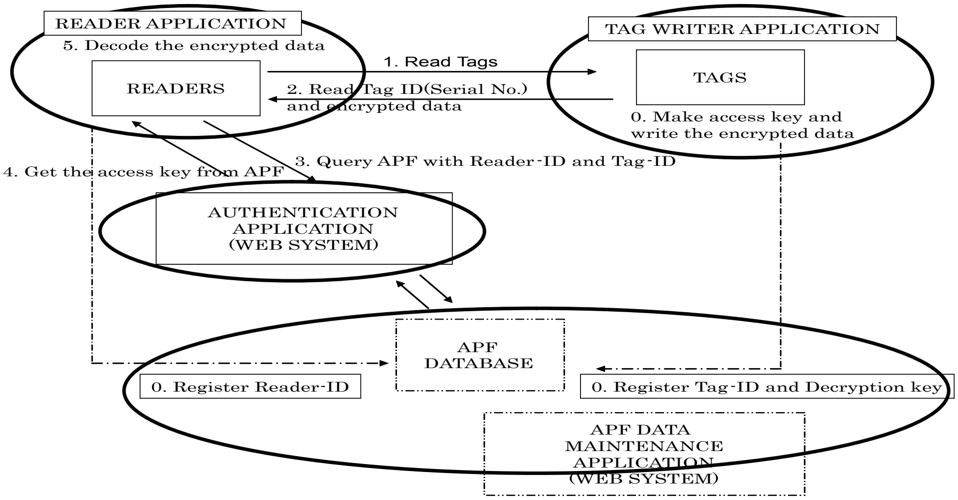
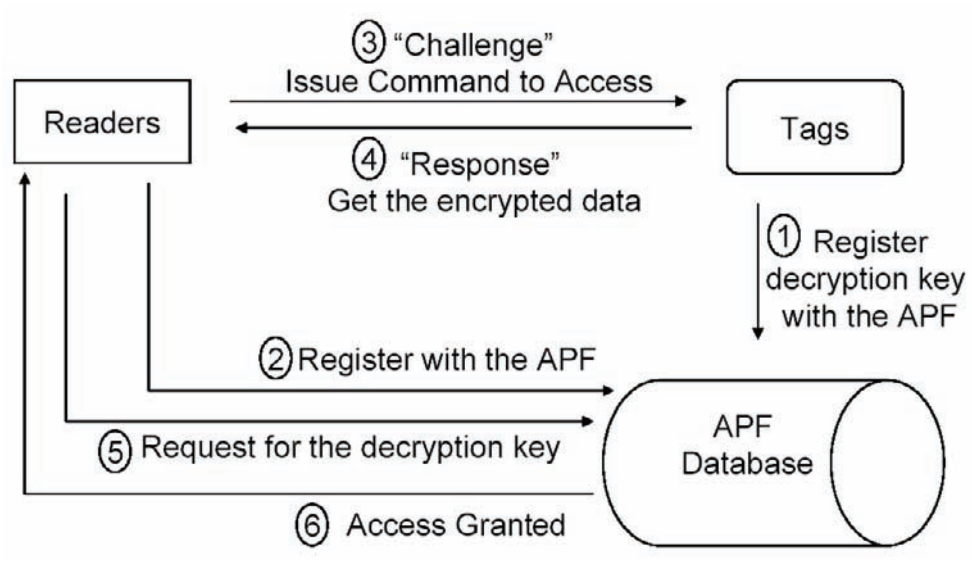


Figure 2. The flowchart of the APF



key will be granted and the reader will be granted access and if not, the decryption key will be denied and the reader will not be able to decrypt the information stored in the tag.

The Methodology of the APF System

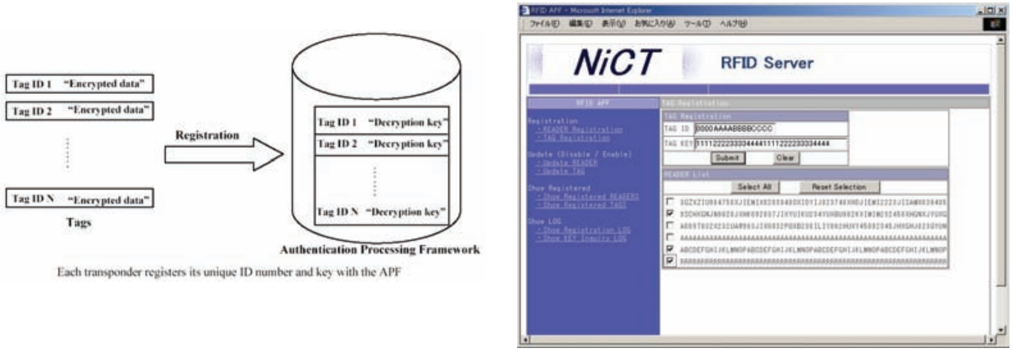
Figure 2 is the step by step representation of the APF. Initially, tags will register their identification numbers and the decryption keys with the APF database. Also, readers will register their identification numbers with the APF database. Normally, readers will send a "challenge" command in order to access the information in the tags. However, with the APF protocol, tags will send a "response" command consisting of the tags' identification numbers and the encrypted data to the readers. The response message from the tag will instruct the reader to get the decryption key from the APF database in order to decrypt and read the data in the tag. Since, authenticating readers would have registered with the APF database then, only authenticating readers would be given the decryption key to decrypt the encrypted data in the tags.

In order to prevent illegal access to the information stored in the tags there should be a procedure for access control to the information stored in the tags. As shown in Figure 3, and discussed above, each tag will register its unique ID and decryption key with the APF database. This is necessary for the protection of tags from unscrupulous readers that may have ulterior intentions. Once a tag registers its unique identity and decryption key with the APF, it will be difficult for unregistered readers to have access to the data in the tag without possessing the decryption key to the tag. This means every registered reader will be authenticated prior to getting the decryption key to access stored data in the tag.

In the next paragraph we discuss how the authenticated reader would have access to stored data in the tag.

Every reader will register its identification number with the APF in order for it to be authenticated prior to the time the reader will request the decryption key to access the data in the tag. In a nutshell, every reader will register its unique identification number with the APF and this will be confirmed by the APF before releasing the

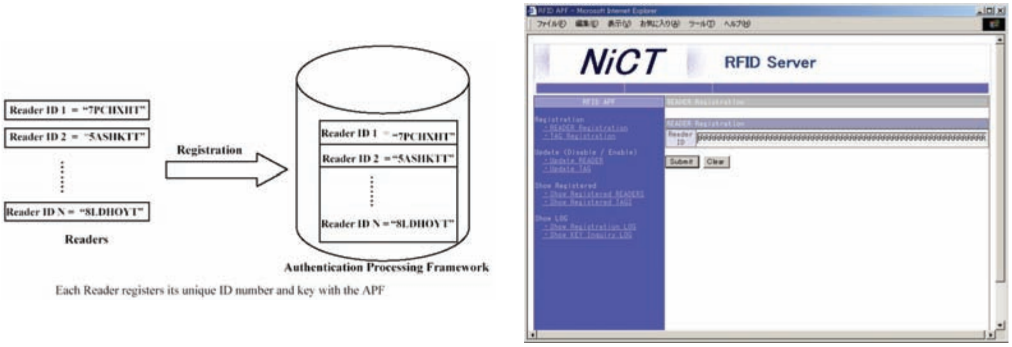
Figure 3 The registration of tags with the APF



TAG ID: 0000AAAABBBBCCCC

TAG KEY: 11112222333344441111222233334444

Figure 4 The registration of readers with the APF

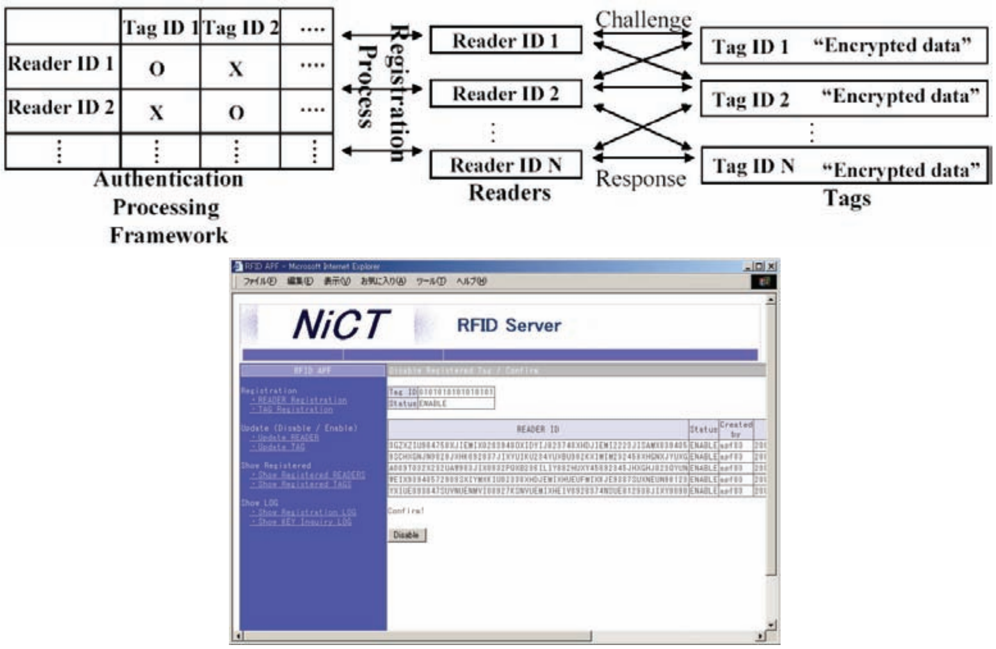


decryption key to the reader in order to read the encrypted data in the specific tag.

Figure 4 shows that every reader registers its unique identification number with the APF. However, since both readers and tags register their identification numbers with the APF, this serves as mutual authentication and it protects the information in the tags from malicious readers which is one of the concerns users have. This means that unauthorized access to the tag will be almost impossible if the APF system is correctly implemented. In the next paragraph the authors of this paper discuss the registration and access control of readers to the APF.

In the previous paragraphs, the authors of this paper discuss the registration of the tags' unique ID and the decryption key with the APF. Also, we discuss the registration of readers with the APF prior to accessing the information in the tags. When the reader sends a "read" command to the tag, it replies with its identification number and encrypted data. In this case the data is encrypted and the reader registered with the APF will be able to get the decryption key in order to decrypt the data. Once the key is received the data in the tag will be readable. In this framework there are two important processes: first, mutual authentication is carried out by the APF because it authenticates the reader and the tag; secondly, privacy is guaranteed because the data stored in the tag is protected from malicious readers. Since, the information the reader obtained from the tag is encrypted, it can only be read after the decryption key needed to access the information is received from the APF.

Figure 5. The registration/access control of readers to the APF/Tag



Tag ID 0101010101010101
Status ENABLE

READER ID	Status	Created by
[illegible]	ENABLE	apf03
[illegible]	ENABLE	apf03
[illegible]	ENABLE	apf03
[illegible]	ENABLE	apf03
[illegible]	ENABLE	apf03

Confirm!

Note: O-means access granted X-means access denied

APPLICATION OF THE APF

The APF described in this paper has many applications. For example, it can be deployed in the supply chain management, or in granting or in restricting access to information for certain groups of people in a hospital. This has been a major concern in many large hospitals (RFIDGazette, 2004). The APF could help to control these security concerns. Take for example, in a hospital where the RFID system is used. The APF will guarantee total data security of the information in the tag from malicious readers because every authentic reader will register its ID with the APF prior to reading the information in the tags and all tags that will be read by those readers will register with the APF. This means that there will be mutual authentication and the information in the tags will be secure.

One of the areas in which the APF could be deployed in a hospital is for the protection of medical records.

In (Patient Tracking, 2005), the implementation of a RFID system for hospital asset management was discussed. Such RFID systems may be used to track patients, doctors and expensive equipment in hospitals. The RFID tags can be attached to the ID bracelets of all patients, or just patients requiring special attention, so their location can be monitored continuously.

One of the benefits of the above mentioned system is the use of the patient's RFID tag to access a patient's information for review and update via hand-held computer or PDA (Patient Tracking, 2005). In such applications there is a tendency for unauthorized readers to access the information stored in a patient's tag. This is obviously of great concern to patients. In order to prevent this kind of problem, the APF would offer secure solutions.

Hospital patient data is not easily protected by the currently available security measures already discussed. The Kill Command would not work because the data does not have a finite life as products on a shop shelf do. The Faraday Cage

Approach would not be practical as a metal mesh or foil container would make an RFID bracelet very difficult to work with and to wear. Active Jamming would be dangerous and would interfere with other systems in a hospital environment. Similarly, the Blocker tag method would interfere with other systems in the hospital environment. Therefore, hospital patient data is a good case study for the APF because conventional privacy and security measures are not appropriate for application and the problem is hindering the development of RFID patient care systems in hospitals.

The APF Case Study

This experimental case study was carried out to test the possibility of deploying the APF to deter illegal access by unauthorized readers to RFID tags containing medical records of patients. Figure 6 is a screenshot of the tag writer (writer application) application and it shows the practical possibility of using RFID tags for storing the medical record of patients in the hospital. However, patients will not want their medical record accessed by an unauthorised person because they want their privacy protected from others except their doctor.

Moreover, with a typical RFID system anybody who has a reader can access the information in the tag within its read or write vicinity. This means that any patient that has their confidential information stored in the tag is prone to abuse and invasion of privacy.

However, using the APF, the information stored in the tag will be encrypted in order to secure it from unauthorized readers. This is the underline text shown in Figure 6. As Figure 6 shows the APF tag writer (writer application) subsystem reads the Tag ID in its vicinity, then generates a random encryption key. The encryption key is used to encrypt the plaintext information about the patient about to be written to the tag. After the encryption of the information, the encrypted text will be written into the tag. This information will be secured from unauthorized readers, unlike a typical RFID system.

Figure 7 shows that readers have to be registered. This means that, only readers registered in APF database can access the information in the tag. In this case study it was demonstrated that readers unregistered in the APF database would not be able to access the medical records stored in the tag. Once an authenticating reader is opened, then the tag reader (reader application), has to obtain the decryption key of the encrypted information stored in the tag. However, prior to that it needs to send its ID to the APF database and the APF database will check whether or not it is an authenticating reader and once that is confirmed the decryption key will be released for it to access the encrypted information stored in the tag, provided it is an authentic reader. However, if it is not an authenticating reader, the reader will be denied access to the stored information. This is shown in Figure 8.

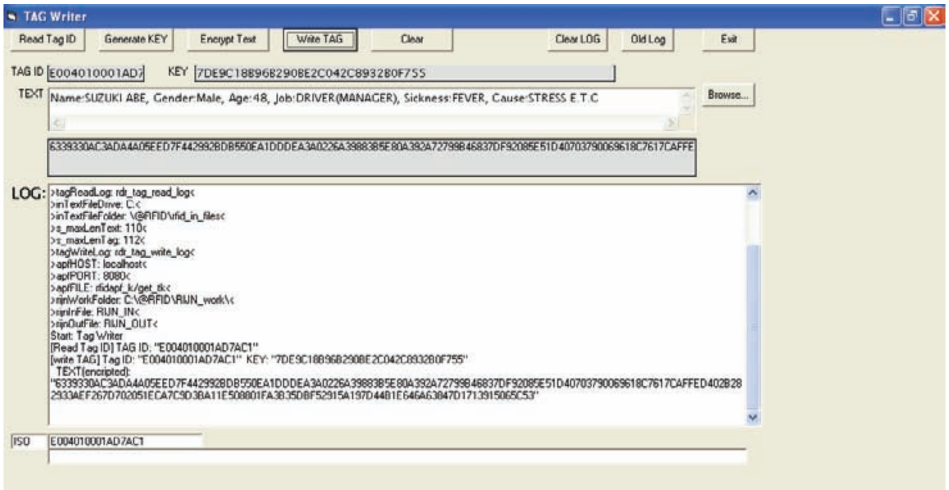
In this case study, the authors assumed that the patient's doctor alone will be in control of the three application subsystems that is: the tag writer (writer application), the tag reader (reader application), and the APF protected application software.

Thus, the patient whose information is stored within the APF protected system can rest assured that their confidential medical information stored in their tag are secure from violation of unauthorized readers.

There are a number of well-established RFID security and privacy threats:

i. **Sniffing:** RFID tags are designed to be read by any compliant reading device. Tag reading may happen without the knowledge of the tag bearer or from a far distance from the bearer of the tag (Rieback, 2006). In the APF system, sniffing threat is considered to be very difficult because with the deployment of the APF system every reader that will be part of the system will register and be

Figure 6. The tag-writer application



TAG ID E004010001AD7

KEY 7DE9C18B96B290BE2C042C8932B0F755

TEXT Name:SUZUKI ABE, Gender:Male, Age:48, Job:DRIVER(MANAGER), Sickness:FEVER, Cause:STRESS E.T.C

6339330AC3ADA4A05EED7F442992BDB550EA1DDDEA3A0226A3988385E80A392A72799B46837DF92085E51D40703790069618C7617CAFFE

```
>tagReadLog: rdr_tag_read_log<
>inTextFileDrive: C:<
>inTextFileFolder: \@RFID\rfid_in_files<
>s_maxLenText: 110<
>s_maxLenTag: 112<
>tagWriteLog: rdr_tag_write_log<
>apfHOST: localhost<
>apfPORT: 8080<
>apfFILE: rfidapf_k/get_tk<
>rijnWorkFolder: C:\@RFID\RIJN_work\<
>rijnInFile: RIJN_IN<
>rijnOutFile: RIJN_OUT<
Start: Tag Writer
[Read Tag ID] TAG ID: "E004010001AD7AC1"
[write TAG] Tag ID: "E004010001AD7AC1"  KEY: "7DE9C18B96B290BE2C042C893280F755"
  TEXT(encripted):
"6339330AC3ADA4A05EED7F442992BDB550EA1DDDEA3A0226A39883B5E80A392A72799B46837DF92085E51D40703790069618C7617CAFFED402B28
2933AEF267D702051ECA7C9D38A11E508801FA3835DBF52915A197D44B1E646A63847D1713915065C53"
```

ISO E004010001AD7AC1

mutually authenticated before such reader could be functional or carry out any operation. In essence, it will be impossible for just any reader to function within the APF system and that will make sniffing threat to be difficult.

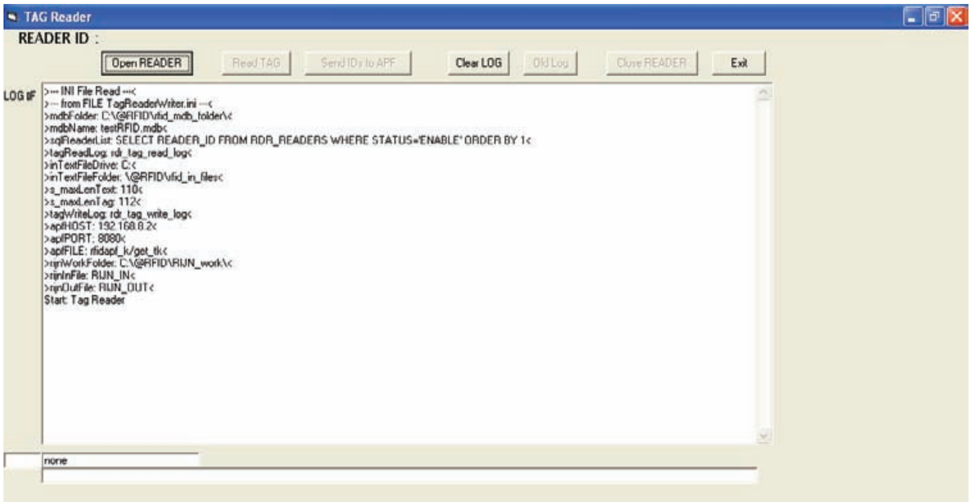
ii. **Tracking:** RFID readers in strategic locations can record sightings of unique tag identifiers (or "constellations" of non-unique tag IDs), which are then associated with personal identities. The problem arises when individuals are tracked involuntarily. Subjects may be conscious of the unwanted tracking (i.e. school kids, senior citizens, and company employees), but that is not always necessarily the case (Rieback 2006). The purpose and goal of the architectural framework design of the APF system is to protect and secure the data content stored in the tag and therefore the focus is not to protect the tracking threat that is possible through the readers associating personal identities with the tag ID's.

iii. **Spoofing:** Attackers can create "authentic" RFID tags by writing properly formatted tag data on blank or rewritable RFID transponders. One notable spoofing attack was performed by researchers from John Hopkins University and RSA Security (Rieback 2006). Spoofing will be difficult or almost impossible because even if the tag ID is spoofed the content of the tag is encrypted and that means without the decryption key from the APF system the content of the tag will not be readable. Therefore, without the mutual authentication between the authenticated reader and the APF system, the content of the spoofed tag is useless.

iv. **Replay attacks:** Attackers can intercept and retransmit RFID queries using RFID replay devices. These transmissions can fool digital passport readers, contactless payment systems, and building access control stations. Fortunately, implementing challenge response authentication between the RFID tags and back-end middleware improves the situation (Rieback 2006). Replay attack will be difficult with the deployment of the APF system because the APF system employs mutual authentication process between the tags and the readers.

v. **Denial of Service:** is when RFID systems are prevented from functioning properly. Tag reading can be hindered by Faraday cage or "signal jamming", both of which prevent

Figure 7. The reader application



```
>--- INI File Read ---<
>--- from FILE TagReaderWriter.ini ---<
>mdbFolder: C:\@RFID\rfid_mdb_folder\<
>mdbName: testRFID.mdb<
>sqlReaderList: SELECT READER_ID FROM RDR_READERS WHERE STATUS='ENABLE' ORDER BY 1<
>tagReadLog: rdr_tag_read_log<
>inTextFileDrive: C:<
>inTextFileFolder: \@RFID\rfid_in_files<
>s_maxLenText: 110<
>s_maxLenTag: 112<
>tagWriteLog: rdr_tag_write_log<
>apfHOST: 192.168.8.2<
>apfPORT: 8080<
>apfFILE: rfidapf_k/get_tk<
>rijnWorkFolder: C:\@RFID\RIJN_work\<
>rijnInFile: RIJN_IN<
>rijnOutFile: RIJN_OUT<
Start: Tag Reader
```

```
none
```

Note: Readers need to declare their IDs prior to reading the information in the tag

Figure 8. The reader application

READER ID : 3GZXZIU984758XJIEMIX0283948OXIDYIJ823748XHDJIEMI2223JISAMX839405

```
[from APF] READER_ID: "3GZXZIU984758XJIEMIX0283948OXIDYIJ823748XHDJIEMI2223JISAMX839405"  TAG_ID : "E004010001AD7AC1"
  KEY: "7DE9C18B96B290BE2C042C8932B0F755"
[decrypted TEXT] "Name:SUZUKI ABE, Gender:Male, Age:48, Job:DRIVER(MANAGER), Sickness:FEVER, Cause:STRESS E.T.C"
Close READER : 3GZXZIU984758XJIEMIX0283948OXIDYIJ823748XHDJIEMI2223JISAMX839405
Open READER : 9SCHXGNJN9028JXHK092837JIXYUIKU234YUXBU982KXIMIM232458XHGNXJYUXG
[TAG READ] TAG ID : "E004010001AD7AC1"
  CONTENTS :
"6339330AC3ADA4A05EED7F442992BDB550EA1DDDEA3A0226A3988385E80A392A72799B46837DF92085E51D40703790069618C7617CAFFED402B28
2933AEF267D702051ECA7C9D3BA11E508801FA3B35DBF52915A197D44B1E646A63847D1713915065C53"
[-- Skip --] TAG ID : "E004010001AD7AC1"
[TAG READ] TAG ID : "E004010001AD7AC1"
  CONTENTS :
"6339330AC3ADA4A05EED7F442992BDB550EA1DDDEA3A0226A3988385E80A392A72799B46837DF92085E51D40703790069618C7617CAFFED402B28
2933AEF267D702051ECA7C9D3BA11E508801FA3B35DBF52915A197D44B1E646A63847D1713915065C53"
[to APF] READER_ID: "9SCHXGNJN9028JXHK092837JIXYUIKU234YUXBU982KXIMIM232458XHGNXJYUXG"  TAG_ID : "E004010001AD7AC1"
[from APF] READER_ID: "9SCHXGNJN9028JXHK092837JIXYUIKU234YUXBU982KXIMIM232458XHGNXJYUXG"  TAG_ID : "E004010001AD7AC1"
  ERR: "Error: READER Not Registered."
--- Skip this TAG ---
Close READER : 9SCHXGNJN9028JXHK092837JIXYUIKU234YUXBU982KXIMIM232458XHGNXJYUXG
Open READER : 3GZXZIU984758XJIEMIX0283948OXIDYIJ823748XHDJIEMI2223JISAMX839405
[TAG READ] TAG ID : "E004010001AD7AC1"
  CONTENTS :
"6339330AC3ADA4A05EED7F442992BDB550EA1DDDEA3A0226A3988385E80A392A72799B46837DF92085E51D40703790069618C7617CAFFED402B28
2933AEF267D702051ECA7C9D3BA11E508801FA3B35DBF52915A197D44B1E646A63847D1713915065C53"
[to APF] READER_ID: "3GZXZIU984758XJIEMIX0283948OXIDYIJ823748XHDJIEMI2223JISAMX839405"  TAG_ID : "E004010001AD7AC1"
[from APF] READER_ID: "3GZXZIU984758XJIEMIX0283948OXIDYIJ823748XHDJIEMI2223JISAMX839405"  TAG_ID : "E004010001AD7AC1"
  KEY: "7DE9C18B96B290BE2C042C8932B0F755"
[decrypted TEXT] "Name:SUZUKI ABE, Gender:Male, Age:48, Job:DRIVER(MANAGER), Sickness:FEVER, Cause:STRESS E.T.C"
```

```
E004010001AD7AC1
6339330AC3ADA4A05EED7F442992BDB550EA1DDDEA3A0226A3988385E80A392A72799B46837DF92085E51D40703790069618C7617CAFFED402B282
```

Note: Authenticating reader declares its ID and accesses the decrypted information. Also, an unregistered reader declares its ID and is denied access to the information

radio waves from reaching RFID tagged objects. Denial of Service (DoS) can be disastrous in some situations, such as when trying to read medical data from VeriMed subdermal RFID chips in the trauma ward at the hospital (Rieback, 2006). The DoS is a difficult threat to handle most especially when it is through "signal jamming".

Furthermore, an attacker can spy out data in a situation in which he uses his own reader to read data from the tags. The device can be installed in a hidden place, or it can be used in a mobile manner (Oertel 2004). In case of the APF system mutual authentication is required between the reader and the tag and this made it difficult for attacker to falsify the identity of the reader because every reader has its unique identity number. Also, the attacker can change the contents of the tag but not the ID (serial number) of an existing tag. This is only possible if the data associated with the ID are stored on the tags themselves (and not in the backend). In this kind of scenario, deployment of the APF secures the application from attackers because the information stored in the data is encrypted.

We will briefly describe some of the approaches and their adverse effects:

a. **The Kill Command:** The standard mode of operation proposed by the AutoID Center is for tags to be "killed" upon purchase of the tagged product. With their proposed tag design, a tag can be killed by sending it a special "kill" command. However, there are many environments in which simple measures like this are undesirable for privacy enforcement. For example, consumers may wish RFID tags to remain operative while in their possession (Liu 2003).
b. **Faraday Cage Approach:** An RFID tag may be shielded from scrutiny using what is known as a Faraday Cage - a container made of metal mesh or foil which is impenetrable to radio signals (of certain frequencies). There have been reports that some thieves have been using foil-lined bags in retail shops to prevent shoplifting-detection mechanisms (Liu 2003).
c. **Active Jamming:** An active jamming approach is a physical means of shielding tags from view. In this approach, the user could use a radio frequency device which actively sends radio signals so as to block the operation of any nearby RFID readers. However, this approach could be illegal for example if the broadcast power is too high it could disrupt all nearby RFID systems. It could also be dangerous and cause problems in restricted areas like hospitals (Juels 2003).
d. **The Blocker tag:** The blocker tag is the tag that replies with simulated signals when queried by reader so that the reader can not trust the received signals. Like active jamming, however, it may affect other legal tags (Juels 2003).

All these approaches could have been effective solutions to the privacy problem but the disadvantages make them unacceptable. In this paper, we propose that a good authentication procedure will be the best option to tackle this problem. The reason is that our proposed solution - APF - provides solutions to the privacy problem and enhances the security of RFID systems. However, in this paper we identified the specific area of application in which the APF system could be used.

THE SCENARIO OF THE AUTHENTICATION PROCESSING FRAMEWORK IN THE HOSPITAL

According to (Parkinson, 2007) hospital patients are used to wearing wristbands, but now those bands have gone high-tech. At the Birmingham Heartlands hospital patients wear RFID wristbands that carry personal data embedded. When they arrive they have a digital photo taken and loaded on to an electronic tag contained in a wristband worn throughout their stay. Staff dealing with the tagged patients has access to PDAs with which they can scan the bands and also access patient details, via wifi, from a secure area on the hospital's central computer system. A 'traffic light' system flashes up when a patient is ready for their operation, and as they go through the theater's doors, a sensor reads the bar code on their wrist and their details are displayed on the theater's computer screen (Parkinson, 2007).

This is the type of RFID application scenario in the hospital which requires the APF systems implementation. The information stored in the wristbands of the patients needs to be protected from various potential security threats. The authors of this paper believe the deployment of the APF system will serve as a deterrent and countermeasures to such security vulnerabilities. From the above scenario, without necessary security countermeasures such as the one APF system will be providing, it means anybody with the PDA that has a reader can read the information stored in the tag about the tagged patients within or around the hospital without the consent or awareness of the patients.

In the APF system every reader will be an authenticating reader which means any other reader will not be able to access the data in the tags associated with the APF system.

CONCLUSION

The potential applications of the RFID system may be identified in virtually every sector of industry, commerce and services where data is to be managed. However, RFID systems have faced widespread resistance due to lack of privacy (Kumar, 2003). This calls for a prompt and concrete solution for the full realization of the RFID system's potential.

This research focuses on an experimental prototype system that uses fictitious data. Future research will seek to implement and test a small implementation with live data and applications as proof of concept. Rigorous testing could investigate whether this system can in fact stand up to the security and privacy threats established earlier in this paper such as sniffing, tracking, spoofing and denial of service attacks.

Future development might also include expansion beyond hospital patient data. For example, where RFID tags might implanted into human flesh for every day use to access property and vehicles. This will open up the RFID market place to longer range RFID tags and readers to replace the current short range (7-10cm) equipment.

Regarding the issue of scalability, the APF system will register only tags and readers that are necessary for a particular application. It will not register tags and readers that are not related to that particular application.

Furthermore, the traffic flows of steps ⑤ and ⑥ in Figure 2 will be encrypted by a secure sockets layer in order to protect the information decrypted by the authenticating reader from being exploited maliciously.

The authors are convinced that the APF system will go a long way to defuse the fears and concerns that consumers have regarding the present lack of privacy in the RFID system. Moreover, in the prototype system the authors extended his research to employ Secure-HTTP and SSL protocols for the protection of the APF database. The authors further their research work on how the APF database will be protected from various malicious attacks.

In summary, the application of the APF system for securing patients medical records in hospitals will be a secure system that will prevent the invasion and abuse of a patient's confidential information. It is believed that the deployment of the RFID system for the management of medical records in hospitals will enhance the efficiency and accuracy of medical treatment. However, without employing effective privacy and security protection for the confidential information stored in the tag, privacy problems will negate the benefits that RFID offers. In conclusion, the authors believe that the application of the APF system is an effective solution to patients' privacy concerns regarding their confidential information stored and has a wide range of other potential applications.

REFERENCES

(Avoine 2004) Avoine J., Oechslin P. "RFID Traceability: A Multilayer Problem" http://fc05.ifca.ai/p11.pdf (2004)

(Ayoade 2004) Ayoade J., "Security and Authentication in RFID" The 8th World Multi-Conference on Systemics, Cybernetics and Informatics, U.S.A (2004).

(Ayoade 2005) Ayoade J., Takizawa O., Nakao K. "A prototype System of the RFID Authentication Processing Framework" International Workshop on Wireless Security Technology (2005) http://iwwst.org.uk/Files/2005/Proceedings2005.pdf

(ECISM 2006) Consultation Initiatives on Radio Frequency Identification (RFID) "RFID Security, Data Protection and Privacy, Health and Safety Issues" http://www.rfidconsultation.eu/docs/ficheiros/Framework_paper_security_final_version.pdf

(Juels 2003) Juels A., Rivest R., Szydlo "The Blocker Tag: Selective Blocking of RFID Tags for Consumer Privacy" http://www.rsasecurity.com/rsalabs/staff /bios/ajuels/publications/blocker/blocker.pdf (2003)

(Juels 2005) Juels A., Molnar D., Wagner D. "Security and Privacy Issues in E-passports" http://eprint.iacr.org/2005/095.pdf (2005)

(Kumar 200) Kumar R., "Interaction of RFID Technology and Public Policy" (2003)

http://www.rfidprivacy.org/2003/papers/kumar-interaction.pdf

(Liu 2003) Liu D., Kobara K., Imai H. "Pretty-Simple Privacy Enhanced RFID and Its Application" (2003)

(Molnar 2006) Molnar D. "Security and Privacy in Two RFID Deployments, With New Methods for Private Authentication and RFID Pseudonyms" http://www.cs.berkeley.edu/~dmolnar/papers/masters-report.pdf (2006)

(Oertel 2004). Oertel B., Wolf M. "Security Aspects and Prospective Applications of RFID Systems" (2004)

(Parkinson 2007) Parkinson C. "Tagging improves patient safety" BBC News http://news .bbc.co.uk/2/hi/health/6358697.stm

(Patient Tracking 2005) "RFID in Hospitals – Patient Tracking " http://www.dassnagar.com/Software/AMgm/RF_products/it_RF_hospitals.htm (2005)

(Psion 2004) Understanding RFID and Associated Applications Http://wwwpsionteklogix.com (the page is dynamic) May,2004

(RFIDGazette 2004) "RFID in the Hospital" Http://www.rfidgazette.org/2004/07/rfid_in_the_hos.html (2004)

(Rieback 2006) Rieback M. Crispo B. Tanenbaum A. "Is your cat Infected with a Computer Virus" http://www.rfidvirus.org/papers/percom.06.pdf (2006)

This work was previously published in International Journal of Advanced Pervasive and Ubiquitous Computing, Vol. 1, Issue 1, edited by J. Symonds, pp. 44-59, copyright 2009 by IGI Publishing (an imprint of IGI Global).

Chapter 3.15

Modeling and Analysis of Surgery Patient Identification Using RFID

Byungho Jeong
Chonbuk National University, Korea

Chen-Yang Cheng
Tunghai University, Taiwan

Vittal Prabhu
The Pennsylvania State University, USA

ABSTRACT

This article proposes a workflow and reliability model for surgery patient identification using RFID (Radio Frequency Identification). Certain types of mistakes may be prevented by automatically identifying the patient before surgery. The proposed workflow is designed to ensure that both the correct site and patient are engaged in the surgical process. The reliability model can be used to assess improvements in patients' safety during this process. A proof-of-concept system is developed to understand the information flow and to use information in RFID-based patient identification. Reliability model indicates the occurrences of patient identification error can be reduced from 90 to as low as 0.89 per 10,000 surgeries using the proposed RFID based workflow.

INTRODUCTION

Improvement in patient safety in medical care continues to be a very important issue in the medical care community. According to an Institute of Medicine (IOM) report, 44,000 to 98,000 people die each year as a result of preventable medical errors (Kohn, Corrigan, & Donaldson, 1999). The percentage of hospital inpatient admissions experiencing adverse events has been estimated at 3.7% in the U.S., 16.6% in Australia, and 10% in the UK (MF & JD, 2004). Various types of medical errors occur during the course of healthcare delivery, such as improper transfusions, wrong-site surgery, and mistaken patient identities. High error rates with serious consequences are most likely to occur in intensive care units, such as operating rooms and emergency departments ("What an unbelievable surgery!-Perform an operation with exchanged charts", 2006). Many of these medical errors are due mainly to avoidable human errors that can be potentially eliminated by proper design and error-proofing of the associated workflow. Surgery generally involves the execution of many complex tasks and each task is composed of multiple steps. The most common human error in the medical process is unintentional omission of one or more steps, especially when there are a large number of steps (Reason, 2002).

Patient identification is one of the necessary processes performed prior to anesthesia and surgery. Errors in this process can lead to unrecoverable medical accidents and there are numerous such accidents reported ("What an unbelievable surgery!-Perform an operation with exchanged charts", 2006). One instance of such an error involved intake nurses and surgery doctors: two patients—one with thyroid cancer and one with stomach cancer—had their identities exchanged in the surgery. As a result, the thyroid of the patient with stomach cancer was removed and the stomach of the patient with thyroid cancer was removed. There are other instances where medical doctors have reported performing invasive procedures on the wrong patients (Mark R. Chassin & Elise C. Becher, 2002).

The IOM report revealed that the majority of medical errors are not caused by individual recklessness or the actions of a particular group (Kohn, Corrigan, & Donaldson, 1999). More commonly, faulty systems, processes, and conditions lead people to make mistakes or fail to prevent them. Therefore there is a need to design and error-proof workflow systems that render human error essentially impossible or at least extremely difficult (Etchells, O'Neill, & Bernstein, 2003). Barcode system such as the Global Service Relation Number (GSRN) from GS1, which is used to identify patients and the services provided to them, may be helpful in addressing some of these needs (http://www.gs1.org/docs/patient_safety). However, use of such a barcode system may impose awkward constraints on the surgery team because a bar code must be within the line of sight of the scanner. Ideally, patient identification technology should be simple and reliable so that the overall activities and associated workflow of the surgical team is smooth and efficient. In this context, RFID technology offers an attractive solution because it does not need a line of sight and its reading range is greater than that involved with a barcode system. RFID technology is one potential solution in resolving occurrences of patient misidentification (Fisher, 2006; MF & JD, 2004).

We suggest a model that applies RFID technology to the patient identification process prior to entry into the operating room, and a prototype system for the application model. Automatic recognition eliminates the possibility of misidentification error by displaying the patient's identification information on the computer monitor of the operating room as s/he is being rolled into the room. A reliability model is used to show that the probability of patient identification error can be reduced by the proposed RFID based workflow. The next section provides a literature review on the RFID application in medicine and an overview of current costs. In the third section a typical workflow process for identifying a surgery patient is described and a process involving the RFID identification system is suggested. The suggested process is evaluated according to workflow process reliability model. Lastly, the prototype system developed to serve as a proof-of-concept of the proposed workflow process is discussed.

RFID TECHNOLOGY IN THE MEDICAL AREA

RFID technology may dramatically improve an organization's capability to obtain real-time information on the location and properties of tagged moving objects, such as people, materials, or equipment. It has been utilized in many areas, such as luggage tracking, security keys, toll collection, and supply chain management (SCM) (Angeles, 2005; Srivastava, 2004). The healthcare area is regarded as promising application area for RFID technology (Ericson, 2004;, "RFID in the Hospital", 2004).

A limited number of hospitals are reportedly testing RFID. Most began with tracking and managing equipment. One hospital installed an RFID equipment tracking system to monitor 12,000 pieces of medical equipment. The hospital estimated that it had gained a $200,000 benefit per year over and above the cost of the RFID system's installation and maintenance costs ("Patient Safety Applications of Bar Code and RFID Technologies"). Another hospital utilized inventory RFID tags, cutting inventory losses in half ("Patient Safety Applications of Bar Code and RFID Technologies"). RFID technology has also been used in tracking sponges in surgery (Alex Macario, Dean Morris, & Sharon Morris, 2007; Schwaitzberg, 2006). Tagging equipment or materials may be simpler than tagging people as proven in its uses in the manufacturing and retail sectors.

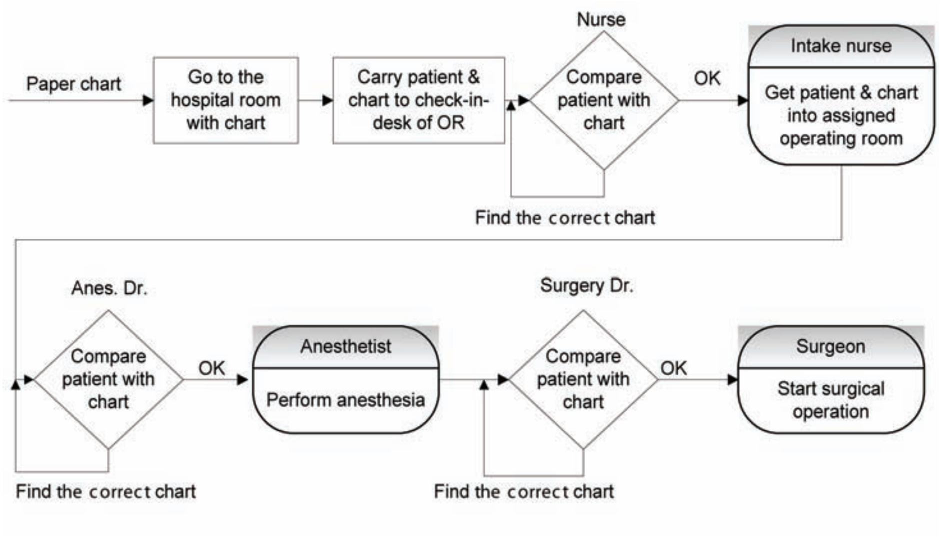
RFID technology has rarely been used in tracking and managing people, such as patients, physicians and nurses. A location-based Medicare service project with a hospital-wide RFID system was conducted in a university hospital in Taiwan (Wang, Chen, Ong, Liu, & Chuang, 2006). Two Singaporean hospitals implemented a RFID system for tracking visitors, patients and staff in the Accident and Emergency Department. These systems were used to identify and trace the contact history of Severe Acute Respiratory Syndrome (SARS) infected patients ("Singapore Fights SARS with RFID", 2003).

Tagging people, however, is more challenging and requires more circumspection because of other technical and organizational problems. Many medical electronic devices use radio waves in a hospital. The presence of these devices raises the possibility of interference with RFID radio waves. Although the range of its operating frequency is restricted to free ISM (industrial, scientific, medical) bands, these frequencies can be a source of interference, too, and can interfere with RFID devices (Srivastava, 2004). Cost issues are another major obstacle to hospital-wide use of RFID technology. An RFID company estimated that it could cost between $500 and $2,000 per hospital bed to install its RFID system ("Health Care RFID Startup Scores $9 Million in Venture Funding", 2004). Like most electronic devices, even though RFID unit cost has fallen dramatically over the past few years, it is still too expensive for hospital-wide use. Unless these obstacles, such as unit price and device interference issues are resolved, application of RFID is likely to be limited to restricted areas of the hospital. Thus, it may be more efficient to deploy the RFID system in a specific area and for a specific function, such as patient identification in operating rooms. Such targeted uses may help to eliminate the possibility of unrecoverable and serious medical errors, such as performance of surgery on the wrong patient or at the wrong site.

RFID FOR SURGERY PATIENT IDENTIFICATION

A medical doctor decides to perform surgery on in- or outpatients, based upon the results of the patient's medical examination. A patient's surgery schedule is usually developed according to the schedule of the surgery doctor in charge. The patient, if an outpatient, is required to check into the hospital one day prior to the operating day if the operating schedule has been set. An operating room and an anesthetist are assigned to the patient on the previous afternoon of the operating day. The preoperative setting for the next day's operation usually begins in an operating room after finishing the scheduled surgical operations for the day. The anesthetist in charge checks the medical status and physical constitution of the patient during rounds and determines the anesthetic method to be used in the next day's opera-

Figure 1. The original workflow diagram



tion. The results of the anesthetic round must be recorded on the patient's chart and the hospital's information system. The workflow process involving the movement and identification of a surgery patient begins after completion of the necessary preoperative setting.

Figure 1 describes the typical workflow process around the movement of a surgery patient who is scheduled for an operation, focusing on consultation of a paper chart on the day of the surgery. A nurse or commensurate employee brings the patient to the designated surgery according to the surgery schedule. The worker takes the patient to the check-in desk in the operating room and turns him and the paper chart over to a nurse in charge. At that time, patient identification is confirmed by the nurse and the worker who brought the patient in. The nurse could ask for the name and compare it on the wristband and chart of the patient. After confirming the identity of the patient and presence of the correct chart, the patient moves into the assigned operating room. The nurse and anesthetist in charge of the operation confirm again identify of the patient and the chart before performing anesthesia. The surgeon then checks the identification of the patient by comparing the wristband and the chart of the patient before beginning the operation.

In order to eliminate the possibility of human errors in confirming the patient's identification, it is necessary for any automatic error-free process to be introduced in parallel to the current confirmation process relied upon by a surgical team. We suggest a workflow process that prevents human error by deploying the characteristics of an RFID system. Figure 2 contains a conceptual diagram for an automatic identification system using RFID technology. RFID antennae may be placed at the entrance of each operating room and check-in room. An RFID reader may be connected to the existing information system through an RFID server. An RFID tag is attached to a surgery patient's wristband. The hospital information system is used in tandem with the prototype described in this article. We assume the existence of a hospital information system and ability to retrieve necessary information from the system using the patient's ID.

Figure 3 shows a diagram of the suggested workflow process for identifying a surgery patient using an RFID reader in each confirming step of the current identification process. The possibility of human error in the confirmation process

Figure 2. Conceptual diagram of an operating room with RFID system

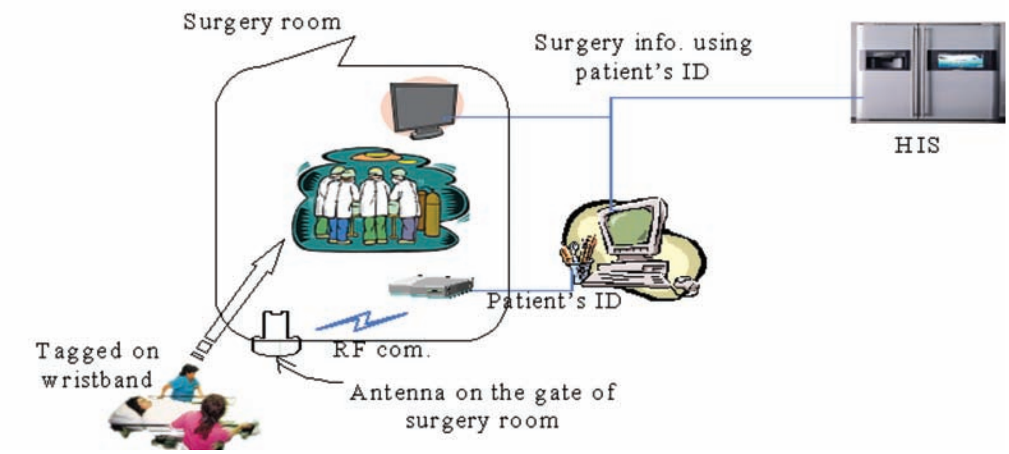
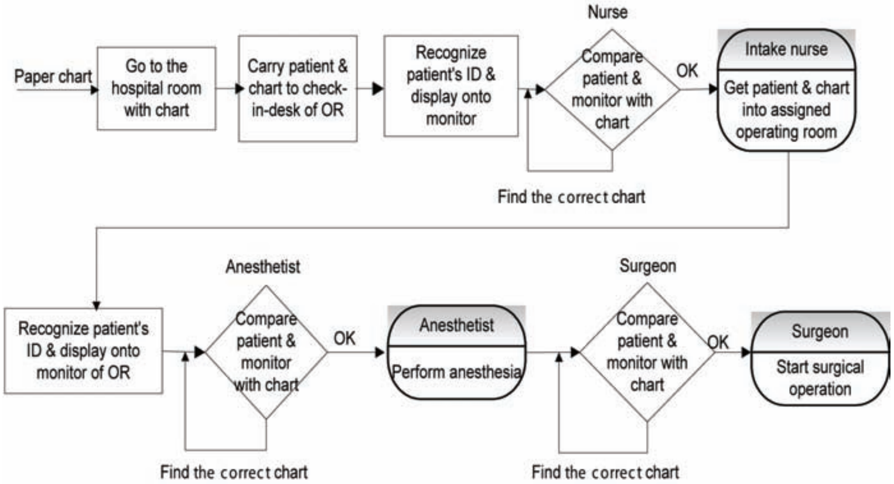


Figure 3. New workflow diagram using RFID in patient identification



may be reduced by adapting RFID technology to identification of a moving object. In the proposed process, a patient is wearing a wristband with an RFID tag on his wrist. The surgeon confirms the patient's identity during rounds the morning of the surgery. When the patient is brought to the check-in area of the operating room, the identification is confirmed by the intake nurse and the worker who took the patient into the operating room. At this time, the patient's identification information is recognized by an RFID reader and displayed on a computer screen, allowing the intake nurse to again compare the displayed patient's name to the name on the paper chart. After the confirmation and check-in processes are complete, the patient is rolled into the surgery. As he passes through the entrance of the surgery, an RFID antenna at the entrance reads the RFID tag within the wristband and uploads information into the computer system in the operating room. The computer immediately queries the scheduling system about surgical operation to confirm that the patient is indeed scheduled to be in that specific operating room and then uploads the patient's identification information and other necessary information from the electronic medical record, including allergies, blood type, and laboratory reports, including laterality from radiology studies. If the RFID system indicates that the wrong patient has entered the room, a warning is provided (e.g., beeping sound) and a warning sign is displayed on the monitor. At the instant the patient wearing an RFID tag enters the operating room, the computer system confirms that the right surgeon and right patient are in the right place before the surgical procedure begins.

Although the RFID technology contributes to patient safety and traceability, it may increase the complexity of processes and decrease hospital performance. In the next section, we analyze the reliability of the workflow process and compare it with a paper-based process.

ANALYSIS OF PROCESS RELIABILITY

The reliability models can be applied in this case to evaluate error probability (Kuo & Zuo, 2002). Let x_i indicate the error probability of component i for $1 \le i \le n$. Then, vector $x = (x_1, x_2, ..., x_n)$ represents the state of all components and is called the component error vector. Let $R(x)$ represent the reliability of system x.

Serial system:

The reliability function of a serial is given by (Figure 4):

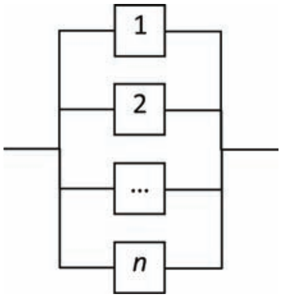
$$R(x) = \prod_{i=1}^{n}(1 - x_i)$$

Parallel system:

The reliability function of a parallel is given by (Figure 5):

Figure 4. Structure of serial system

Figure 5. Structure of parallel system



$$R(x) = 1 - \prod_{i=1}^{n}(x_i)$$

Serial-Parallel System:

A serial-parallel system includes an *m* disjoint module connected in a series and module (Figure 6).

The single module is:

$$R_i(x) = 1 - \prod_{j=1}^{n_i}(x_{ij}) \ , \qquad R_i(x) = 1 - \prod_{j=1}^{n_i}(x_{ij})$$

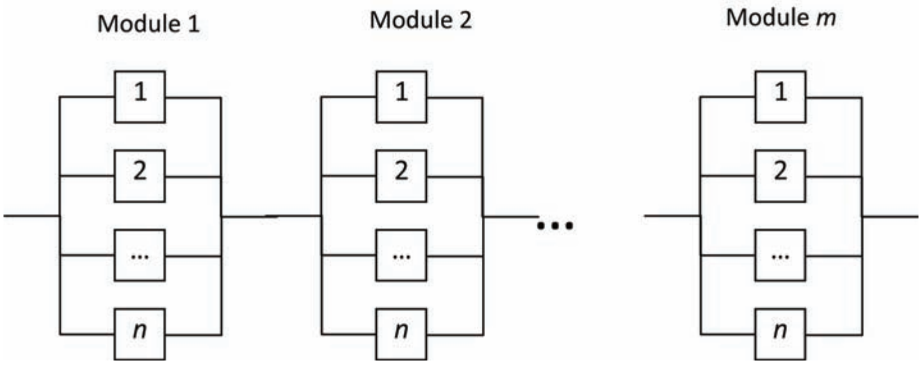
$$i = 1,2,...m\ ,\ i = 1,2,...m$$

The reliability function of a serial-parallel is given by:

$$R(x) = \prod_{i=1}^{m} R_i(x) = \prod_{i=1}^{m}\left(1 - \prod_{j=1}^{n_i}(x_{ij})\right)$$

Surgical processes contain many steps and tasks. Usually, the error rate for a process may increases as the number of steps in the process increases. Unfortunately, any empirical or experimental data about human error rate or error possibility in medical area has not been reported even though various types of medical accidents based on human error occur in healthcare. The incidences of incorrect surgery on patients are

Figure 6. Structure of serial-parallel system



due to errors in the checking process and may be regarded as a kind of human error of omission. Since any kind of omission error rate has not been reported in healthcare area, we use the error probability of omission in similar situations to show how much the error rate may be reduced by RFID applications in the patient identification process in the operating room. General human errors of omission, those in which the items being omitted are embedded in a procedure, have an error probability of 99.7% (Park, 1997). Such studies have also been proposed for identifying human error in general anesthesia administration (Blatt, 2007). On the other hand, the accurate rate of RFID reader is more than 99.9% in an area of 0-5m (Yoo et al., 2007) that is, the probability of misidentification error is at most 0.001 in the case of RFID.

As shown in Figure 2, a nurse, an anesthesiologist, and a surgeon must compare a surgery patient with his paper chart. This procedure follows a serial procedure in which each component has an error probability of 0.003, with reliability r=0.997, as shown in Figure 7(a). The reliability of the total patient identification system involving a series of three components is R=.991027 (99.10%). Use of an RFID warning system as a parallel component in the series, as shown in Figure 7(b), increases the reliability of the total system to R=0.999991 (99.99%). In other words, this can be expressed to reduce the occurrences of error from 90 per 10,000 times to 0.089 per 10,000 times. On the other hand, if manual operations are eliminated and the patient identification procedures are relied on then the RFID warning system as a serial component in the series, as shown in Figure 7(c), the reliability of the total system can still reach R=0.997003 (99.70%). In this case we assume that the probability of missing an RFID warning is the same as that of errors in the procedure followed to check a patient's medical chart. Thus, RFID warnings via either beeping or display on a computer monitor dramatically reduce misidentification errors to nearly zero.

DEVELOPMENT OF A PROOF-OF-CONCEPT RFID SYSTEM

Design of the Proof-of-Concept System

We developed a prototype system to show that an RFID system can be used in the identification process of a surgery patient. The hardware component of the RFID system is an RFID tool kit, manufactured by Alien, which includes ALR-9800 Enterprise RFID reader and ALR-9610-BC antenna. The ALR-9800 model uses an electromagnetic wave of 900MHz band and the ALR-9610-BC model has a standard antenna. We experimented to investigate the identification ratio of this RFID

Figure 7. Human reliability model before and after using RFID

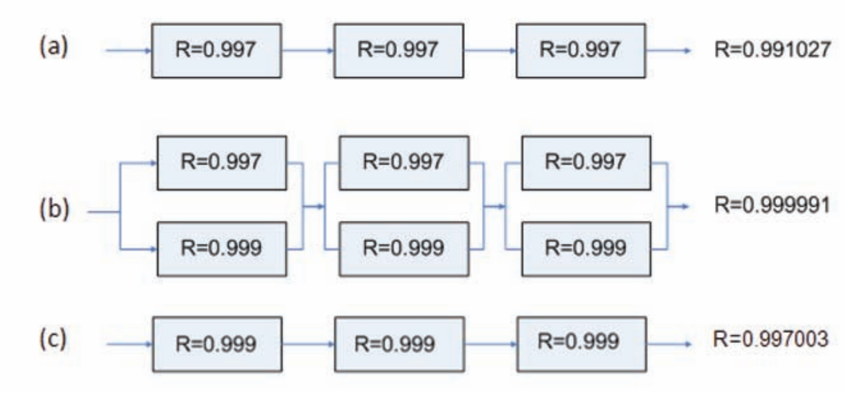
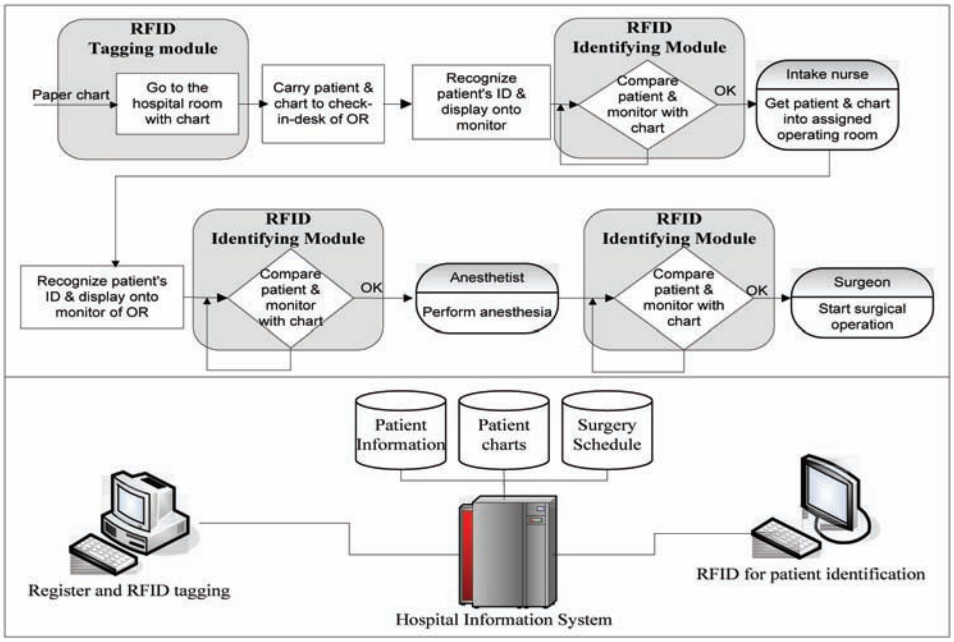


Figure 8. Process flow with two modules

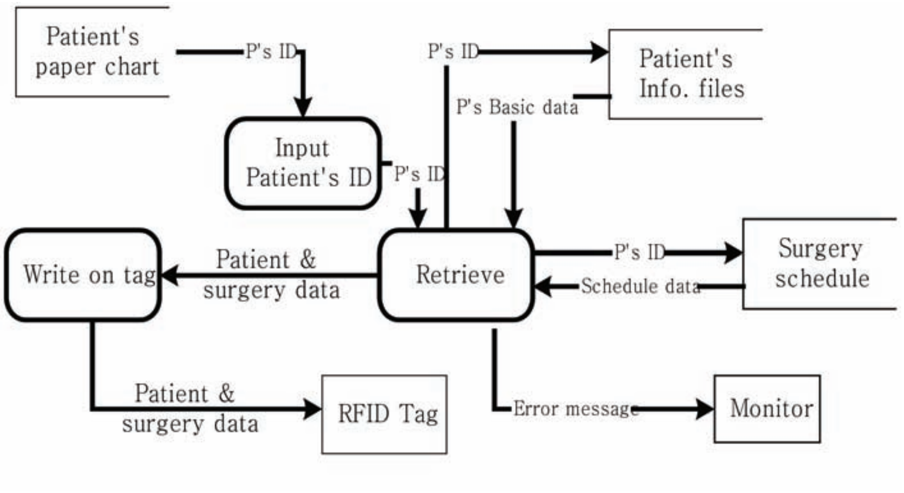


system. The experiment was performed in open space with an object moving at working speed. The results revealed an identification ratio of 99.9% within a 4-meter distance, and may correspond to a reliability prediction model.

Figure 8 shows a tagging module and an identifying module required in the prototype system. The first one is used to write a patient's basic information to a tag attached to a wristband to be worn by the patient. The function of the other module is to recognize the patient's basic information from the tag on the patient's wristband and to display it on the monitor in the room where the surgery will be performed. These modules can be easily connected to a legacy system to retrieve detailed information on the patient and surgery.

Figure 9 shows a data flow diagram of the tagging module. The module retrieves basic

Figure 9. DFD for tagging



information, such as the patient's ID, name, diagnostic department, hospital room number and surgery room number, from the legacy database and records the information on the RFID tag that is attached to the wristband. The data flow diagram for the identification module is shown in Figure 10. As a patient is rolled into the operating room, the RFID antenna on the door frame of each operating room recognizes the tag information on the patient's wristband and uploads it into the RFID identification module in the specific operating room into which the patient is being transported. The module immediately queries the surgery's scheduling module in the legacy system to confirm that the patient is indeed scheduled to be in the operating room and then uploads information about the electronic medical record from the legacy database. The system confirms that the right patient is in the right room before the surgery procedure begins.

Implementation of the Prototype

We developed a prototype module for middleware that may be used to enable an information interchange between the RFID module and the legacy system. The prototype system involves a tagging module, recognition module and tag manager module. Figure 11 shows the screen of the tagging module. Once a patient's surgical schedule has been finalized, the patient is hospitalized in preparation for preliminary procedures and a wristband with RFID tag is attached to his wrist. At this time, the tag information is assigned to the patient. Figure 11 shows a tagging form that is used to match a patient's identification information with the information on the tag on his wristband. A nurse presses the search button and types the patient's name onto a search screen. If the screen reveals the patient's name in the surgery schedule in the legacy database, the nurse highlights and double-clicks on the name. The basic information on the patient is loaded into the tagging form as shown in Figure 11 and the tagging information is recorded into a tag by pressing the save button.

Figure 12 shows a form that may be used to display information for a patient who is being rolled into an operating room. An RFID antenna that sends radio waves continually communicates whether a patient with an RFID tag is approaching or not. If a patient passes through the entrance of an operating room, the RFID reader recognizes the patient's tag and displays basic information on the operating room monitor. The information may be retrieved from the hospital's legacy system using the tag information recognized by the RFID

Figure 10. DFD for patient identification

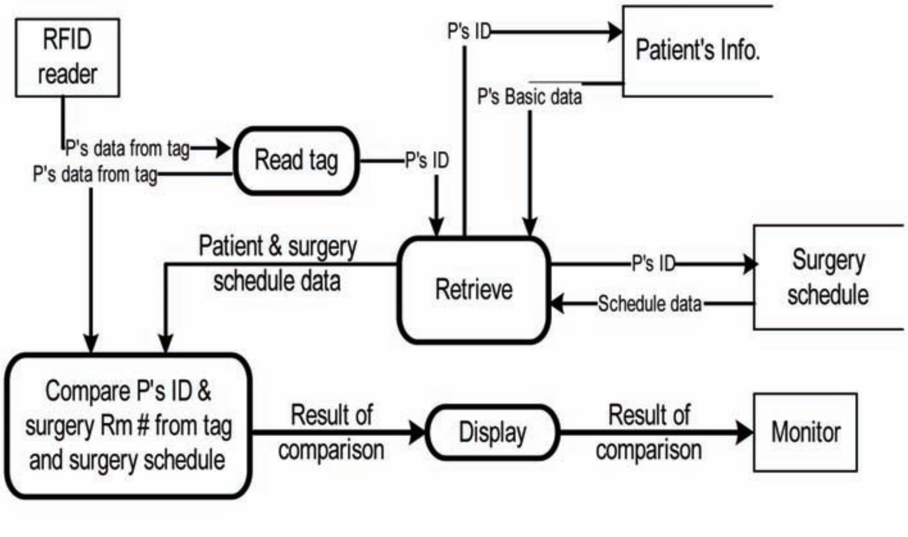
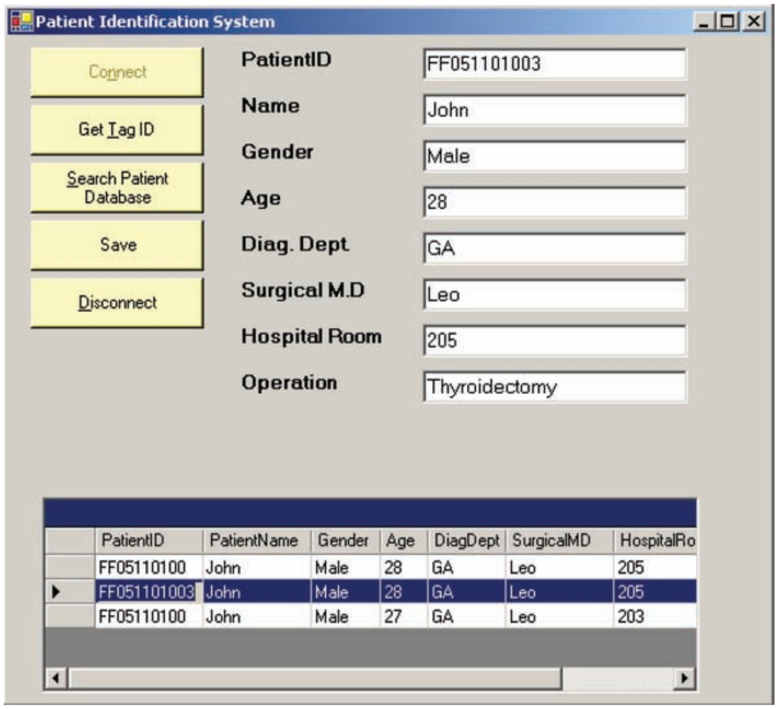


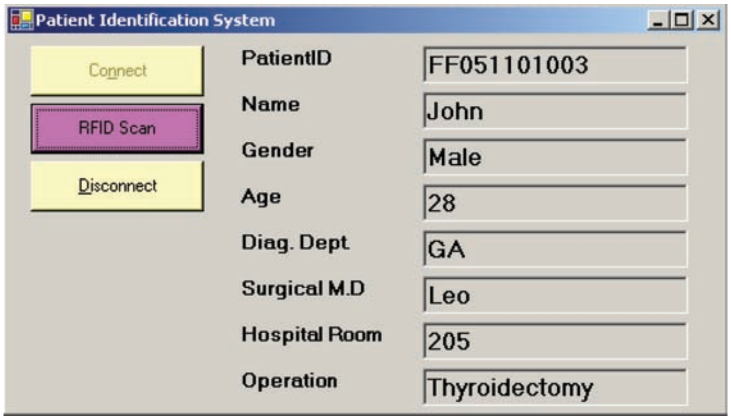
Figure 11. Screen for tagging



PatientID	FF051101003
Name	John
Gender	Male
Age	28
Diag. Dept	GA
Surgical M.D	Leo
Hospital Room	205
Operation	Thyroidectomy

PatientID	PatientName	Gender	Age	DiagDept	SurgicalMD	HospitalRo
FF05110100	John	Male	28	GA	Leo	205
FF051101003	John	Male	28	GA	Leo	205
FF05110100	John	Male	27	GA	Leo	203

Figure 12. Screen for displaying the basic information of an identified patient



PatientID: FF051101003
Name: John
Gender: Male
Age: 28
Diag. Dept: GA
Surgical M.D: Leo
Hospital Room: 205
Operation: Thyroidectomy

Table 1. The evaluation model of keyboard and RFID test

Scenario	*Evaluation Process*	*Time*	*Accuracy*
Scenario 1	Manual Entry process	2.1 min	98%
	RFID-based automated process	1 min	100%
Scenario 2	Manual Entry process	2.5 min	95%
	RFID-based automated process	0.8 min	100%
Scenario 3	Manual Entry process	3-5 days	99%
	RFID-based automated process	5 min	100%

system. Surgical team members, such as surgery doctors and nurses in charge of the operation, may then again confirm whether this is the right patient by comparing the patient's name on the PC monitor and paper chart while the patient is under anesthetic. This prototype system displays only basic information on the patient as recognized on the RFID system. In real applications, however, other important medical information required for an operation may be easily retrieved through the existing hospital information system.

Preliminary Evaluation

In order to examine the impact of RFID in information accuracy and productivity improvements by reducing the keyboard entry, we had a preliminary evaluation in three scenarios. Each scenario contains two tests, user entry from the keyboard and RFID-based data collection. The user entry data mix with different data type including text, numerical, and date. The average length of a single record input data is 6.56 characters. Table 1 presents the preliminary evaluation result. The detail of the experiment is studied in (Cheng & Prabhu, 2007). Based on three-scenario evaluation processes, the accuracy of RFID data collection enables the end-to-end process automation that reduces the processing time and eliminates potential data entry errors. The evaluation result shows we can improve the accuracy of data acquisition, which is the main objective in this study.

CONCLUSION

In this article a workflow model is suggested that utilizes RFID technology to improve patients' safety during a surgical operation. A workflow process that involves RFID technology in the identification process is proposed and a prototype system for RFID middleware is developed here. Some obstacles to RFID use remain hospital-wide, but it is becoming a promising option for some areas in healthcare. Furthermore, the suggested process offers the potential to reduce human errors by reducing/eliminating data entry. The proposal mathematical model indicates that such error can be reduced from 90 to as low as 0.89 per 10,000 surgeries using the proposed RFID based workflow. In conclusion, this article shows that using RFID can be expected to reduce patient identification errors significantly, thereby reducing potential harm to patients in terms of injury or death. A major caveat is that these results are theoretical and must be considered preliminary therefore no assertions can be made about eventual reductions in injuries or deaths with further research. Experimental research can also be used for assessing some of the technical challenges such as interference of RFID and other medical instruments, and assessing changes in workflow complexity caused by introduction of RFID. Future work could also consider changes in the workflow complexity by introducing RFID technology and applying RFID for monitoring patient flow through healthcare systems.

REFERENCES

Alex Macario, M., Dean Morris, M., & Sharon Morris, R. (2007). Initial clinical evaluation of a handheld device for detecting retained surgical gauze sponges using radiofrequency identification yechnology. Archives of Surgery, 141, 659–662. doi:10.1001/archsurg.141.7.659

Angeles, R. (2005). RFID technologies: supply chains applications and implementation issues. Information Systems Management, 22, 51–56. d oi:10.1201/1078/44912.22.1.20051201/85739.7

Blatt, D. (2008). Methodology to Identify Systematic Vulnerabilities to Human Errors during General Anesthesia Administration. In Proceedings of the 2008 Industrial Engineering Research Conference, Vancouver, Canada, 799-804.

Chassin, M., & Becher, E. C. (2002). The wrong patient. Academia & Clinic, 136(11), 826–833.

Cheng, C. Y., & Prabhu, V. (2007). Applying RFID for cutting tool supply chain management. In Proceedings of the 2007 Industrial Engineering Research Conference, Nashville, USA.

Ericson, J. (2004). The RFID for hospital care. The E-Business Executive Daily.

Etchells, E., O'Neill, C., & Bernstein, M. (2003). Patient safety in surgery: error detection and prevention. World Journal of Surgery, 27(8), 936–941. doi:10.1007/s00268-003-7097-2

Fisher, J. A. (2006). Indoor positioning and digital management: emerging surveillance regimes in hospitals. In T. Monahan (Ed.), Technological Politics and Power in Everyday Life (pp. 77-88).

Health care RFID startup scores $9 million in venture funding. (2004, July 12, 2004). Dow Jones Reuters Business Interactive. http://www.gs1.org/docs/patient_safety. GS1 standards in healthcare.

Kohn, L. T., Corrigan, J. M., & Donaldson, M. S. (1999). To err is human: building a safer health system. Washington, D.C.: Institute of Medicine, National Academy Press.

Kuo, W., & Zuo, M. J. (2002). Optimal reliability modeling: principles and applications. Wiley.

MF, M., & JD, K. (2004). Patient identification: problems and potential solutions. Vox Sanguinis, 87, 197–202. doi:10.1111/j.1741-6892.2004.00482.x

Park, K. (1997). Human error. In G. Salvendy (Ed.), Handbook of Human Factors and Ergonomics (pp. 150-171). New York: John Wiley & Sons.

Patient safety applications of bar code and RFID technologies. A Zebra Black & White Paper.

Reason, J. (2002). Combating omission errors through task analysis and good reminders. Quality & Safety in Health Care, 11(1), 40–44. doi:10.1136/qhc.11.1.40

RFID in the hospital. (2004, July 15, 2004). RFID Gazette.

Schwaitzberg, S. D. (2006). The emergence of radiofrequency identification tags: applications in surgery. Surgical Endoscopy, 20(8), 1315–1319. doi:10.1007/s00464-006-2050-8

Singapore fights SARS with RFID. (2003, June 4, 2003). RFID Journal.

Srivastava, B. (2004). Radio frequency ID technology: The next revolution in SCM. Business Horizons, 47(6), 60–68. doi:10.1016/j.bushor.2004.09.009

Wang, S.-W., Chen, W.-H., Ong, C.-S., Liu, L., & Chuang, Y.-W. (2006). RFID application in hospitals: A case study on a demonstration RFID project in a Taiwan hospital, 8, 184a-184a.

What an unbelievable surgery!-Perform an operation with exchanged charts. (2006, January 15). Donga News.

Yoo, D.-S. K., Kim, S. K., Chang, H. O., Bae, B. C., Kim, H. S., & S.J. (2007). Location based blood bag management using active RFID and ubiquitous sensor network. This paper appears in: Information Technology Applications in Biomedicine, 2007. ITAB 2007. 6th International Special Topic Conference on ITAB, Tokyo,2007 (pp. 320-322).

This work was previously published in International Journal of Information Systems in the Service Sector, Vol. 1, Issue 4, edited by J. Wang, pp. 1-14, copyright 2009 by IGI Publishing (an imprint of IGI Global).

Chapter 3.16

Internet as a Source of Health Information and Its Perceived Influence on Personal Empowerment

Guy Paré
HEC Montréal, Canada

Jean-Nicolas Malek
HEC Montréal, Canada

Claude Sicotte
University of Montreal, Canada

Marc Lemire
University of Montreal, Canada

ABSTRACT

The primary aim of this study is twofold. First, the authors seek to identify the factors that influence members of the general public to conduct Internet searches for health information. Their second intent is to explore the influence such Internet use has on three types of personal empowerment. In the summer of 2007 the authors conducted a household sample survey of a population of Canadian adults. A total of 261 self-administered questionnaires were returned to the researchers. Our findings indicate that use of the Internet as a source of health information is directly realted to three main factors: sex, age and the individual's perceived ability to understand, interpret and use the medical information available online. Further, their results lend support to the notion that using the Internet to search for information about health issues represents a more consumer-based and participative approach to health care. This study is one of the first to relate Internet use to various forms of personal empowerment. This area appears to have great potential as a means by which consumers can become more empowered in managing personal health issues.

INTRODUCTION

A number of studies have confirmed growing use of the Internet to find information on personal health issues. For example, it has been estimated that of the 15 million Canadians who had Internet access in the home in 2005, 58%, or 8.7 million, used it to search for health information (Underhill & McKeown, 2008). The majority of these users said that they had searched for information about a specific ailment or about lifestyle issues such as nutrition, diet or exercise. More recent data from the United States have shown that in 2007, 71% of adults turned to the Internet for health information. This percentage stood at 61% in 2006 and 53% in 2005 (Harris Interactive, 2007).

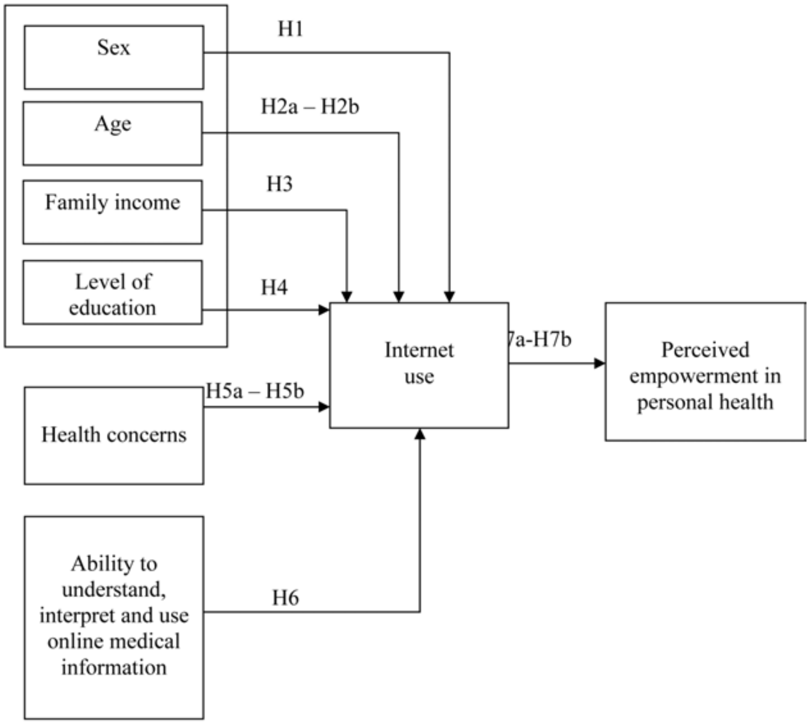
Increased use of the Internet by the general public is transforming people's relationships with their health. By providing wide access to information, advice and health services, the Internet is increasingly seen as a powerful lever for personal empowerment (Wilson, 2001). These opportunities therefore deserve a closer examination. In recent years, various studies have shed light on the opportunities provided by the Internet with regard to personal empowerment in health. These studies have been based on different visions of the construct, which is generally defined as the development of the individual's involvement in responsibility to their health care. According to Lemire et al. (2008), studies on this subject have focused on the impact of Internet use on the development of one of three forms of personal empowerment: *professional* empowerment, which is focused on the individual's self-actualization for approaches more consistent with expert knowledge (Fox et al., 2005; Henwood et al., 2003); *consumerist* empowerment, which is focused on choices based on personal judgement and resources (Kalichman et al., 2002); and *community* empowerment, which is focused on better social inclusion in a group or community (Radin, 2006; Hsiung 2000; Burrows et al., 2000).

However, there are two main reasons why only limited generalizations can be made from past studies. First, the data was collected from very specific groups. For example, the samples consisted of people who had serious illnesses (e.g., Kalichman et al., 2002; Radin, 2006), who were using a specific drug (e.g., Henwood et al., 2003) who had similar health concerns (e.g., Fox et al., 2005), or who relied on the same Web site as the main source of their health information (e.g., Fox et al., 2005; Radin, 2006; Hsiung, 2000). Second, the data were often collected without trying to understand the development of personal empowerment in relation to past research on searches for information on the Internet and to the specific nature of how online health information is consulted. To our knowledge, the study by Lemire et al. (2008) is the only one that has examined simultaneous development of the three forms of empowerment mentioned above. Our research is an extension of their study, inasmuch as it tries to extend the reach of its theoretical and practical contributions. More specifically, instead of analyzing the three forms of user empowerment on a single Web site, we shall examine opinions and points of view expressed by a sample of the general public. In other words, in order to sidestep the above-mentioned limitations, the present study sought to identify the factors that influence members of the general public to conduct Internet searches for health information and explore the influence of Internet use on three types of personal empowerment.

RESEARCH MODEL

The research model presented in Figure 1 links previous research on Internet use as a source of health information to its impact on the empowerment or self-empowerment of individuals in how they manage personal health issues.

Figure 1. Research model



Prior Research on Using the Internet as a Source of Health Information

Previous studies have shown that some demographic factors influence whether or not an Internet user conducts searches for health information. According to a Statistics Canada survey, Internet users who are women are twice as likely as their male counterparts to be concerned with health issues (Underhill & McKeown, 2008). It is now well established that women are more likely to get involved in the decision-making process in personal health issues (Barrett et al., 2003; Nease & Brooks, 1995); they are therefore more inclined than men to turn to the Internet for health information (Pew Internet and American Life Report, 2006; Rice, 2006; Nicholas et al., 2003; Cotton and Gupta, 2004). This may be explained by the traditional role of women in the family, expressed by a sense of responsibility for the health of all the other members of the family (Hibbard et al., 1999; Dolan et al., 2004). This result seems consistent with the fact that men are more reticent than women to consult a health professional and seek professional help when it is needed (Broom, 2005). According to Pandey et al. (2003), women use the Internet more for disease prevention and health promotion. We therefore arrived at the following hypothesis:

Hypothesis 1: Women use the Internet more than men to search for health information, mainly for preventive purposes.

Age is another factor presented in the literature as a possible antecedent of belonging to the group of users concerned with health. In contrast to the results on sex, the findings associated with age are contradictory. Several studies have found a negative association between age and using the Internet as a source of health information (e.g., Cotton & Gupta, 2004; Pandey et al., 2003; Anderson, 2004; Licciardone et al., 2001; Laurence & Park, 2006). On the other hand, Nicholas and al. (2003) found a positive link between age and Internet use, while other investigators found no significant relationship between the frequency of Internet use for health purposes and user age (e.g., Underhill & McKeown, 2008; Lemire et al., 2008).

A recent Statistics Canada study (Underhill & McKeown, 2008) revealed that it is the type or nature of the information sought by Internet users that varies by age group. Their study found that a greater percentage of people in the 18 to 44 age group were looking for information about lifestyle and the health care system (for preventive purposes), while an even greater percentage of people 45 years and over were looking for information on specific illnesses and drugs (for curative purposes). Given these results, we made the following hypotheses:

Hypothesis 2a: Age is positively associated with frequency of Internet use for curative purposes.

Hypothesis 2b: Age is negatively associated with frequency of Internet use for preventive purposes.

In a recent study, Reddick (2006) demonstrated that among households with Internet access in the home, those reporting an annual income under $75,000 were less likely to consult the Internet for health information than those with an annual income of over $75,000. These results have been confirmed in a review of the literature (Renahy & Chauvin, 2006) and by recent data from Statistics Canada (Underhill & McKeown, 2008). The data indicate that Internet users seeking health information have higher income levels than those who do not.

Hypothesis 3: Household income is positively associated with using the Internet to search for health information.

Level of education is also considered a factor positively associated with using the Internet to search for information on personal interests. Studies have shown that Internet users concerned with health issues are better educated than other users (e.g., Cotton & Gupta, 2004; Reddick, 2006; Renahy & Chauvin, 2006). It would therefore appear that education is one of the main predictors of whether the Internet is used to search for health information.

Hypothesis 4: Level of education is positively associated with the frequency of online searches for health information.

In addition to the four socio-demographic factors presented above, it would appear that an individual's concern for their own state of health also has an impact on whether they will use the Internet to obtain health information. Several studies have shown that people who are ill or handicapped or who consider themselves in poor health more frequently search for health information online (e.g., Rice, 2006; Goldner, 2006; Baker et al., 2003). A recent study has also found that 86% of Internet users who are chronically ill search the Internet for health information on a regular basis, as compared to 79% of users who do not suffer from serious illnesses (Pew Internet and American Life Report, 2007). On the other hand, Cotten and Gupta (2004) found that individuals who actively searched the Internet for health information considered themselves in better health than people who did not. Since contradictory results have been obtained and age seems to be closely associated with concern for personal health, we made the following hypotheses:

Hypothesis 5a: Frequent use of the Internet for curative purposes is positively associated with level of concern for personal health.

Hypothesis 5b: Frequent use of the Internet for preventive purposes is negatively associated with level of concern for personal health.

Finally, in a study commissioned by EuroHealthNet—the European network for public health, health promotion and illness prevention—Christmann (2005) examined people's capacity to understand, interpret and use medical information properly. In a recent article, Norman and Skinner

Table 1. Contact, acceptance and response rates

	N	Rates
Homes visited	1 439	-
Contact established	619	Contact rate = 43%
Individuals willing to participate	368	Acceptance rate = 59%
Returned questionnaires	261	Response rate = 71%
Completed questionnaires	255	-

(2006) raised the same idea, indicating that the health information that is available online is not widely consulted due to Internet users' lack of knowledge or skills in health matters. The two articles raise the issue of e-health literacy. Based on this work, we made the following hypothesis:

Hypothesis 6: Use of the Internet as a source of information on health is positively influenced by an individual's ability to understand, interpret and properly use the medical information that is available online.

Influence of Internet Use on Perceived Empowerment in Health

Using the Internet for health purposes includes various goals or motivations; identifying them could shed light on their relationship with the concept of empowerment in personal health. According to Lemire et al. (2008), what motivates Internet users to seek health information could be closely linked to their perception of the resulting personal empowerment. More specifically, the authors found that individuals who believed that they could follow prescriptions, according to the medical model, used the Internet mainly to gain a better understanding of a problem or illness, while those who relied more on their ability to make personal choices were seeking alternate views from those associated with traditional medicine. Again according to these authors, information searches based on social motivations (e.g., participating in online forums or helping a loved one who is ill) were found to be more closely associated with the community logic of empowerment described above. We therefore made the following hypotheses:

Hypothesis 7a: Frequent use of the Internet for curative purposes fosters the development of the professional logic of empowerment in personal health.

Hypothesis 7b: Frequent use of the Internet for preventive purposes fosters the development of the consumerist logic of empowerment in personal health.

Hypothesis 7c: Frequent use of the Internet for social or community purposes fosters the development of the community logic of empowerment in personal health.

METHODS

Applying a methodological approach proposed by d'Astous (2005), in the summer of 2007 we conducted a household sample survey using a self-administered questionnaire addressed to an adult Canadian population. This method is akin to a mail survey, except that the questionnaires are administered in the respondent's home. One of the researchers left the questionnaires with the individuals willing to participate and made arrangements to pick them up once completed. In terms of the sampling, this method has four advantages: there is no need to have a list of all the addresses corresponding to the targeted population; an efficient selection can be made randomly using a city map and targeting streets in pre-selected residential neighbourhoods according to the needs of the study; the personal contact with respondents has a positive impact on the response rate; the quality of data is generally higher than that from mail surveys; and the home selection process is relatively flexible and corresponds to the needs of the study.

The study was conducted in Montreal, Canada, the world's second largest French-speaking city on the basis of the number of inhabitants whose mother tongue is French. The city is also the second largest city in Canada and North America's only French-speaking metropolis. Boroughs were identified for questionnaire distribution by consulting the Internet portal of the City of Montreal's municipal services.[1] This allowed us identify two predominantly French-speaking boroughs with different socio-demographic profiles: Outremont and Montreal North. Outremont represented the borough with the highest percentage of people with university degrees and the highest average income. In contrast, Montreal North offered the lowest percentage of people with a university degree and one of the lowest average levels of family income.

A random selection algorithm was used to determine which streets to visit in each borough. To avoid any bias, we eliminated streets neighbouring one of the city's four universities. These neighbourhoods usually have a large student population made up of young people with low incomes and high levels of education.

The specific nature of our methodological approach required a particular interpretation of the response rate. Clear distinctions had to be made between the contact rate, the acceptance rate and the response rate (d'Astous, 2005). The contact rate refers to the percentage of the homes that were visited in which contact was established with a resident; the acceptance rate indicates the percentage of individuals who were contacted and who agreed to participate in the study; and the response rate provides the percentage of individuals who agreed to take part in the study and who returned the questionnaire. As shown in Table 1, contacts were not established in more than half of the homes visited. Residents in these homes either were away (e.g., for vacation, work) at the time when the interviewer attempted to make contact or they just did not want to open the door to an unfamiliar person. Among those residents with whom we established a contact, nearly 60% agreed to participate in our survey. Refusals generally result from apathy, fear of invasion of privacy or any number of reasons. Finally, a total of 261 questionnaires were returned, for a response rate of 71%. Six of the 261 returned questionnaires were incomplete and had to be discarded from the database. The final sample came to 255 respondents.

Operationalization of the Variables

The variables associated with the respondents' socio-demographic profiles—sex, age, income level and level of education—were all measured with a single item. Concerns with personal health (continuous variable) were measured with two items adapted from work by Lemire et al. (2008). On the other hand, the variable associated with the concept of e-health literacy was measured using the seven items suggested by Norman and Skinner (Christmann, 2005). The three categories of motivations underlying Internet use for health purposes (curative, preventive and social) were measured with two items. Finally, the dependent variable corresponding to the three logics of empowerment was adapted from Lemire et al. (2008). Some of the items needed to be reworded in order to compare empowerment levels among individuals interested in health information (the only population targeted by Lemire's study) with that of other users. The measure distinguished between skills and sense of control based on professional expertise, those that were based on personal judgement, and those generated by exchanges in support and discussion groups (five items each). All the items included in the questionnaire (except those associated with socio-demographic variables) are listed in the Appendix.

Pre-Testing

Questionnaires need to be pre-tested in order to ensure that the items included in the instrument are reliable. This pre-testing is crucial since, as pointed out by Kumar (2005), respondents to self-administered questionnaires generally do not ask for clarifications and will respond according to what they understand in the statements. Clear, well-phrased statements can reduce the risk associated with misinterpretation. A total of 10 individuals with different socio-demographic profiles were selected from the researchers' networks of contacts. Based on their comments, minor changes were made to some items and some of the text was edited to improve readability.

RESULTS

This section presents the profile of the respondents who participated in this study, the psychometrics of the measures used, and the results of the hypothesis testing.

Respondent Profiles

As indicated in Table 2, our sample included an equal number of men and women, and no significant difference was found between the two boroughs as far as this variable was concerned (p=.353). A significant difference was found between the two boroughs in terms of the average age of respondents. The Outremont respondents were, in general, older than the respondents in Montreal North. Respondents 39 years of age or younger made up 63% of the Montreal North sample as compared to 43% of the Outremont sample. In Outremont, respondents aged 50-59 represented 21% of the sample, compared to only 7% in Montreal North. Given these demographics, it is not surprising that the Outremont respondents reported more concern about their health than those in Montreal North. In terms of education, a significant difference was again found between the two boroughs.

The respondents who participated in the study were relatively well educated, and 68% of them had completed a university degree. As expected, however, the respondents from Montreal North were less educated than those in Outremont. While 77% of Outremont respondents had a university degree, the rate fell to 57% in Montreal North. In terms of average family income, another significant difference was found between the two boroughs. As expected, the average family income of respondents was higher in Outremont than in Montreal North. Finally, the percentage of respondents who never used the Internet was low and not significantly different between the two boroughs.

Psychometric Qualities of Measures

We examined the reliability as well as the convergent and discriminatory validity of the measures used. Reliability refers to the precision and internal consistency of a measure. It was measured using Cronbach's alpha (α) with a minimum acceptable threshold of 0.7 (Nunnally, 1978). Convergent validity preserves the unidimensionality of each variable (Usunier et al., 2000), which is usually attained when only one factor emerges from a factorial analysis that includes all the items associated with the same construct. Finally, the discriminative validity of a variable is confirmed when the square root of the variance it shares with its own items is greater than its inter-correlations with the research model's other variables.

The results of the reliability analysis led to the removal of 2 of the 15 items associated with the three forms of empowerment in personal health (item 2, associated with professional empowerment, and item 3, associated with consumerist empowerment). We were also obliged to remove the variable associated with Internet use for social or community purposes. Both of the items associated with this variable gave a Cronbach's alpha of 0.48, a level markedly below the required minimal threshold. Therefore Hypothesis 7c of

Table 2. Respondent profile

		Complete Sample (n=255)	**Comparisons Between Boroughs**		
			Outremont (n=138)	**Montreal North (n=117)**	**t and χ^2**
Sex	Men	51%	54%	48%	χ^2= 0.9 p = .353
	Women	49%	46%	52%	
Age	18-29	31%	25%	40%	χ^2= 15.4 p = .03
	30-39	21%	18%	23%	
	40-49	19%	22%	15%	
	50-59	14%	21%	7%	
	60+	15%	14%	15%	
Education	High School	15%	14%	18%	χ^2= 15.7 p = .02
	College	17%	9%	26%	
	University –Undergraduate	38%	42%	33%	
	University - Graduate	30%	35%	24%	
Average family income	Less than $10,000	9%	2%	17%	χ^2= 63.2 p < .001
	$10,000 - $29,999	23%	12%	35%	
	$30,000$ - $49,999	20%	14%	27%	
	$50,000$ - $69,999	20%	27%	11%	
	$70,000$ - $89,999	14%	21%	6%	
	$90,000$ - $109,999	7%	11%	3%	
	$110,000 +	7%	13%	2%	
Internet use	Yes	87%	90%	85%	χ^2= 1.1 ns p = .248
	No	13%	10%	15%	
Concerns about personal health (1 to 10)		7.3	7.4	6.7	*t* = 2.0 p = .04

the research model could not be tested. Finally, analyses aimed at testing the convergent validity of each construct led to the removal of a second item associated with the professional form of empowerment (item 5).

Tables 3 and 4 present the psychometric qualities associated with the measures used to test the model's hypotheses, excluding the four socio-demographic variables.

Hypothesis Testing

To ensure consistency in the results presented below, respondents who indicated that they never used the Internet for personal purposes were removed from the sample. They represented 13% of all respondents, leaving 222 respondents in the sample.

Before testing the model's hypotheses, we examined the relative importance of the Internet as a source of health information. Respondents were asked to indicate the frequency of use of each source of information about personal health presented in Table 5. The results corroborated the findings of earlier studies (e.g., McMullan, 2006; Dumitru et al., 2007; Hesse et al., 2005), which suggested that health professionals and especially physicians are still the preferred source of information on personal health issues, and that the Internet represents a complementary source of information, such as information from friends,

Table 3. Factorial analysis and reliability results

	1	2	3	4	5	6
Professional_logic_1	.035	.007	**.905**	.016	.032	.006
Professional_logic_3	.031	.096	**.928**	.028	.065	.008
Professional_logic_4	.099	.054	**.804**	.035	.026	.027
Consumerist_logic_1	.243	**.733**	.038	.092	.087	.008
Consumerist_logic_2	.265	**.773**	.096	.183	.168	.230
Consumerist_logic_4	.123	**.764**	.054	.058	.055	.142
Consumerist_logic_5	.178	**.749**	.098	.102	.142	.004
Preventive_use_1	.107	.144	.037	**.832**	.278	.071
Preventive_use_2	.102	.094	.255	**.788**	.231	.034
Curative_use_1	.393	.070	.059	.295	**.784**	.052
Curative_use_2	.376	.158	.158	.242	**.716**	.065
e-Health_literacy_1	**.836**	.003	.013	.240	.099	.082
e-Health_literacy_2	**.821**	.292	.116	.011	.019	.085
e-Health_literacy_3	**.828**	.286	.093	.059	.101	.002
e-Health_literacy_4	**.840**	.314	.045	.088	.143	.051
e-Health_literacy_5	**.848**	.120	.029	.274	.211	.105
e-Health_literacy_6	**.830**	.067	.009	.304	.241	.033
e-Health_literacy_7	**.791**	.310	.010	.226	.103	.056
Concern_own_health_1	.143	.156	.062	.003	.005	**.867**
Concern_own_health_2	.057	.020	.076	.028	.039	**.901**
Eigenvalue	5.3	2.8	2.7	2.6	2.4	1.7
Explained variance	36%	14%	13%	12%	8%	4%
Cumulative variance	36%	50%	63%	75%	83%	87%
Cronbach's alpha	.95	.81	.87	.80	.89	.87

relatives and the print media. Our data also reveal that Internet users turn to this source mainly for curative rather than preventive purposes (t=-11.5; $p < .001$).

A *t*-test was then used to verify the influence of sex on turning to the Internet for issues of personal health (H1). The results which are presented in Table 6 suggest that women consult the Internet more often than men for preventive and curative purposes. However, this difference was only statistically significant for Internet use for preventive purposes, supporting Hypothesis 1.

Under Hypothesis 2, age is positively associated with frequency of Internet use for curative purposes (H2a) and negatively associated with Internet use for preventive purposes (H2b). To test this hypothesis, we broke the sample down into three age groups: 18-29 (young adults), 30-49 (adults) and 50 and over (mature adults). The results from the variance analysis (presented in Table 7) suggest that young adults turn to the Internet more often for preventive and curative purposes than adults in the other two age groups. As with sex, this difference was statistically significant only when the Internet was used for

Table 4. Descriptive statistics and discriminant validity

	Mean [1-10]	Standard Deviation	1	2	3	4	5	6
1. Professional empowerment	8.0	1.8	**.88**					
2. Consumerist empowerment	6.6	1.9	.15 p = .04	**.79**				
3. Internet use for preventive purposes	3.5	2.4	.10 p = .17	.19 p = .004	**.90**			
4. Internet use for curative purposes	5.3	2.8	.10 ns p = .15	.25 p < .001	.60 p < .001	**.94**		
5. e-Health literacy	5.9	2.4	.12 p = .08	.45 p < .001	.32 p < .001	.53 p < .001	**.87**	
6. Concern for own health	3.7	2.2	-.15 p = .03	-.17 p = .02	.02 p = .817	-.02 p = .821	-.18 p = .01	**.91**
The ratios in bold on the diagonal correspond to the square root shared by each of the variables and their respective items. The ratios appearing under the diagonal correspond to the correlations between variables.								

Table 5. Sources of information on personal health issues

Sources of Information	Mean [1 to 10]	Standard Deviation
Health professionals	7.7	2.3
Friends and relatives	5.6	2.6
Internet	5.0	2.8
Print media (books, magazines)	4.7	2.7
Support groups	1.7	1.6

Table 6. Results associated with sex

		N	Mean	Standard Deviation	*t*	*P*
Frequency of Internet use for preventive purposes	Women	106	3.9	2.4	2.7	.05
	Men	107	3.1	2.3		
Frequency of Internet use for curative purposes	Women	106	5.7	2.8	1.9	.07
	Men	107	4.9	2.8		

preventive purposes. The results therefore only support Hypothesis 2a.

The next hypothesis states that Internet users interested in health issues would be found to have a higher average annual income than other users (H3). To test the hypothesis, we divided our sample into two groups of similar size: respondents whose family income was lower than $50,000 and those with a family income over $50,000. Results from the *t*-test, presented in Table 8, clearly indicate that family income does not appear to be associated with the frequency of Internet use for issues of personal health.

The fourth socio-demographic variable included in our research model was level of education. Hypothesis 4 states that level of education would be found to be positively associated with using the Internet to search for health information for curative or preventive purposes. To test it, respondents were divided into two groups: those

Table 7. Results associated with age

		N	Mean	Standard Deviation	*F*	*P*
Frequency of Internet use for preventive purposes	18-29	76	3.8	2.5	3.4	.04
	30-49	89	3.2	2.2		
	50+	48	2.8	2.1		
Frequency of Internet use for curative purposes	18-29	76	5.6	2.7	1.7	.18
	30-49	89	5.5	2.8		
	50+	48	4.7	2.9		

with a university degree and those without. As indicated in Table 9, our results do not support a link between level of education and use of the Internet for personal health.

In addition to the socio-demographic profile, two more variables were hypothetically associated with the frequency of Internet use for health purposes: individual's concerns about their own health (H5) and their capacity to understand, interpret, and use available medical information on the Internet (H6). Correlation analyses were used to test both hypotheses. As shown in Table 4, only the ability to understand, interpret and use online medical information is positively correlated to Internet use for health purposes. This link was stronger in the case of Internet use for curative purposes as compared with preventive purposes. The data could not support Hypothesis H5. Based on our sample, there does not appear to be a significant relationship between the level of concern for one's health and frequency of Internet use for preventive and curative purposes.

The final two hypotheses state that what motivates the Internet user to search for health information online is closely linked to the different forms of empowerment. Before testing these hypotheses, we wanted to capture our respondents' perceived level of empowerment with respect to their own health. It should be recalled that empowerment related to professional logic involves a self-empowerment process, through which the individual learns about expert knowledge and how to use it. This allows them to be proactive in dealing with personal health issues. This logic as-

Table 8. Results associated with average annual household income

		N	Mean	Standard Deviation	*t*	*P*
Frequency of Internet use for preventive purposes	< $50,000	119	3.1	2.3	0.3	.76
	> $50,000	114	3.2	2.4		
Frequency of Internet use for curative purposes	< $50,000	119	4.6	2.9	0.8	.45
	> $50,000	114	4.9	3.0		

Table 9. Results associated with level of education

		N	Mean	Standard Deviation	*t*	*P*
Frequency of Internet use for preventive purposes	University degree	100	3.5	2.4	0.6	.57
	College or high school diploma	103	3.4	2.5		
Frequency of Internet use for curative purposes	University degree	100	5.5	2.9	1.1	.28
	College or high school diploma	103	5.4	2.7		

sumes that the individual becomes an active agent in the prevention, care or management of their illness and condition, but nevertheless agrees with the prescriptive vision of the biomedical model, under which the health professional is a legitimate expert. Consumerist empowerment, on the other hand, is seen as a demonstration of individual freedom of choice based on personal judgement and resources. This form of empowerment is seen when the individual develops their personal autonomy by identifying options, choosing from among these different options and managing the consequences of such choices. The data in Table 10 suggests that our respondents perceive that they have developed skills and a sense of control over their personal health. However, these skills belong mainly to the professional logic, which means that they are aligned with the views of health professionals (t=8.5; p < .001).

As far as our hypotheses are concerned, it should be recalled that the work of Lemire et al. (2008) reveals that a search for information associated with typically curative motivations is more likely to foster the development of empowerment under the biomedical perspective, as suggested by the professional logic (H7a), while a search for information associated with typically preventive motivations falls under the consumerist logic (H7b). Interestingly, as indicated in Table 11, the data only supported Hypothesis H7b. It would appear that the use of health professionals, and not the Internet, is positively associated with professional empowerment. Frequent use of the Internet as a source of information is more closely associated with an approach aimed at making informed choices on the basis of personal judgement, i.e. the consumerist logic.

DISCUSSION

Our results support the idea that the Internet represents a complementary source of information and that health professionals (and especially physicians) remain by far the main source of information used by individuals in matters of personal health.

In terms of the testing of our hypotheses, our study has confirmed the results of prior research that found that women are more inclined than men to search for health information online. Like Pandey et al. (2003), we observed that women use the Internet more often, especially to consult medical information for preventive purposes. As mentioned above, one explanation may be found in the traditional role of women, who often feel responsible for the health and well-being of other family members.

Our results contradict those of Cotten and Gupta (2004), suggesting that young adults represent the group which makes the most use of the Internet as a source of information for preventive purposes. Contrary to what we may have expected, older Internet users appear not to consult the Internet for curative purposes more often than young adults. There may be several explanations for these results. For one thing, it is well known that young people are the most active users of the Internet and that they connect to the world and to information largely through this technology. It is therefore not surprising to see a significant difference between young adults and older adults when it comes to their perceived capacity to understand, interpret and use the medical information that is readily available on the Internet (t=2.2; p=.04). On the other hand, it

Table 10. Levels of empowerment in personal health

Form of Empowerment	Mean (1 to 10)	Standard Deviation
Professional	8.0	1.8
Consumerist	6.6	1.9

Table 11. Relationship between Internet use and forms of empowerment

	N	Professional Empowerment	Consumerist Empowerment
Frequency of Internet use for preventive purposes	217	.10 p = .16	.19 p = .006
Frequency of Internet use for curative purposes	211	.10 p = .15	.25 p < .001
Frequency of use of health professionals	220	.48 p < .001	.10 p = .15

seems simpler to obtain easy-to-interpret information about lifestyle for preventive purposes than it is to obtain personalized information on illnesses for curative purposes. Finally, older adults' concerns with respect to health are greater, are may be more urgent. They do not have the same level of comfort or knowledge using the Internet as younger people, so they are less likely to use it, relying instead on their physicians.

Existing literature on the subject inspired us to hypothesize that income and education levels would be positively associated with use of the Internet as a source of health information. Like Lemire et al. (2008), we could not support these findings and found no significant association between frequency of use of the Internet and these two sociodemographic variables.

As for the link between perceived health status and use of the Internet as a source of health information, the existing literature provides contradictory evidence. As mentioned above, some studies have shown that people who feel that they are in poorer health or who are concerned about their health consult the Internet the most, while other studies have found the opposite: that the people who actively look for health information online are the ones who worry the least about their health. Our results confirm those studies which suggested a negative association between health concerns and use of the Internet as a source of information.

Our results also confirm an idea introduced by Norman and Skinner (2006): that the health information available online is underutilized due to Internet users' lack of knowledge and/or skills in health matters. We found a significant, positive association between an individual's ability to understand, interpret and use the medical information available online and the frequency with which an individual uses the Internet as a source of information on personal health issues. It should be recalled that, for our respondents, the Internet represents the third most important source of information, after health professionals and family and friends.

Use of the Internet for personal health information is not necessarily associated with a personal self-empowerment strategy aimed at acheiving greater compliance with the vision of physicians and other health professionals (the professional logic). It is more clearly associated with a desire to make more informed decisions by exercising personal judgment (the consumerist logic). These results depart from Lemire et al. (2008), who demonstrated that these two empowerment logics coexist in the users of a widely admired health information site and that the perception of empowerment was stronger among Internet users who subscribed to the professional logic. In this study we observed that it is the use of physicians and other health professionals, rather than use of the Internet, that is positively associated with a professional logic of empowerment. This may be explained by differences in the populations targeted by the two studies (the general public vs. the well-informed users of a health portal) and certain differences in the operationalization of the measures.

A large percentage of our respondents therefore feel that their use of the Internet mainly allows them to be better decision makers. More specifically, they perceive Internet allows them to make better personal health decisions based on personal judgement. These results provide some support to authors who have seen the growth in Internet use as evidence of a more participative and consumer-oriented approach to health care (Kalichman et al., 2002). Our results express this willingness, present among many Internet users, to more or less free themselves from medical authority and adopt an approach that is more centered on themselves, their preferences and their decision-making autonomy. Other empirical studies have provided a complementary illustration of this phenomenon, including Nicholas et al. (2003), who suggested that using the Internet to gain access to health information is accompanied by changes in behaviour, such as better eating habits, physical exercise, relaxation and the consumption of vitamins and supplements. This trend reflects a questioning of the classical approach to health, which has essentially been based on medical authority and passive patient obedience (Lewis, 2006).

To summarize, our results indicate that using the Internet as one's source of health information is directly associated with three main factors. First, women, who accounted for close to half of our sample, use the Internet for health information more often than men and, more specifically, they use it for preventive purposes. Second, young adults tend to consult the Internet more than older adults, and they use the information mostly for preventive purposes. Finally, using the Internet as one's source of information is strongly associated with an individual's perceived ability to understand, interpret and use the medical information that is available online. In addition, this study is one of the first to have explored the influence of Internet use on multiple forms of empowerment. This development appears to have significant potential, particularly in terms of the general public's decision-making autonomy.

Given the small size of our sample and the inherent limits of transversal surveys, we believe that caution should be exercised when interpreting these results. In addition, we collected the opinions and points of view of the residents of a single region that has its own characteristics. Future research should therefore see if these results can be validated in a larger sample of Internet users in other parts of the world.

REFERENCES

Anderson, J. G. (2004). Consumers of e-health: Patterns of use and barriers. *Social Science Computer Review*, *22*, 242–248. doi:10.1177/0894439303262671

Baker, L., Wagner, T. H., Singer, S., & Bundorf, M. K. (2003). Use of the Internet and e-mail for health care information: Results from a national survey. *Journal of the American Medical Association*, *289*(18), 2400–2406. doi:10.1001/jama.289.18.2400

Barrett, B., Marchand, L., & Scheder, J. (2003). Themes of holism, empowerment, access, and legitimacy define complementary, alternative, and integrative medicine in relation to conventional biomedicine. *Journal of Alternative and Complementary Medicine (New York, N.Y.)*, *9*, 937–947. doi:10.1089/107555303771952271

Broom, A. (2005). Virtually healthy: The impact of internet use on disease experience and the doctor-patient relationship. *Qualitative Health Research*, *15*(3), 325–345. doi:10.1177/1049732304272916

Burrows, R., Nettleton, S., Pleace, N., Loader, B., & Muncer, S. (2000). Virtual community care? Social policy and the emergence of computer mediated social support. *Inform C Soc*, *3*(1), 95–121. doi:10.1080/136911800359446

Christmann, S. (2005, April). *Health literacy and Internet: recommendations to promote health literacy by the means of Internet.*http://www.eurohealthnet.eu/images/ publications/pu_8.pdf.

cotton, S.R., & Gupta, S.S. (2004). Characteristics of online and offline health information seekers and factors that discriminate between them. *Soc Sci Med, 59*(9), 1795-1806.

d'Astous, A. (2005). *Le projet de recherche en marketing,* Montréal, Canada. Éditions Chenelière Éducation.

Dolan, G., Iredale, R., Williams, R., & Ameen, J. (2004). Consumer use of the Internet for health information: A survey of primary care patients. *International Journal of Consumer Studies*, *28*(2), 147–153. doi:10.1111/j.1470-6431.2003.00363.x

Dumitru, R. C., Bürkle, T., & Potapov, S. (2007). Use and perception of Internet for health related purposes in Germany: Results of a national survey. *International Journal of Public Health*, *52*(5), 275–285. doi:10.1007/s00038-007-6067-0

Fox, N. J., Ward, K. J., & O'Rourke, A. J. (2005). The 'expert patient': empowerment or medical dominance? The case of weight loss, pharmaceutical drugs and the Internet. *Social Science & Medicine*, *60*(6), 1299–1309. doi:10.1016/j.socscimed.2004.07.005

Goldner, M. (2006). Using the Internet and email for health purposes: The impact of health status. *Social Science Quarterly*, *87*(3), 690–710. doi:10.1111/j.1540-6237.2006.00404.x

Harris Interactive. (2007). *Harris Poll #76.* July 31, http://www.harrisinteractive.com/harris_poll/index.asp?PID=792.

Henwood, F., Wyatt, S., Hart, A., & Smith, J. (2003). Ignorance is bliss sometimes: constraints on the emergence of the 'informed patient' in the changing landscapes of health information. *Sociology of Health & Illness*, *25*(6), 589–607. doi:10.1111/1467-9566.00360

Hesse, B. W., Nelson, D. E., & Kreps, G. L. (2005). Trust and sources of health information: the impact of the Internet and its implications for health care providers. Findings from the first Health Information National Trends Survey. *Archives of Internal Medicine*, *165*(22), 2618–2624. doi:10.1001/archinte.165.22.2618

Hibbard, J. H., Greenlick, M., & Jimison, H. (1999). Prevalence and predictors of the use of self-care resources. *Evaluation & the Health Professions*, *22*(1), 107–122. doi:10.1177/01632789922034194

Hsiung, R. C. (2000). The best of both worlds: An online self-help group hosted by a mental health professional. *Cyberpsychology & Behavior*, *3*(6), 935–950. doi:10.1089/109493100452200

Kalichman, S. C., Benotsch, E. G., & Weinhardt, L. S. (2002). Internet use among people living with HIV/AIDS: Association of health information, health behaviors, and health status. *AIDS Education and Prevention*, *14*(1), 51–61. doi:10.1521/aeap.14.1.51.24335

Kumar, R. (2005). *Research Methodology: A step-by-step guide for beginners.* Thousand Oaks: CA, Sage Publications.

Laurence, D. P., & Park, H. (2006). New technology and old habits: The role of age as a technology chasm. *Technology and Health Care*, *14*(2), 91–96.

Lemire, M., Sicotte, C., & Paré, G. (2008). Internet use and the logics of personal empowerment in health. *Health Policy (Amsterdam)*, *88*, 130–140. doi:10.1016/j.healthpol.2008.03.006

Lewis, T. (2006). Seeking health information on the Internet: Lifestyle choice or a bad attack of cyberchondria? *Media Culture & Society*, *28*(4), 521–539. doi:10.1177/0163443706065027

Licciardone, J. C., Smith-Barbaro, P., & Coleridge, S. T. (2001). Use of the Internet as a resource for consumer health information: Results of the second osteopathic survey of health care in America (OSTEOSURV-II). *Journal of Medical Internet Research*, *3*(4), E31. doi:10.2196/jmir.3.4.e31

McMullan, M. (2006). Patients using the Internet to obtain health information: How this affects the patient-health professional relationship. *Patient Education and Counseling*, *63*(1-2), 24–28. doi:10.1016/j.pec.2005.10.006

Nease, R. F. Jr, & Brooks, W. B. (1995). Patient desire for information and decision making in health care decisions: The Autonomy Preference Index and the Health Opinion Survey. *Journal of General Internal Medicine*, *10*(11), 593–600. doi:10.1007/BF02602742

Nicholas, D., Huntington, P., & Gunter, B. (2003). The British and their use of the web for health information and advice: A survey. *Aslib Proceedings*, *55*(5-6), 258–260.

Norman, C. D., & Skinner, H. A. (2006). eHEALS: The eHealth literacy scale. *Journal of Medical Internet Research*, *8*(4), E27. doi:10.2196/jmir.8.4.e27

Nunnally, J. (1978). *Psychometric Methods.* New York: Éditions McGraw-Hill.

Pandey, S. K., Hart, J. J., & Tiwary, S. (2003). Women's health and the Internet: Understanding emerging trends and implications. *Social Science & Medicine*, *56*, 179–191. doi:10.1016/S0277-9536(02)00019-9

Pew Internet and American Life Report (2006, October 29). *Online Health Search 2006.*

Pew Internet and American Life Report (2007, October 8). *E-patients with a disability or chronic disease.*

Radin, P. (2006). To me, it's my life: Medical communication, trust, and activism in cyberspace. *Social Science & Medicine*, *62*, 591–601. doi:10.1016/j.socscimed.2005.06.022

Reddick, C. G. (2006). The Internet, health information, and managing health: An examination of boomers and seniors. *Int J Health Care Inform Syst Inform*, *1*(2), 20–38.

Renahy, E., & Chauvin, P. (2006). Internet uses for health information seeking: A literature review. *Revue d'Epidemiologie et de Sante Publique*, *54*(3), 263–275. doi:10.1016/S0398-7620(06)76721-9

Rice, R. E. (2006). Influences, usage, and outcomes of Internet health information searching: multivariate results from the Pew surveys. *International Journal of Medical Informatics*, *75*(1), 18–25. doi:10.1016/j.ijmedinf.2005.07.032

Underhill, C., & McKeown, L. (2008, March). Getting a second opinion: Health information and the Internet. *Statistics Canada, 19*(1), 1-6.

Usunier, J. C. Easterby-Smith, M., & Thorpe, R. (2000). Introduction à la recherche en gestion (2nd ed.). Paris, Economica.

Wilson, P. M. (2001). A policy analysis of the expert patient in the United Kingdom: Self-care as an expression of pastoral power? *Health & Social Care in the Community*, *9*(3), 134–142. doi:10.1046/j.1365-2524.2001.00289.x

ENDNOTE

[1] This municipal portal can be found at the following address: http://ville.montreal.qc.c

APPENDIX: QUESTIONNAIRE ITEMS

Item	Description
Professional_logic_1	I always follow the instructions of the physician and the other health professionals that I consult.
Professional_logic_2	I make my own decisions about my health, without necessarily ignoring instructions from the physician that I consult. (removed item)
Professional_logic_3	I always apply instructions from the physician or the other health professionals that I consult.
Professional_logic_4	I have a good understanding of my medical condition because of the knowledge and advice I receive from my physician and the other health professionals I consult.
Professional_logic_5	I play an active role in my relationships with the physician and the other health professionals that I consult. (removed item)
Consumerist_logic_1	The sources of information that I consult (magazines, the Internet, health professionals, etc.) give me a better understanding of my medical condition through my own ability to analyze what is relevant or not.
Consumerist_logic_2	The sources of information that I consult (magazines, the Internet, health professionals, etc.) help me feel better able to choose on my own which treatments or drugs I feel best meet my needs.
Consumerist_logic_3	I make decisions on my health based on my preferences and means rather than just following instructions from my physician or the other health professionals I consult. (removed item)
Consumerist_logic_4	Generally speaking, I trust my decisions about possible treatments and drugs.
Consumerist_logic_5	I am very well informed about the treatments or drugs recommended to me.
Community_logic_1	I make decisions about my health based on the experience and opinions of people I know (friends, family, colleagues, etc.)
Community_logic_2	The sources of information I consult (magazines, the Internet, health professionals, etc.) are useful when I discuss my health with the people I know (friends, family, colleagues, etc.)
Community_logic_3	Based on the sources of information that I consult (magazines, the Internet, health professionals, etc.), I feel more confident when talking with the people I know (friends, family, colleagues, etc.).
Community_logic_4	I have a very good understanding of my medical condition due to the support groups and focus groups that I belong to.
Community_logic_5	I know a lot about the opinions of people in a state of health similar to my own.
Preventive_use_1	I often consult the Internet to learn how to prevent disease by adopting a healthy lifestyle.
Preventive_use_2	I often consult the Internet to obtain points of view that are different from those in traditional medicine.
Curative_use_1	I often consult the Internet to better understand a health problem or a disease.
Curative_use_2	I often consult the Internet to find a specific solution or treatment for a health problem.
Social_use_1	I often participate in online discussions about health. (removed item)
Social_use_2	I often consult the Internet in order to help a friend or family member who is ill. (removed item)
e-Health_literacy_1	I know how to find useful information about health on the Internet.

This work was previously published in International Journal of Healthcare Information Systems and Informatics, Vol. 4, Issue 4, edited by J. Tan , pp. 1-18, copyright 2009 by IGI Publishing (an imprint of IGI Global).

Chapter 3.17

A Software Tool for Biomedical Information Extraction (And Beyond)

Burr Settles
University of Wisconsin-Madison, USA

ABSTRACT

ABNER (A Biomedical Named Entity Recognizer) is an open-source software tool for text mining in the molecular biology literature. It processes unstructured biomedical documents in order to discover and annotate mentions of genes, proteins, cell types, and other entities of interest. This task, known as named entity recognition (NER), is an important first step for many larger information management goals in biomedicine, namely extraction of biochemical relationships, document classification, information retrieval, and the like. To accomplish this task, ABNER uses state-of-the-art machine learning models for sequence labeling called conditional random fields (CRFs). The software distribution comes bundled with two models that are pre-trained on standard evaluation corpora. ABNER can run as a stand-alone application with a graphical user interface, or be accessed as a Java API allowing it to be re-trained with new labeled corpora and incorporated into other, higher-level applications. This chapter describes the software and its features, presents an overview of the underlying technology, and provides a discussion of some of the more advanced natural language processing systems for which ABNER has been used as a component. ABNER is open-source and freely available from http://pages.cs.wisc.edu/~bsettles/abner/

DOI: 10.4018/978-1-60566-274-9.ch017

INTRODUCTION

Efforts to organize the wealth of biomedical knowledge in the primary literature have resulted in hundreds of databases and other resources (Bateman, 2008), providing scientists with access to structured biological information. However, with nearly half a million new research articles added to PubMed annually (Soteriades & Falagas, 2005), the sheer volume of publications and complexity of the knowledge to be extracted is beyond the means of most manual database curation efforts. As a result, many of these resources struggle to remain current. Automated *information extraction* (IE), or at least automated assistance for such extraction tasks, seems a natural way to overcome these information management bottlenecks.

Named entity recognition (NER) is a subtask of IE, focused on finding mentions of various *entities* that belong to semantic classes of interest. In the biomedical domain, entities of interest are usually references to genes, proteins, cell types, and the like. Accurate NER systems are an important first step for many larger information management goals, such as automatic extraction of biologically relevant relationships (e.g., protein-protein interactions or sub-cellular location of gene products), biomedical document classification and retrieval, and ultimately the automatic maintenance of biomedical databases.

In order to facilitate and encourage research in the area of biomedical NER, several "bake-off" style competitions have been organized, in particular the NLPBA shared task (Kim et al., 2004) and the BioCreative challenge (Yeh et al., 2005). For these events, several research teams rapidly design, build, and submit results for machine learning systems using benchmark annotated text collections. The challenges showcase a variety of approaches to the problem, and provide a wealth of insights into what sorts of models and features are most effective. However, few of the resulting systems have been made publicly available for researchers working in related areas of natural language processing (NLP) in biomedicine.

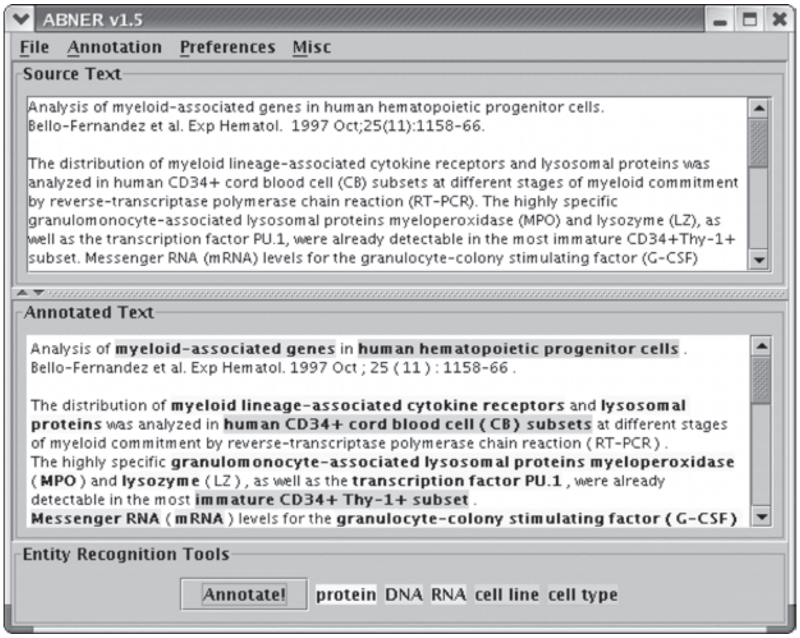
I first released ABNER (Settles, 2005) in July 2004 as a demonstrational graphical user interface (GUI) for the system I developed as part of the NLPBA shared task challenge (Settles, 2004). In March 2005, a revised, open-source version of the software was released with some performance improvements and a new Java application programming interface (API). The goal is to encourage others to write custom interfaces to the core NER software, allowing it to be integrated into other, more sophisticated biomedical information management systems. ABNER also supports training new models on corpora labeled for different knowledge domains (e.g., particular organisms, since gene naming conventions vary from species to species).

Figure 1 shows a screenshot of the intuitive GUI when ABNER is run as a stand-alone application. Text can be typed in manually or loaded from a file (top window), and then automatically tagged for multiple entities in real time (bottom window). Each entity type is highlighted with a unique color for easy visual reference, and tagged documents can be saved in a variety of annotated file formats. The application also has options for processing plain text documents on the file system in batch mode offline.

ABNER has built-in functionality for tokenization and sentence segmentation, which are fairly robust to line breaks and biomedical abbreviations (users can choose to bypass these features in favor of their own text preprocessing as well). The bundled ABNER application is implemented in Java and is therefore platform-independent, and has been tested on Linux, Solaris, Mac OS X, and Windows.

The basic ABNER distribution includes two built-in entity-tagging models trained on the NLPBA (Kim et al., 2004) and BioCreative (Yeh et al., 2005) corpora. The first is a modified version of the GENIA corpus (Kim et al., 2003), contain-

Figure 1. A screenshot of ABNER's graphical user interface



Analysis of myeloid-associated genes in human hematopoietic progenitor cells.
Bello-Fernandez et al. Exp Hematol. 1997 Oct;25(11):1158-66.

The distribution of myeloid lineage-associated cytokine receptors and lysosomal proteins was analyzed in human CD34+ cord blood cell (CB) subsets at different stages of myeloid commitment by reverse-transcriptase polymerase chain reaction (RT-PCR). The highly specific granulomonocyte-associated lysosomal proteins myeloperoxidase (MPO) and lysozyme (LZ), as well as the transcription factor PU.1, were already detectable in the most immature CD34+Thy-1+ subset. Messenger RNA (mRNA) levels for the granulocyte-colony stimulating factor (G-CSF)

Analysis of **myeloid-associated genes** in **human hematopoietic progenitor cells** .
Bello-Fernandez et al. Exp Hematol. 1997 Oct ; 25 (11) : 1158-66 .

The distribution of **myeloid lineage-associated cytokine receptors** and **lysosomal proteins** was analyzed in **human CD34+ cord blood cell (CB) subsets** at different stages of myeloid commitment by reverse-transcriptase polymerase chain reaction (RT-PCR) .
The highly specific **granulomonocyte-associated lysosomal proteins myeloperoxidase** (**MPO**) and **lysozyme** (LZ) , as well as the **transcription factor PU.1** , were already detectable in the most **immature CD34+ Thy-1+ subset** .
Messenger RNA (**mRNA**) levels for the **granulocyte-colony stimulating factor (G-CSF)**

ing five entity types labeled for 18,546 training sentences and 3,856 evaluation sentences. The latter corpus contains only one entity type that subsumes both genes and gene products (proteins, RNA, etc.) labeled for 7,500 training sentences and 2,500 evaluation sentences. Evaluation of NER systems is typically done in terms of recall $R = tp/(tp+fn)$, precision $P = tp/(tp+fp)$, and the harmonic mean as a summary statistic, $F_1 = (2 \times R \times P)/(R+P)$, where tp means true positives, fn means false negatives, and fp means false positives. Table 1 presents results for the two built-in models, trained and evaluated on the designated train/evaluation splits for these corpora.

ABNER's accuracy is still roughly state-of-the-art. To my knowledge, only two systems with published results have outperformed ABNER on the NLPBA corpus (Zhou & Su, 2004; Friedrich et al., 2006), and neither is freely available. Comparisons to published results on the BioCreative

Table 1. Evaluation results for ABNER's two built-in tagging models

Corpus	Recall	Precision	F1
NLPBA (all entities)	0.720	0.691	0.705
protein	0.778	0.681	0.726
DNA	0.631	0.672	0.651
RNA	0.619	0.613	0.616
cell line	0.582	0.539	0.560
cell type	0.656	0.798	0.720
BioCreative (gene)	0.659	0.745	0.699

corpus are more difficult to interpret, as the figures in Table 1 reflect only perfectly accurate entity predictions (i.e., exact word-boundary matches), and official BioCreative evaluation gives some "partial credit" to incomplete entity extractions (Yeh et al., 2005). When adjusted for this, ABNER is competitive with the leading systems on this corpus as well, and is again the only freely available open-source system among them.

Third-party research also indicates that ABNER is among the most accurate publicly available NER tools for biomedical text. Kabiljo et al. (2007) performed a comparative analysis of three systems: ABNER (using the BioCreative model), GAPSCORE (Chang et al., 2004), and NLProt (Mika & Rost, 2004) on a new benchmark corpus called ProSpecTome, which is a subset of NLPBA re-annotated with more stringent labeling conventions. They found ABNER to be the most accurate on this new corpus by a significant margin. Lam et al. (2006) also conducted an informal comparison of ABNER (using the NLPBA model) to PowerBioNE (Zhou et al., 2004) when deciding which to use as a component in their automated database maintenance system, and found ABNER to be consistently the best. Furthermore, most other systems are only available as web services or platform-specific compiled binaries, whereas ABNER is designed to be portable, flexible, and integrated into third-party biomedical NLP applications.

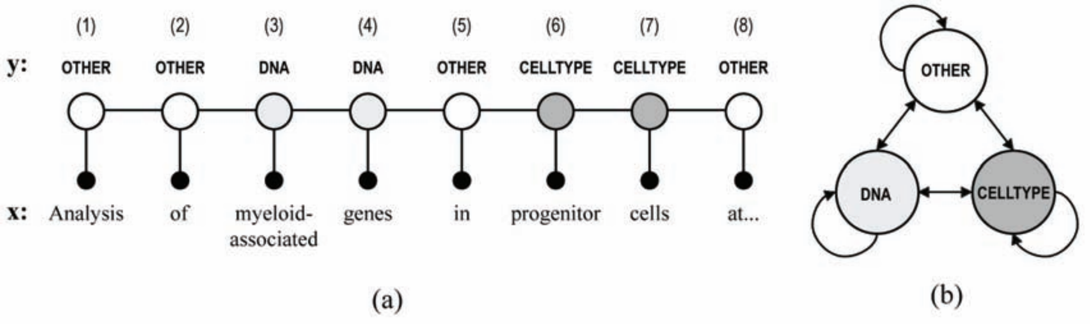
BACKGROUND AND TECHNOLOGY

The NER problem can be thought of as a *sequence-labeling task*: each word is a *token* in a sequence to be assigned a *label* (which corresponds to an entity class of interest). Once upon a time *hidden Markov models* (HMMs), which are statistical finite-state machines (Rabiner, 1989), were the machine learning method of choice for sequence labeling, such as part-of-speech tagging. However, more complex problems like NER tend to require larger, more sophisticated sets of features (e.g., words, prefixes or suffixes, capitalization patterns, neighboring words within a certain window of distance, etc.) which are certainly not independent, and can present difficulties for generative models like HMMs if the dependencies are not modeled explicitly. As a result, some researchers opt to use simple discriminative classifiers (which are more robust to such independence violations) to label each word separately, in lieu of graphical sequence models altogether (Kudoh & Matsumoto, 2000; Kazama et al., 2002).

However, *conditional random fields* (CRFs) have emerged as a sort of "best-of-both-worlds" solution (Lafferty et al., 2001). CRFs are undirected statistical graphical models (a special case of which is a linear chain, corresponding to a statistical finite-state machine), but they are also conditionally trained in a way that overcomes feature independence and other shortcomings of HMMs. After being shown effective for other NLP sequence labeling tasks like part-of-speech tagging (Lafferty et al., 2001), phrase chunking (Sha & Pereira, 2003), and named entity recognition for newswire text (McCallum & Li, 2003), they naturally became a popular candidate for solving the biomedical NER problem as well (Settles, 2004; McDonald & Pereira, 2004; Settles, 2005; Friedrich et al., 2006).

Let $\mathbf{x} = \langle x_1, x_2, \ldots, x_T \rangle$ be a sequence of observed words (i.e., a sentence) of length T, and let $\mathbf{y} = \langle y_1, y_2, \ldots, y_T \rangle$ be a sequence of labels that are assigned to the words in the input sequence $\mathbf{x}$. Figure 2(a) illustrates an example sentence and how it might be labeled. The labels in $\mathbf{y}$ represent the entities of interest (e.g., DNA, cell type, other), which also correspond to states in a statistical finite state machine, such as the one in Figure 2(b). A first-order linear-chain CRF defines the conditional probability of a label sequence $\mathbf{y}$ given an input sequence $\mathbf{x}$ to be:

Figure 2. Example CRF graphs for (a) a labeled input sequence, and (b) the structure of a corresponding finite-state machine.



(a) (b)

$$P(\mathbf{y} \mid \mathbf{x}) = \frac{1}{Z(\mathbf{x})} \exp\left(\sum_{t=1}^{T} \sum_{k=1}^{K} \theta_k f_k(y_{t-1}, y_t, \mathbf{x}_t) \right),$$

where $Z(\mathbf{x})$ is a normalization factor over all possible label sequences, f_k is one of K binary functions describing a features that characterize position t in sequence $\mathbf{x}$, and θ_k is the weight for that feature. For example, f_k might be the feature WORD=*myeloid-associated* and have value 1 at position t=3 in the sequence from Figure 2(a). Other features that are set to 1 for this position might be HASDASH, SUFFIX=*ated*, and NEXTWORD=*genes*. The weight θ_k for each feature should be positive for a feature correlated with the target label, negative for a feature that is anti-correlated, and near zero for a relatively uninformative feature. One can think of CRFs as a sequence-based generalization of maximum entropy (also known in the literature as multinomial logistic regression) classifiers (Nigam et al., 1999). In order to learn these weights properly, we can use gradient ascent to maximize the conditional log likelihood of N labeled sequences in a training set $D = \{\langle \mathbf{x}, \mathbf{y} \rangle_{(1)}, \ldots, \langle \mathbf{x}, \mathbf{y} \rangle_{(N)}\}$:

$$LL(D) = \sum_{n=1}^{N} \log\left(P(\mathbf{y}_{(n)} \mid \mathbf{x}_{(n)}) \right) - \sum_{k=1}^{K} \frac{\theta_k^2}{2\sigma^2},$$

where the second term is simply a Gaussian prior over feature weights to help to prevent over-fitting due to sparsity in D. If the training sequences are fully labeled, the objective function $LL(D)$ is convex and the model is guaranteed to converge to an optimal set of feature weights. New sequences can then be labeled using an inference algorithm such as Viterbi. For more information on CRFs, their typical training procedures, and their relationship with other graphical models, see Sutton & McCallum (2006) for a good introduction.

ABNER uses a first-order CRF with a default feature set comprised of orthographic and contextual features, mostly based on regular expressions, prefixes or suffixes, and neighboring tokens. The full feature set is viewable (and editable) in the ABNER distribution source code. Some research indicates that additional features like part-of-speech tags and lexicon (dictionary) membership can improve accuracy, however ABNER does not have native support for such features at this time. My own research indicates that the gains of such features for ABNER are only slight, and pose several software engineering challenges at the expense of its currently robust, portable, and fast performance.

ABNER is written entirely in Java using graphical window objects from the Swing library. The CRF models are implemented with the MALLET toolkit (http://mallet.cs.umass.edu), which uses a quasi-Newton method called L-BFGS (Nocedal &

Wright, 1999) to learn the optimal feature weights efficiently. ABNER conducts its built-in tokenization using a deterministic finite-state lexical scanner built with JLex (http://www.cs.princeton.edu/~appel/modern/java/JLex/).

BEYOND NAMED ENTITIES

As stated earlier, accurate NER systems are an important first step for many larger information management goals. This section briefly discusses some more recent work by other researchers who are using ABNER as a component in larger biomedical text processing systems. These applications generally fall into three main categories: higher-level information extraction, document categorization and information retrieval, and the automatic maintenance or curation of biological databases.

Higher-Level Information Extraction

NER is a basic subtask of information extraction (IE), focused only on finding *entity* mentions in text. Naturally, the next step in IE is identifying the *relationships* among such entities directly from text. For example, in mining the biomedical literature this can mean extracting protein-protein interactions or identifying the sub-cellular localization of gene products.

Madkour et al. (2007) developed an extraction system for protein-protein interactions that employs ABNER in the protein identification phase. After proteins are annotated, the articles are mined using an unsupervised mutual reinforcement algorithm to rank textual patterns indicating an interaction relationship. They report an F_1 score of 0.55 on a corpus of MEDLINE abstracts, which appears to be near the current state-of-the-art for this formulation of the problem. To facilitate further progress in the area of extracting protein-protein interactions, a few variants of the task were proposed as part of the BioCreative2 challenge, and ABNER was also chosen as an NER component in at least four of the competing approaches (Abi-Haidar et al., 2007; Figueroa & Neumann, 2007; Gonzalez et al., 2007; Huang et al., 2007). Results from this evaluation are somewhat mixed, however, and substantially lower than those reported by Madkour et al.

Bethard et al., (2008) propose another interesting IE task that involves extracting semantic role arguments for protein transport predicates. Consider the following sentence: “IRS-3 expression blocked glucose/IGF-1 induced IRS-2 translocation from the cytosol to the plasma membrane.” They developed a system that attempts to automatically extract relational predicate records like TRANSLOCATION(*IRS-2*, *cytosol*, *plasma membrane*) from such passages of the biomedical literature. The extracted predicate name represents the type of protein transport, and the arguments correspond to the target protein and the sub-cellular source and destination locations of the transport action, respectively. The authors employ ABNER’s protein predictions as part of the predicate extraction system, resulting in an F_1 score of 0.792 (compared to 0.841 if protein mentions are already perfectly known).

Document Categorization and Information Retrieval

Most information retrieval (IR) systems aim to retrieve documents that are relevant to the user’s particular information needs. Recently, however, interest has grown in developing systems that combine IR (particularly in the biomedical domain) with text categorization and information extraction, attempting to answer user questions or put them in context, while providing supplementary information and linking to the original sources (Hersh et al., 2007).

Several researchers who work on these more sophisticated IR systems have found that utilizing named entity predictions can improve their accuracy. For example, Tari et al. (2007) employ

ABNER to process query topics in a Q&A-style document retrieval system. The extracted entities are then matched against synonym lists in gene databases as part of a query-expansion step to improve recall. Another task, part of the Text Retrieval Conference (TREC) 2005 genomics track, involves filtering a set of documents for those which are appropriate for manual curation in four different biological databases. Several systems developed to solve this task (Yang et al., 2006; Yu et al., 2006; Li et al., 2007) use ABNER's entity predictions to enhance the feature set in this classification problem. Similarly, ABNER is used effectively by IR systems designed to filter passages of text for mentions of protein-protein interactions (Abi-Haidar et al., 2007; Figueroa & Neumann, 2007; Huang et al., 2007).

Automatic Maintenance of Biological Databases

Biological researchers often rely on specialist databases to maintain an in-depth repository of domain knowledge. For example, a database may only catalog information on a single, organism-specific genome, or functionally classified toxins and other chemicals. However, as indicated in the introduction, the rate of growth for new information to be mined from the primary literature or filtered from larger, general-purpose databases each year far eclipses the ability of curators to keep things up-to-date manually, even with a focused and specialized scope of interest.

Lam et al. (2006) present a novel system to address some of these issues, combining ABNER with a protein sequence motif extractor to automatically update special-interest databases. Entities are extracted from the textual fields of target database records (e.g., titles and abstracts or reference articles), and motifs are likewise extracted from the protein sequence fields (i.e., the actual amino acid sequences). The entity keywords and sequence motifs are then combined to generate queries for more general-purpose databases in the public domain, such as GenBank or SwissProt. The idea is to filter the records from these broader interest databases and automatically extract the records that are relevant to the special-interest resources at hand. Their experiments in automatically maintaining a snake venom database achieve an F_1 score of 0.80 using both ABNER keywords and sequence motifs (as opposed to 0.045 and 0.41, respectively, using either one in isolation).

Cakmak & Ozsoyoglu (2007) present another system that uses ABNER to extract gene mentions from the literature, and infer new function annotations from the Gene Ontology (GO Consortium, 2004) that may have been overlooked. The GO is a standardized vocabulary for molecular function of gene products used in most model organism genome databases. The resulting GO annotations can be appended to the extracted genes' database records automatically. They report F_1 scores of 0.66, 0.66, and 0.64 for the Biological Process, Molecular Function, and Cellular Component sub-ontologies, respectively.

CONCLUSION

ABNER is an efficient, accurate, cross-platform software tool for finding named entities in biomedical text. It has been demonstrated to perform at or near the state-of-the-art on multiple benchmark corpora, and remains one of the few high-accuracy NER systems available freely and under an open-source license at the time of this writing. It also ships with its own API, allowing users to re-train the underlying machine learning system for specific tasks, or to integrate it into larger, more sophisticated information management systems. So far, ABNER has been used as a vital component in several such systems, including applications for higher-level information extraction, document classification and retrieval, and the automatic maintenance of biological databases.

ACKNOWLEDGMENT

I would like to thank Mark Craven for his guidance and support of this project. Research related to the software was supported by NLM grant 5T15LM007359 and NIH grant R01-LM07050.

REFERENCES

Abi-Haidar, A., Kaur, J., Maguitman, A., Radivojac, P., Retchsteiner, A., Verspoor, K., et al. (2007). Uncovering protein-protein interactions in the bibliome. In *Proceedings of the BioCreative2 Workshop*, (pp. 247–255).

Bateman, A. (2008). Editorial. *Nucleic Acids Research*, *33*(Database issue), D1. doi:10.1093/nar/gki133

Bethard, S., Lu, Z., Martin, J., & Hunter, L. (2008). Semantic role labeling for protein transport predicates. *BMC Bioinformatics*, *9*, 277. doi:10.1186/1471-2105-9-277

Cakmak, A., & Ozsoyoglu, G. (2007). Annotating genes using textual patterns. In [PSB]. *Proceedings of the Pacific Symposium on Biocomputing*, *12*, 221–232. doi:10.1142/9789812772435_0022

Chang, J. T., Schutze, H., & Altman, R. B. (2004). GAPSCORE: finding gene and protein names one word at a time. *Bioinformatics (Oxford, England)*, *20*(2), 216–225. doi:10.1093/bioinformatics/btg393

Consortium (2004). The Gene Ontology (GO) database and informatics resource. *Nucleic Acids Research*, 32, D258-D261.

Figueroa, A., & Neumann, G. (2007). Identifying protein-protein interactions in biomedical publications. In *Proceedings of the BioCreative2 Workshop*, 217-225. GO

Friedrich, C., Revillion, T., Hofmann, M., & Fluck, J. (2006). Biomedical and chemical named entity recognition with conditional random fields: The advantage of dictionary features. In *Proceedings of the International Symposium on Semantic Mining in Biomedicine (SMBM)*, (pp. 85-89).

Gonzalez, G., Tari, L., Gitter, A., Leaman, R., Nikkila, S., Wendt, R., et al. (2007). Integrating knowledge extracted from biomedical literature: Normalization and evidence statements for interactions. In *Proceedings of the BioCreative2 Workshop*, (pp. 227-235).

Hersh, W., Cohen, A., Roberts, P., & Rekapalli, H. (2007). TREC 2006 genomics track overview. In *Proceedings of the Text Retrieval Conference (TREC)*.

Huang, A., Ding, S., Wang, H., & Zhu, X. (2007). Mining physical protein-protein interactions from literature. In *Proceedings of the BioCreative2 Workshop*.

Kabiljo, R., Stoycheva, D., & Shepard, A. (2007). ProSpecTome: A new tagged corpus for protein named entity recognition. In *Proceedings of the ISMB BioLINK*, 24-27. Oxford University Press.

Kazama, J., Makino, T., Ohta, Y., & Tsujii, J. (2002). Tuning support vector machines for biomedical named entity recognition. In *Proceedings of the ACL Workshop on NLP in the Biomedical Domain*, 1-8.

Kim, J., Ohta, T., Teteisi, Y., & Tsujii, J. (2003). GENIA corpus - a semantically annotated corpus for bio-textmining. *Bioinformatics (Oxford, England)*, *19*(Suppl. 1), I180–I182. doi:10.1093/bioinformatics/btg1023

Kim, J., Ohta, T., Tsuruoka, Y., Tateisi, Y., & Collier, N. (2004). Introduction to the bio-entity recognition task at JNLPBA. In *Proceedings of the International Joint Workshop on Natural Language Processing in Biomedicine and its Applications (NLPBA)*, 70–75.

Kudoh, T., & Matsumoto, Y. (2000). Use of support vector learning for chunk identification. In *Proceedings of the Conference on Natural Language Learning (CoNLL)*, 142-144.

Lafferty, J., McCallum, A., & Pereira, F. (2001). Conditional random fields: Probabilistic models for segmenting and labeling sequence data. In *Proceedings of the International Conference on Machine Learning (ICML)*, (pp. 282–289). Morgan Kaufmann.

Lam, K., Koh, J., Veeravalli, B., & Brusic, V. (2006). Incremental maintenance of biological databases using association rule mining. In *Lecture Notes in Computer Science*, 140–150. Springer-Verlag.

Li, Y., Lin, H., & Yang, Z. (2007). Two approaches for biomedical text classification. In Proceedings of the *International Conference Bioinformatics and Biomedical Engineering (ICBBE)*, (pp. 310–313). IEEE Press.

Madkour, A., Darwish, K., Hassan, H., Hassan, A., & Emam, O. (2007). BioNoculars: Extracting protein-protein interatctions from biomedical text. In *BioNLP 2007: Biological, translational, and clinical language processing*, (pp. 89–96). ACM Press.

McCallum, A., & Li, W. (2003). Early results for named entity recognition with conditional random fields, feature induction and web-enhanced lexicons. In *Proceedings of the Conference on Natural Language Learning (CoNLL)*, (pp. 188–191).

McDonald, R., & Pereira, F. (2004). Identifying gene and protein mentions in text using conditional random fields. In *Proceedings of the BioCreative Workshop*.

Mika, S., & Rost, B. (2004). Protein names precisely peeled off free text. *Bioinformatics (Oxford, England)*, *20*(Suppl. 1), I241–I247. doi:10.1093/bioinformatics/bth904

Nigam, K., Lafferty, J., & McCallum, A. (1999). Using maximum entropy for text classification. In *Proceedings of the IJCAI Workshop on Information Filtering*, (pp. 61-67).

Nocedal, J., & Wright, S. J. (1999). *Numerical Optimization*. Springer.

Rabiner, L. R. (1989). A tutorial on hidden Markov models and selected applications in speech recognition. *Proceedings of the IEEE*, *77*(2), 257–286. doi:10.1109/5.18626

Settles, B. (2004). Biomedical named entity recognition using conditional random fields and rich feature sets. In *Proceedings of the International Joint Workshop on Natural Language Processing in Biomedicine and its Applications (NLPBA)*, (pp. 104–107).

Settles, B. (2005). ABNER: an open source tool for automatically tagging genes, proteins, and other entity names in text. *Bioinformatics (Oxford, England)*, *21*(14), 3191–3192. doi:10.1093/bioinformatics/bti475

Sha, F., & Pereira, F. (2003). Shallow parsing with conditional random fields. In *Proceedings of the Human Language Technology and North American Association for Computational Linguistics Conference (HLT-NAACL)*, 213–220. ACL Press.

Soteriades, E. S., & Falagas, M. E. (2005). Comparison of amount of biomedical research originating from the European Union and the United States. *British Medical Journal*, *331*, 192–194. doi:10.1136/bmj.331.7510.192

Sutton, C., & McCallum, A. (2006). An introduction to conditional random fields for relational learning. In L. Getoor & B. Taskar (Eds.), *Introduction to Statistical Relational Learning*. MIT Press.

Tari, L., Gonzalez, G., Leaman, R., Nikkila, S., Wendt, R., & Baral, C. (2007). ASU at TREC 2006 genomics track. In *Proceedings of the Text Retrieval Conference (TREC)*.

Yang, Z., Lin, H., Li, Y., Liu, B., & Lu, Y. (2006). TREC 2005 genomics track experiments at DUTAI. In *Proceedings of the Text Retrieval Conference (TREC)*.

Yeh, A., Morgan, A., Colosimo, M., & Hirschman, L. (2005). BioCreative task 1a: Gene mention finding evaluation. *BMC Bioinformatics*, *6*(Suppl. 1), S2. doi:10.1186/1471-2105-6-S1-S2

Yu, L., Ahmed, S., Gonzalez, G., Logsdon, B., Nakamura, M., Nikkila, S., et al. (2006). Genomic information retrieval through selective extraction and tagging by the ASU-BoiAI group. In *Proceedings of the Text Retrieval Conference (TREC)*.

Zhou, G., & Su, J. (2004). Exploring deep knowledge resources in biomedical name recognition. In *Proceedings of the International Joint Workshop on Natural Language Processing in Biomedicine and its Applications (NLPBA)*, (pp. 96-99).

Zhou, G., Zhang, J., Su, J., Shen, D., & Tan, C. L. (2004). Recognizing names in biomedical texts: A machine learning approach. *Bioinformatics (Oxford, England)*, *20*(7), 1178–1190. doi:10.1093/bioinformatics/bth060

This work was previously published in Information Retrieval in Biomedicine: Natural Language Procesing for Knowledge Integration, edited by V. Prince; M. Roche, pp. 315-324, copyright 2009 by Medical Information Science Reference (an imprint of IGI Global).

Section IV
Utilization and Application

This section introduces and discusses the utilization and application of health information systems. These particular selections highlight, among other topics, challenges in electronic medical record system adoption, wireless technology adoption in healthcare, and current practices in healthcare systems. Contributions included in this section provide excellent coverage of today's online environment and insight into how health information systems impact the fabric of our present-day global village.

Chapter 4.1

Challenges with Adoption of Electronic Medical Record Systems

Abirami Radhakrishnan
Morgan State University, USA

Dessa David
Morgan State University, USA

Jigish Zaveri
Morgan State University, USA

INTRODUCTION

Among health care information systems, past research has credited Electronic Medical Records (EMR) systems with offering the greatest potential for improving quality within health care environments. Benefits range from reducing errors to cutting overall health care costs. For instance, the utility of an EMR system will allow physicians' enterprise wide access to a patient's entire medical chart, monitor patients' care for possible drug interaction, proactively prompt doctor(s) with recommended treatment, provide clinical decision support, simplify record keeping, e-prescription, documented referrals, and reminders to patients and health care providers.

Despite these benefits and a defined movement to integrate EMR systems in medical outfits, adoption of EMR systems by health care professionals has been very slow (Audet, Doty, Peugh, Shamasdin, Zapert, & Schoenbaum, 2004; Burt, Hing, & Woodwell, 2005; Miller & Sim, 2004; Simon & Simon, 2006). According to the National Ambulatory Medical Care Survey Report (2005) only 25% of office-based physicians are recorded as partial or fully using EMR systems. Nevertheless, interest to adopt EMR systems continues to be significant (Miller & Sim, 2004).

What accounts for the slow adoption of EMR systems? To answer, we must identify and address challenges associated with this process. A review of the recent practitioners, academic health informatics literature, and provisions of HIPPA Act of 1996 (Adler & Edsall, 2005; Audet et al., 2004;

DOI: 10.4018/978-1-59904-889-5.ch027

Baharozian, 2005; Edsall & Adler, 2005; Hough, Chen, & Lin, 2005; Lenhart, Loomis, Criswell, & Meggs, 2000; Miller & Sim, 2004; Retchin, Wenzel, &, 1999; Swartz, 2005; Valdes, Kibbe, Tolleson, Kunik, & Petersen, 2004) cite several barriers faced with the adoption process. Further analysis also suggests that the promises of successful EMR deployment will not be fully realized unless concerns linked to the EMR implementation process are alleviated. We investigated EMR adoption by conducting open ended interviews with EMR managers, vendors, and physicians to explore their experiences with their EMR implementation.

In this article, we present the results from our study. The next section highlights challenges associated with EMR adoption and use. We conclude by suggesting solutions geared towards lessening these challenges thereby clearing the path for successful EMR adoption and use.

CHALLENGES

Our meta-analysis identified several barriers experienced by professionals regarding EMR adoption and use. These challenges include: cost, difficulty in calculating return on investment, lack of education, physicians' and staff concerns, technology related concerns, inadequate complementary changes to organizational processes, lack of IT support, and lack of incentives.

Costs

EMR systems are costly. Many health care institutions cite cost as a primary prohibitive factor with adoption of EMR. There are high up-front installation costs and recurring expenses for operation and maintenance. During our interviews, the interviewees clarified that up-front costs range from $15,000-$60,000 per physician. Initial set-up costs include purchase cost of hardware, software, network infrastructure, trainin, and workflow reorganization. Operation and maintenance costs include data conversion, ongoing training, hardware and software, and specialized IT support staff.

With such exorbitant costs and uncertainty regarding return on investments, we can assume that small companies may not find adoption of EMR systems feasible thus prohibiting implementation (Audet et al., 2004; Miller & Sim, 2004; Retchin et al., 1999; Winn, 2002).

Additional expenses are incurred during the EMR transition period due to physicians attending to fewer patients translating to decreased revenue.

Difficulty in Calculating Return on Investment

One of the major concerns with new projects for upper level management is financial payoff. Is this worth the investment? As mentioned earlier, the level of initial investment is high. There is an uncertainty over the size of financial benefits that may accrue over time (Audet et al., 2004; Miller & Sim, 2004).

Benefits obtained from EMR can be complex to measure with long pay back period. Most health care institutions lack the financial and operational analysis tools for an "uninformed" EMR buyer to make a competent decision on behalf of their organization.

Lack of Education

Most health care institutions lack knowledgeable personnel capable of evaluating and managing implementation EMR system for their organizations. EMR systems are complex with several modules and requiring special expertise.

During the implementation phase there is a need for a champion. The literature states projects without a champion are most likely to fail. A champion is one that promotes the benefits of EMR within the organization. He or she is a person capable of aligning the systems' functions with the needs of the health care organization. A champion can properly assist in defining the scope, allocating resources and preparing the organization for the transition that will come with EMR implementation.

Concerns of Physicians and Staff

The concerns of physicians and staff to use and manage EMR systems remain another major challenge. Physicians are very reluctant to adopt and use EMR systems. Physicians view their role primarily about patients, with automation secondary. Many fear the use of EMR systems will take them away from their primary duties.

Physicians and nurses also fear that managers could measure, compare, and evaluate the amount of time each professional spends on each task. Physicians and other medical staff are apprehensive that they may be reprimanded for "slacking off" or deviating from predetermined practice sequence. These concerns act as an impediment for adoption and use of EMR systems (Bar-Lev & Harrison, 2006). During our interviews, however, this factor did not emerge as one of the areas of concerns.

Physicians and staff are also reluctant to use EMR because they need to take time off their schedule for training on coding, documentation, and e-prescription capabilities of EMR systems (Berkowitz, 1997; Lenhart et al., 2000). Training requirements erode the initial enthusiasm for use among some users. During our interviews, a few physicians expressed that they spent a significant amount of time meeting the training requirements.

Physicians are also resentful with receiving clinical recommendations from EMR. They believe that after years of medical training, accepting recommendations from a computer information system is demeaning and a threat to their independent thinking.

Technology Related Concerns

There are several concerns related to EMR technology.

Technophobia

There are people within the health care clinics that are intimidated by technology. They simply panic when interacting with technology. Fears range from care providers perceiving that their jobs are at stake (EMR will replace or outperform them) to "what if I hit an incorrect key stoke and erase critical data from the system?" Such fears have crippling effects on EMR implementation.

Other Technology Concerns

Interoperability is another major concern. Interoperability refers to the ability of EMR system to facilitate exchange of patients' medical records across medical institutions such as hospitals, polyclinics, independent testing labs, and medical centers. This factor is important because there are more than 264 different software programs currently used in the U.S. and most of these programs are not compatible with each other (Retchin et al., 1999; Valdes et al., 2004). Poor interoperability results in poor electronic data exchange across institutions. Support staff and physicians get frustrated as they are forced to spend more time to manually enter data from external systems.

System difficulty is another technology related concern. This issue pertains to the difficulty associated with conversion of old paper based documents into electronic medical records (Berkowitz, 1997; Retchin et al., 1999). This factor need to be considered because many documents involve extensive handwritten content, some of which may have been generated by different health care professionals over the life span of the patient and some of the content is illegible for conversion. Moreover, the digital scanning process involved in conversion of these physical records to electronic documents is an expensive, time-consuming process, which must be done to exacting standards to ensure exact capture of the content.

Usability remains as a major concern. There are multiple screens, options, and navigational aids in the EMR system. Problems with EMR usability, especially documenting progress notes cause physicians to spend extra time learning effective ways to use the EMR (Audet et al., 2004; Miller & Sim, 2004). This issue is compounded by the fact that smaller medical institutions often lack financial resources to train physicians on usability.

Health care information is sensitive. There are concerns pertaining to data security and privacy (Baharozian, 2005; Rind & Safran, 1993). HIPPA Act (1996) mandates that all health care providers adhere to national standards while conducting electronic exchange of health data and emphasis should be laid on the security and privacy of health data. Even though it is recognized that EMR systems are better than paper based systems in terms of data security and privacy, these concerns still persist (Baharozian, 2005; Hsieh & Lin, 2006). There is a persistent fear that hackers can destroy sensitive patients' records.

Inadequate IT Support

With the implementation of any major information system as EMR, there is a need for IT support. Factors range from hardware, software, or network ongoing issues to training. EMR is also considered a reengineered process. Most professionals found in health care environments are medical professions with limited technology expertise. Many care providers express being more at ease using the system with IT support close by.

Inadequate Complementary Changes to Organizational Processes

EMR hardware and software cannot simply be used as "out of box" to reap superior business value. As Wade and Hulland (2004) point out, managers should effectively use outside-in and spanning resources such as IT management practices, IT change management, business systems thinking together with inside-out IT resources such as basic IT infrastructure and IT technical manpower. This simply means that information technology innovations and organizational process changes in tandem. Complementary changes needs to be done to the hospital processes such as patient registration, diagnosis, medical/surgical process, prescription generation and billing, and so forth. These complementary changes exact a great deal of time from physicians, nurses, front-office staff, and hospital managers. Physicians have to redesign their workflows (i.e., how they work in the exam room). Managers and support staff have to redesign office workflows. Practitioners' literature (Miller & Sim, 2004) point out that office-based physicians and solo physicians do not spend enough time in redesigning workflows. It is well known that hospitals that install sophisticated EMR systems before they have done the necessary organizational process changes are not going reap benefits from EMR investments. In our interviews, EMR managers agreed that extensive changes are needed in the management of work flow while trying to implement EMR systems.

Lack of Incentives

It is agreed upon that EMR systems are expensive and most medical professionals require extensive training to reap full benefits. The evidence from the literature suggests that given a choice many physicians will not use EMR systems. They view use of this system as time consuming and distracting from their primary duties. Without incentives by their institutions or government many health care professionals will not implement EMR systems.

SOLUTIONS

There are no simple anecdotes to overcome the challenges referenced above. We therefore propose a multifaceted solution. To expedite the process of EMR implementation, barriers experienced by health care professionals must be addressed at the individual, organization and governmental levels. On one hand we have risks feared by health care professionals and institutions. On the other hand we have a lack of incentives to entice businesses to adopt EMR.

We believe that interventions at the governmental and institutional levels can play a role in stimulating the adoption process. Each intervention increases the attractiveness of EMR use by hospitals and medical institutions.

Governmental Level Interventions

Certain interventions could be undertaken at the governmental level in order to spur the EMR adoption and use.

a. Federal and state governments could provide financial incentives, subsidies, and tax breaks to hospitals and medical institutions that adopt and use EMR systems. As we mentioned before, lack of financial resources is one of the major challenges faced by medical institutions and hospitals. This scheme of providing financial incentives would promote medical institutions and hospitals to invest and effectively use EMR systems. Audet et al. (2004) report that in European countries such as the UK and Sweden, physicians who invest in EMR systems receive government subsidies, which has spurred adoption of EMR systems. Such policies could be adopted by the U.S. federal government also. This scheme would also benefit the patients as EMR systems improve the overall efficiency of health care service providers.

b. As we mentioned before, system interoperability is one of the major technology related concerns. In order to address this concern, the U.S. Department of Health and Human Services could develop a process to harmonize EMR system applications and create industry-wide standards for operation and maintenance of EMR systems and exchange of health data. Vendors who sell EMR systems would be forced to come up with software applications that are compatible with each other. This would promote better standardization of the product, interoperability of EMR systems and information sharing of health records across medical institutions, hospitals and testing centers. This scheme would in turn promote usage of EMR systems. Miller and Sim (2004) report that the government has initiated some data exchange standards such as HL7, LOINC, and provisions of HIPPA Act of 1996 also mandate use of data exchange standards. We hope that more organizations use these data exchange standards so as to improve system interoperability.

Institutional Level Interventions

Hospitals and medical institutions could undertake the following interventions in order to promote adoption and effective usage of EMR systems by physicians and other staff.

a. **Provide performance incentives to physicians and other staff:** Hospitals and medical institutions could consider providing performance improvement based financial incentives to physicians and other staff. As mentioned before, many hospitals and clinics have reported that EMR systems have improved the throughput for diagnosis, treatment, and consultation, reduced the time taken for delivery of services, improved the speed and accuracy of medical insurance claims registration, reduced the number of medical coding and transcription errors, and improved the data integrity of patient's medical records and the institution's overall responsiveness to patient's needs. Hospitals could come up with a set of process based metrics (such as diagnosis throughput, number of medical errors, number of correct insurance claims registered, etc.) and evaluate the performance improvements associated with the use of EMR systems. Based on the extent of performance improvements achieved, physicians and other staff could be provided extra financial incentives. This would motivate the physicians and other staff to use EMR systems.

b. **Consider temporal aspect of technology payoff:** As IT business value studies (Brynjolfsson & Hitt, 2000; Devaraj & Kohli, 2000, 2003) suggest, top management of hospitals and medical institutions should consider the temporal aspect of technology payoff; that is, payoffs may not be realized instantaneously, but only after certain periods of time, which is usually 2-3 years. Hence it becomes important for top management to consider the lag effect when they conduct cost-benefit analysis of EMR systems.

c. **Top management support for use of advanced capabilities of EMR systems:** As mentioned before, the capability of EMR to document progress notes and facilitate audit trails create fear in the minds of physicians and nurses that managers could measure, compare and evaluate the amount of time each professional spent on each task. Physicians and other medical staff also fear that they might be reprimanded for "slacking off" or deviating from predetermined practice sequence. These fears act as an impediment for usage of EMR systems. Top management should lend its support to physicians and work to alleviate these fears. Top management should develop strong channels of communication and co-operatively work with physicians and other staff members. Also, physicians should be made to understand that coding, documentation, and audit trail capabilities should be viewed as positive features as they provide the required checks and balances in the health care delivery system.

d. **Increase thrust on training:** In order to work around technology usability issue, hospital management should place increased emphasis on training of system users (i.e., physicians and other office staff). Users should be given time off their regular work schedules so that they can be trained to use EMR systems effectively.

e. **Emphasize complementary process changes:** Managers and physicians should stop viewing EMR as a "mere technology." To derive value out of EMR, it has to be viewed as "Joint EMR- organization" endeavor. It is important to recognize that information technologies such as EMR interact with key organizational processes in order to bring about business value. Swanson (1994) calls such a joint endeavor as Type III innovation (Swanson, 1994). Complementary changes needs to be done to hospital processes such as patient registration, diagnosis, medical/surgical process, prescription generation and billing, and so forth.

f. **IT support:** Technical support is critical when implementing complex computer information systems. Problems can arise from hardware, software, network or user initiated failure. The provision of adequate IT support is essential to achieving maximum results of EMR with minimal downtime. Medical personnel also report feeling more comfortable transitioning to EMR when IT support is available. Health care institutions should never underestimate the value of IT support. During IT planning, institutions should consider acquiring IT support from

EMR vendors and independent consultants, as well as establishing an in house support center.

CONCLUSION

Implementation of EMR systems can be a daunting task. Many health care advocates as well as the government are promoting EMR to become a standard in health care. The promised benefits of EMR are enticing. This process is also accelerated by changes in health care and reporting demands from the influx of managed care plans. We reviewed the existing literature as well as conducted our own study to unearth key barriers that affect EMR adoption. In this article, we highlighted these challenges and proposed solutions.

We urge researchers to continue this line of research. Several interesting topics still need to be explored. Is cost really the main inhibitor of EMR adoption? What organizational factors affect the success or failure of EMR adoption? Initial evidence suggests that the size of a practice matters with EMR; more work is needed to confirm this. What demographics data affect EMR adoption; for instance, does age or medical school education of physicians affect EMR adoption/use. The literature reports that many of the benefits of EMR will be realized later. As such, this gives us a need to conduct longitudinal studies at health care organizations.

Additionally, researchers should seek to evaluate EMR adoption research with the theoretical lenses of transaction cost economics, resource based view, social network theory, digital options theory, diffusion of innovation, and other grounded IT adoption theories.

REFERENCES

Adler, K. G., & Edsall, R. L. (2005). Electronic health records: A user-satisfaction survey. *Family Practice Management*, *1*(1), 1–6.

Audet, A.-M., Doty, M., Peugh, J., Shamasdin, J., Zapert, K., & Schoenbaum, S. (2004). Information technologies: When will they make it into physicians black bags? *Medscape General Medicine*, *6*(4), 2–7.

Baharozian, D. B. (2005). Electronic medical records in practice: Are we there yet? *Ophthalmology Times*, *30*(22), 45–52.

Bar-Lev, S., & Harrison, M. I. (2006). Negotiating time scripts during implementation of an electronic medical record. *Health Care Management Review*, *31*(1), 11–18.

Berkowitz, L. L. (1997). Breaking down the barriers: Improving physician buy-in of CPR systems. *Healthcare Informatics*, *14*(10), 73–76.

Brynjolfsson, E., & Hitt, L. (2000). Computing productivity: Are computers pulling their weight? *Mimeo . MIT and Wharton*, *1*(1), 21–43.

Burt, C. W., Hing, E., & Woodwell, D. (2005). *Electronic medical record use by office-based physicians.* United States. Retrieved February 14, 2008, from http://www.cdc.gov/nchs/products/pubs/pubd/hestats/electronic/electronic.htm

Devaraj, S., & Kohli, R. (2000). Information technology payoff in the health care industry: A longitudinal study. *Journal of Management Information Systems*, *16*(14), 41–68.

Devaraj, S., & Kohli, R. (2003). Performance impacts of information technology: Is actual usage the missing link? *Management Science*, *49*(3), 273–289. doi:10.1287/mnsc.49.3.273.12736

Edsall, R. L., & Adler, K. G. (2005). An EHR user satisfaction survey: Advice from 408 family physicians. *Family Practice Management*, *2*(1), 29–36.

Hough, C. B. H., Chen, J. C. H., & Lin, B. (2005). Virtual health/electronic medical record: Current status and perspective. *International Journal of Healthcare Technology and Management*, *6*(3), 257–275. doi:10.1504/IJHTM.2005.006523

Hsieh, C., & Lin, B. (2006). *Electronic medical records: current status and future development.* Paper presented at the National Decision Sciences Institute Conference Proceedings, San Antonio, Texas.

Lenhart, J., Loomis, G., Criswell, D., & Meggs, W. (2000). An analysis of trends, perceptions, and use patterns of electronic medical records among U.S. family practice residency programs. *Family Medicine*, *32*(2), 109–114.

Miller, R. H., & Sim, I. (2004). Physicians use of electronic medical records: Barriers and solutions. *Health Affairs*, *23*(2), 116–126. doi:10.1377/hlthaff.23.2.116

Retchin, S., & Wenzel, R. (1999). Electronic medical record systems at academic health centers: Advantages and implementation issues. *Academic Medicine*, *74*(5), 493–498. doi:10.1097/00001888-199905000-00013

Rind, D., & Safran, C. (1993). *Real and imagined barriers to an electronic medical record.* Paper presented at the Proceedings of the Annual Symposium of Computing Applications in Medical Care.

Simon, S. J., & Simon, S. J. (2006). An examination of the financial feasibility of electronic medical records (EMRs): A case study of tangible and intangible benefits. *International Journal of Electronic Healthcare*, *2*(2), 185–200.

Swanson, E. B. (1994). Information systems innovation among organizations. *Management Science*, *40*(9), 1069–1092. doi:10.1287/mnsc.40.9.1069

Swartz, N. (2005). Electronic medical records' risks feared. *Information Management Journal.*

Valdes, I., Kibbe, D., Tolleson, G., Kunik, M., & Petersen, L. (2004). Barriers to proliferation of electronic medical record. *Informatics in Primary Care*, *12*(1), 3–9.

Wade, M., & Hulland, J. (2004). Review: The resource based view and information systems research: Review, extension, and suggestions for future research. *MIS Quarterly*, *28*(1), 107–142.

Whitten, J. L., & Bentley, L. D. (2007). *Systems analysis and design methods.* New York: McGraw Publications

Winn, D. (2002). EMR: Not a question of when but a question of how. *Group Practice Journal*, *1*(1), 1–5.

KEY TERMS

Electronic Medical Records System: An interorganizational information system that captures the essential components of a patient's medical encounter with the medical provider, including storage and retrieval of subjective, objective patient information, assessment, and plans for patient care (Lenhart et al., 2000).

EMR Challenges: Any factor that would impede the adoption and use of EMR.

Health Care Information System: An arrangement of information technology, people, data, and processes that interact to gather, process, store, and disseminate health care information (adapted from Whitten & Bentley, 2007).

IS Adoption: The deployment of information systems within an organization.

This work was previously published in Encyclopedia of Healthcare Information Systems, edited by N. Wickramasinghe; E. Geisler, pp. 194-200, copyright 2008 by Medical Information Science Reference (an imprint of IGI Global).

Chapter 4.2

Best Practices for Implementing Electronic Health Records and Information Systems

Beste Kucukyazici
McGill University, Canada

Karim Keshavjee
InfoClin Inc., Canada

John Bosomworth
University of Victoria, Canada

John Copen
University of Victoria, Canada

James Lai
University of British Columbia, Canada

ABSTRACT

This chapter introduces a multi-level, multi-dimensional meta-framework for successful implementations of EHR in healthcare organizations. Existing implementation frameworks do not explain many features experienced and reported by implementers and have not helped to make health information technology implementation any more successful. To close this gap, we have developed an EHR implementation framework that integrates multiple conceptual frameworks in an overarching, yet pragmatic meta-framework to explain factors which lead to successful EHR implementation, in order to provide more quantitative insight into EHR implementations. Our meta-framework captures the dynamic nature of an EHR implementation through their function, interactivity with other factors and phases, and iterative nature.

DOI: 10.4018/978-1-59904-792-8.ch007

INTRODUCTION: OVERVIEW OF THE ISSUE AND THE CHALLENGES

Advances in healthcare technology and the explosion of new therapies have outpaced the ability of healthcare systems, organizations, and professionals to cope. Healthcare costs have spiraled. Medical errors cause thousands of deaths each year and under-treatment is rampant (Institute of Medicine, 2001). Innovations take over 17 years to get from bench to bedside. Although information technology, such as electronic medical records (EMR), electronic health records (EHR) and computerized physician order entry (CPOE) systems, continue to evolve as technologies for use in clinical practice and show great promise, they are fraught with high implementation failure rates and sometimes cause even greater harm than previous paper systems (Koppel, Metlay, Cohen et al., 2005).

Typically, most of the investment of system implementation is born up-front both in terms of finances, and in time and energy. With increasing fiscal restraint and a greater demand by all stakeholders for demonstrated value, it is important to ensure that health information technology implementations are successful, yet, in spite of over three decades of experience with EHR implementation, the penetration of the EHR is still less than 20% in the United States and in Canada (Duke Clinical Research Institute, 2005). The failure rates of EHR and CPOE implementations are also consistently high at close to 50% (Centre for Health Policy and Research, 2006). As experience with implementations of technology in medical practice increases, new knowledge is gained on how to make those implementations more successful. The acceleration of EHR adoption and increasing success may depend in part on better understanding of the factors that influence the success and failure of EHR implementations (Studer, 2005). The existing empirical literature is beginning to reflect this knowledge in a series of case studies, limited randomized controlled trials, review articles and numerous qualitative studies exploring various factors and frameworks aimed at explaining how to best implement health record and information systems to achieve a successful outcome (Ash et al., 2003; Berg, 2001; Collins, 1998; Curtis et al., 1995; Golden & Martin, 2004; Rogers, 1995).

Existing implementation frameworks do not explain many features experienced and reported by users and have not helped to make health information technology implementation any more successful. To close this gap, we have developed an EHR implementation meta-framework that integrates the experiences of actual implementations and underpins those experiences using multiple conceptual frameworks from a variety of theoretical perspectives from the information technology (IT), business and EHR implementation literatures. This meta-framework is an overarching, yet pragmatic framework to explain the factors which are important in EHR implementations and how they interact in a dynamic and mutually reshaping manner which leads to successful EHR implementation.

BRIEF LITERATURE REVIEW

As experience with implementations of technology in medical practice increases, a cumulative literature of empirical support, in the form of case studies, limited randomized controlled trials, and numerous qualitative studies, has begun to emerge (Ash, 2003; Berg, 2001; Collins, 1998). The high failure rates seen in information systems implementation calls for a better understanding of the critical success factors necessary for EHR implementation (Somers et al., 2000). Listing ‘success factors’ has been the most popular approach in the literature for describing implementation approaches (Chiang & Starren, 2002, Chin, 2004; Saleem et al., 2005; Smith, 2003; Tape & Campbell, 2003; Weir et al., 1995), but has not been fully explanatory and predictive of success or failure (Kukafka et al., 2003; Studer, 2005). The factor approach however is too static to account for the evolving nature of EHR implementation experienced by implementers. Development of a more comprehensive framework which takes into account the dynamic, iterative and interactive aspects of EHR implementations is necessary to provide a sounder theoretical basis to underpin practical EHR implementations. Kukafka et al.

(2003) confirm in their systematic review of the healthcare IT implementation literature that the integrative impact of multiple factors on implementations and indeed the development of multi-dimensional interventions is lacking (Kukafka et al., 2003). Several different factors and frameworks have been put forward in the literature for explaining how to best implement the EHR to achieve a successful outcome and to improve EHR diffusion and uptake. These include Rogers' diffusion of innovations model (Rogers, 1995), Collins' risk mitigation model (Collins, 1998) and Ash et al's success factor matrix model (Ash et al., 2003). More recently, Berg has described the socio-technical model (Berg, 2001) and Heeks describes a 'design-reality' gap model (Heeks, 2006). The technology acceptance model (TAM) of Davis and Wilder (1998) provides understanding of human behavior relative to potential technology uptake. However, most models explain only a small component of the complex interplay of factors that are inherent in an EHR implementation. Only Ash et al. (2003) take a comprehensive view of IT implementations, but they do not explain how the various factors interact nor do they underpin their framework with a theoretical base.

The success of information systems implementation and utilization depends on the integration of the information technology (IT) into an often complex organizational setting (Golden & Martin, 2004). In this context, EHR implementation should be understood in a much more complex framework (Curtis et al., 1995). Without addressing the full range of factors in an implementation framework, EHR implementers run the risk of being ineffective because they fail to recognize the interdependencies between individual, organizational and technological factors (Kukafka et al., 2003). There are several features of EHR implementations that require frameworks from organization behavior and IT literature to fully explain what implementers observe and experience during an implementation. Golden's systems theory approach using his Strategic Star Model (Golden & Martin, 2004) provides a framework for organizational change which is rooted in the organizational behavior literature. The people-capability maturity model (P-CMM), which utilizes the people, process, and technology model (Curtis et al., 1995), is rooted in the IT literature. Kotter's model of change management which addresses change agent issues, change leadership, and change management is rooted in the business literature (Kotter, 1995).

DEVELOPMENT OF AN INTEGRATED BEST PRACTICES EHR IMPLEMENTATION FRAMEWORK

We integrated multiple conceptual frameworks from the EHR implementation, information technology, business and organizational behavior literatures in the process of developing our EHR implementation meta-framework. The EHR implementation meta-framework was developed through an iterative process of reading primary descriptions of implementations, identifying implementation-relevant factors and iteratively mapping those factors to the various conceptual frameworks we identified earlier. In this manner, we identified and filled gaps in the existing EHR implementation models and used the additional models to label new issues arising from the EHR implementation literature to create our meta-framework. Finally, we developed operational definitions for the factors in our implementation framework. This multi-theoretical, meta-framework for EHR implementation was recently presented and published in a conference proceeding (Keshavjee et al., 2006).

We applied our EHR implementation meta-framework retrospectively to 47 articles, which were primary descriptions of the experiences of EHR implementers obtained through a systematic search of the literature (Keshavjee et al., 2006). Each article was reviewed independently by two authors for whether a factor existed, whether it was correctly implemented and whether that factor had an impact, positive or negative, on the final outcome. Each author also provided a global outcome score for the article. Inter-rater reliability of the factors within the framework and use of the framework to analyze actual implementations will be reported elsewhere. All scores were resolved through consensus and the final scores were analyzed using logistic regression. Odds-ratios reported in this chapter are from this logistic regression analysis. Greater explanation of the methodology will be reported elsewhere and is out of the scope of the current article. This chapter takes a more pragmatic approach and presents a more nuanced discussion on the human and social aspects of EHR implementations.

INTEGRATED FRAMEWORK FOR EHR AND INFORMATION SYSTEMS

Figure 1 illustrates the meta-framework that integrates the theoretical frameworks and factors and is intended to guide multi-level EHR implementations. Key to this framework is its comprehensive and integrative nature for including various thematic threads such as people, process, and technology-related factors. In addition, our framework describes the implementation process as the journey of an EHR implementation through the healthcare system over time with respect to strategic and operational levels. The meta-framework describes three phases over which EMR implementations occur: pre-implementation, implementation and post-implementation phases. Each phase has its specific conceptual 'tasks' or sets of activities that need to be done and 'deliverables' or outcomes that are expected before it can move on to the next phase.

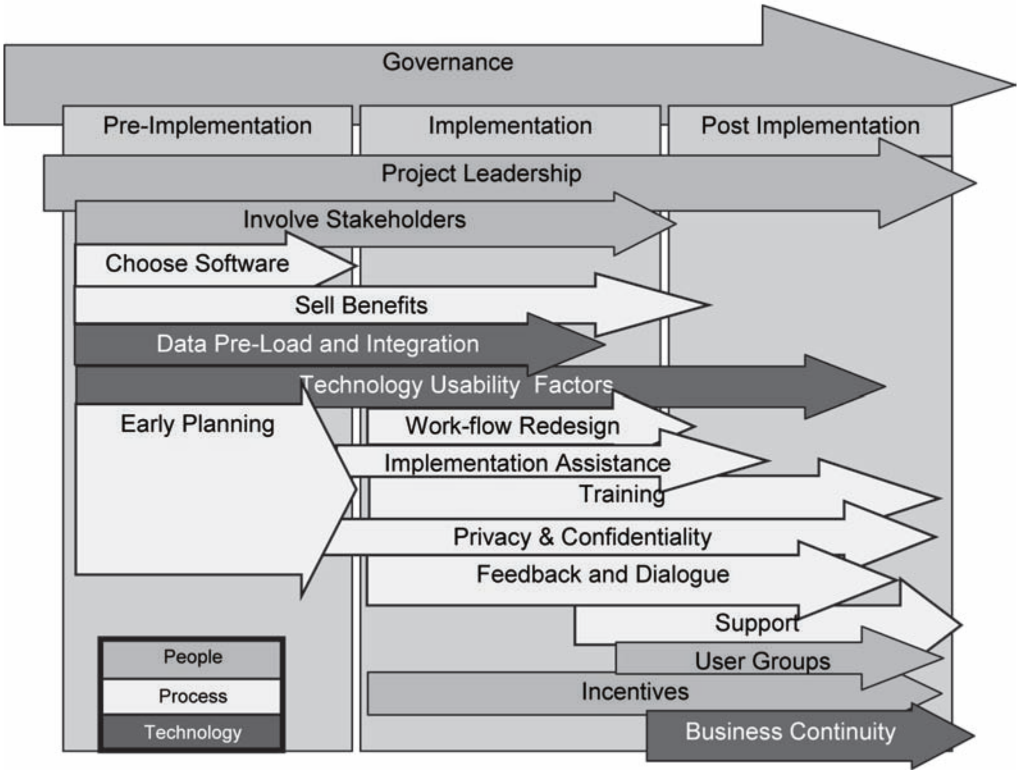
People-Process-Technology

An implementation of a new information systems results in a complex set of interacting forces (Clegg et al., 1997). People and tasks in an organization undergo significant change, learning, adaptation and growth in response to the introduction of information technology (IT). The changes are often drastic and cause intra-organizational tensions (Kuruppuarachchi et al., 2002). For the success of the healthcare delivery institution, an integrated approach to organizational and technical change must be adapted. Our literature review has established that there are many factors influential to understanding the successful EHR implementation in an effective healthcare delivery organization. For these reasons, we have concluded that human factors as well as technology factors need to be taken into consideration. The conceptual bridge between human and technology sides, "process," also has an important contribution. It is the process components of an implementation that allow the people and technology factors to mutually influence and shape each other—the end-users changing and adapting as they learn about the technology and how it will impact their work and the technology changing as vendors and developers better understand the goals and needs of end-users. People, process, and technological issues have to be seen as inextricably linked as a triad for successful change to take place. The people-process-technology triad in each phase has its important tasks which, correctly implemented, lead to appropriate deliverables—both in terms of technology being ready to be implemented and in terms of readiness of people to move on to the next phase.

People

People are one of the most important elements of healthcare delivery systems (Ash et al., 2003). Workforce knowledge and skills are related concepts in explaining the effectiveness of EHR implementation. Human resources of the healthcare delivery organizations include decision makers, such as executives or managers; end users, such as physicians or nurses; and information technology

Figure 1. Integrated meta framework



specialists, such as systems or software related subordinates. Additionally, project leaders have a crucial role during the implementation efforts. We identify four groups of important people in an EHR implementation: (a) senior management, (b) project managers and project champions, (c) end users, (d) information technology specialists and/or vendors.

a. **Senior management:** Initiating an EHR implementation effort is a strategic decision for most organizations. It requires significant investment of organizational resources and energy and it commits the organization to a particular direction. Leadership, commitment, and participation of senior management are prerequisites for EHR implementations (Davis & Wilder, 1998; Laughlin, 1999; Oden et al., 1993; Sherrard, 1998). Senior management is responsible for analyzing and rethinking existing business directions and deciding on future directions for the organization. They also have to weigh integration of a new information technology system against other organization priorities and need to have a keen understanding of the benefits and risks of EHR in terms of operational costs, human resource capabilities and retraining and return on investment (Krupp, 1998; Umble et al., 2003).

b. **Project managers and project champions:** Successful information systems implementation requires skilled and experienced project management (Rosario, 2000). This includes a clear definition of objectives which are congruent with the strategic direction and vision of the organization, a work plan that tracks utilization of resources, continuous monitoring of project progress and management of risks (Bingi et al., 1999; Buckhout et al., 1999; Sumner, 1999). Initially, the scope of the project must be framed accurately, since the project will affect overall business processes (Holland et al., 1999; Rosario, 2000; Umble et al., 2003). Project leadership encompasses two distinct roles: that of a project manager who has skills and experience in managing complex project implementations (Collins, 1998) and that of a project champion who has organizational credibility with clinicians (Ash et al., 2003; Chiang & Starren, 2002; Chin, 2004). Project leaders are responsible for all these planning and managing issues and play key role in successful management of the project. They bridge the strategic needs of senior management and the operational and tactical needs of end users by matching activities to strategic goals, creating an agreeable working climate, solving conflicts, coordinating and enhancing internal communication, managing risk and coordinating users and training of human resource of the organization.

c. **End users:** End-users have a crucial role in EHR system development, specifically in identifying and clearly articulating their needs and requirements and participating actively in designing and implementing new systems (Clegg et al., 1997). Although end-users are very important in implementation, they are rarely influential in designing new systems. End-user participation is usually limited in influencing the design of the technology and their participation is usually poorly managed. End-users need to have a much greater voice in implementations for them to achieve greater success (Clegg et al., 1997). In many cases, system developers are still seen as the `owners' of new technologies, where in reality, end-users are the real customers—those who will actually use the systems. The reason for this is believed to be technical orientation of system developers and the widespread failure to address human and organizational factors when designing technology (Clegg et al., 1997; Kuruppuarachchi et al., 2002).

d. **Information technology specialists and/or vendors:** Assistance to clinicians or primary users by detecting, solving and following up on problems that arise during implementation is essential for the success of the EMR experience. Continuous improvements and/or modifications of the system are important to achieve the expected outcomes. Changes may need to be made to applications for such components as basic configurations and workflows, custom templates, forms and shortcuts (Miller & Sim, 2004), to hardware and network components that are not functioning properly or to network architectures. In many cases, implementations have failed simply because of hardware problems that plagued implementers who had not planned for them; a simple recurring hardware problem that is not solved quickly can create havoc in a production environment and cause healthcare providers to quickly lose confidence in the technology. Vendors and technical support play a key role to assist in implementation. The assistance team, both vendor and technical support, needs to provide rapid and efficient service, or clinical users will stop calling and find some other way to access and record data (Keshavjee, et al. 2001). Implementation assistance should be available on-site initially (Aydin & Forsythe, 1997; Smith, 2003; Tonnesen, et al., 1999) and should be easily accessed throughout the implementation phase. Technical support also has a "bridger" role between end users and vendor (Chin, 2004).

Process

Organizational determinants such as complexity or connectedness to other organizations have a direct impact on the outcome of the implementation. The structure of the organization and existing operational processes also impact outcomes. If poorly handled, they can create significant conflict within the organization. Organizational complexity, which may be regarded as a basis for conflict, is related to the technology used within the organization (Killing, 1988). Healthcare is growing increasingly complex (Bates & Atul, 2003) and complex tasks can be a hindrance to the quality of healthcare delivery outputs.

In our meta-model, process is the arena and mechanism through which people engage with technology and through which each shapes the other along a journey toward a successful transformation of the organization. This is much clearer today than it has been in the past (Aarts & Berg, 2004).

Technology

Enormous improvements have been made in recent years in healthcare delivery technology. Although technological change has been very beneficial in various ways, it also causes many new problems that need to be addressed. These include redistribution of power, new types of errors and requirements for new skills and competencies and new scopes of practice; many of these are human resource, policy and regulatory issues which create friction within and outside the organization and manifest as resistance to change (Ash et al., 2006). In some cases, there is a mismatch between technology and organizational and end-user needs (Lawler, 1993; Massaro, 1993; Tonessen et al., 1999). The scale of health information and the complexity of using it properly make technology another important element for EHR implementations, especially since it is seen to be the vehicle through which the organization will meet its strategic goals.

The increasingly complex technology, task scope, intensity and the number of tasks performed simultaneously by healthcare workers push organizations toward a requirement for coordination and integration and use of information technology (Hage, 1980; Schumaker, 2002). Paradoxically, it is precisely this task complexity and organizational complexity which makes implementation of technology so difficult and prone to failure.

BEST PRACTICES FOR EHR AND INFORMATION SYSTEMS IMPLEMENTATIONS

Implementation of the EHR is not only a technology application at the operational level, but also a major change in the business processes, organizational structure and organizational culture, which are directly related to the mission and vision of an institution. In this context, the decision of transferring the overall system of the healthcare setting from a paper-based environment to a new information system happens at the strategic level, which is followed by operative level management and execution activities (Poskela et al., 2005).

A key aspect of our meta-framework is that it models the time perspective which brings out the dynamic and interactive nature of EHR implementations. The time frame element is modeled as three major operational phases of an EHR implementation: pre-implementation phase, implementation phase and post-implementation phase activities. In each phase, related tasks or factors aggregate together due to similar time courses, functions, and outcomes. A factor can begin in one phase and end in another, but may spend most of its lifetime in a specific phase. It is to this phase that we allocated its primary relevance for the purposes of this framework. However, the strategic level is beyond these phases; the time frame of the strategic level activities starts before these operational phases and goes as long as EHR lives in that setting.

Strategic Level

The meta-framework factor ***governance*** speaks to senior management's activities or substantive personal interventions in the EHR implementation. It is concerned with mission, vision and senior management's behaviors related to pre-implementation, implementation and post-implementation phases of the EHR. Senior management support is a must for EHR implementation (Bingi et al., 1999; Buckhout et al., 1999; Fui-Hoon Nah et al., 2001; Sumner, 1999) and EHR must have a plausible chance of helping attain the strategic business goals (Sumner, 1999). Senior management must allocate valuable resources to the implementation efforts (Holland et al., 1999), including providing the needed people for the implementation (Roberts & Barrar, 1992). Management needs to announce the new system and structures regarding EHR implementation, provide the compelling rationale for taking the EHR pathway and support the key champions and project managers who will communicate the strategy and tactics for EHR implementation throughout the organization (Kotter, 1995). Senior management must create a sense of "urgency" for change, inspiring people to act, think, and make objectives real and relevant (Kotter, 1995). New roles and responsibilities should be established and policies should be set by senior management to suit the new systems in the company (Roberts & Barrar, 1992).

Top-down organizational support is one of the dominant factors associated with successful implementation of EHR. Project leadership must be "empowered to act" by removing obstacles and enabling support from senior management (Kotter, 1995). Our analysis indicates that implementations that had good governance were 6 [95% CI 1.3 to 27, p= 0.025] times more likely to succeed than implementations that had poor governance. Without real commitment from the top, stresses experienced during implementation can easily hinder EHR development (Townes et al., 2000). In some implementations which experienced failure, EHR implementation was either not sanctioned by senior management (Chiang & Starren, 2002; Townes et al., 2000) or senior management was diverted by other organizational priorities (Tonessen et al., 1999) at a crucial time in the EHR implementation. Without top level support, implementations, which hit a snag that requires additional resources to resolve, will quickly die on the vine.

Operational Level

Pre-Implementation Phase

The initial or pre-implementation phase is relatively the most important part of any IT initiative and should focus on activities that facilitate project success, such as goal setting, planning, and communication. Pre-implementation activities set the tone for all other phases of an IT implementation project, and it is important to recognize any potential progress impediments and be prepared to proactively address them (Rosenthal, 2002). The key outcomes of the pre-implementation phase are a consensus within the organization on which technology it will implement, that the technology is the right one for the organization and a willingness and excitement amongst clinician end-users to implement the technology.

Our factor ***project leadership*** combines two important roles in the EHR implementation. This factor runs through the entire implementation, from pre-implementation to post-implementation phases. The first role is that of the experienced and skilled project management. Much has been written about project management and we will not repeat it here. In an EHR implementation, the role of the project manager is to use the process factors of the implementation meta-framework as a series of activities that over time bring about the desired change within end-users and technology for a successful implementation to occur. Successful implementations also need champions who are able to influence operational level activities

(Hauschildt, 1999). Physician champions are central in all phases of an implementation, acting as enabling advocates, selling benefits and engaging in a 'web' of communications with other clinician end-users. Championship, defined as the persistent and persuasive communication between strategic and operational levels, is a crucial instrument for senior management and appears to be an important middle management function (Floyd & Wooldridge, 1992). Our findings show its strong impact, with a 26-fold [95% CI 3 to 234, p = 0.004] increase in likelihood of success with strong project champions and experienced project managers working together to manage the people, process and technology aspects of an implementation.

One of the key activities in the pre-implementation phase is the software selection process, our factor *choose software carefully.* All of the pre-implementation activities and outcomes revolve around this process. It is the process through which end-users buy-in to the needs of the organization, the need for a software solution and the appropriateness of a particular technology to meet organizational needs. Project leaders, both project managers and project champions, need to help stakeholders within the organization to galvanize their commitment to the particular pathway chosen by senior management to achieve its strategic objectives and to put their own stamp on the implementation through participation in the selection process; after all, they will be the ones to live with the day to day consequences of their choices. Project managers also need to hold vendors and system developers accountable to meeting the needs of end-users. This factor is the key mechanism through which the mutual reshaping of end-users and technology takes place. Implementations which correctly implemented this process were 17 [95% CI 2-152, p = 0.011] times more likely to succeed than those that executed it incorrectly or did not use this process at all. User friendliness of the software and meeting users' requirements are important for user acceptance of the system and human related issues. The flexibility of the software and matches with the norms and values of the organization makes this factor crucial in terms of processes. In this context, choosing the software is a central activity that can unite an organization and generate excitement and a shared vision or can create deep divisions. Successful project managers and project champions are able to use a series of pre-planned activities to guide the organization and end-users toward a shared vision and a commitment to the EHR pathway. Unsuccessful project managers were more likely to have embarked on a journey to develop their own software after finding out that they couldn't find a suitable one on the market (Chiang & Starren, 2002) or followed a good process and then sabotaged it at the end because a 'new and improved' software came along "at the 11th hour" (Goddard, 2000).

Involvement of end users was one of the key factors mentioned by implementers as being essential for the implementation. It facilitates creating a better system that is integrated with the existing one and promotes user ownership (Clegg et al., 1997). This factor appears to provide a 4.5-fold [95% CI 0.98 to 20.5, p = 0.054] improvement in success. Although this factor did not achieve statistical significance in our study, a larger sample size might have allowed us to detect statistical significance. It is likely that the ***choosing software carefully*** incorporates this factor. Many failed implementations that did not involve end-users also did not choose their software carefully (Lawler, 1993; Massaro, 1993; Tonesson et al., 1999; Wager et al., 2001).

Selling benefits and addressing barriers leads to a 14-fold [95% CI 1.54 to 119, p=0.019] increase in the likelihood of the success. By selling benefits, the organization and actors of the system are prepared for change by identifying core values, understanding the broader organizational context and stakeholder concerns, understanding end-user needs, creating a vision and compelling need for change, and being sensitive and responsive to organizational stresses resulting from change (Kotter, 1995; Lorenzi & Riley, 1995). Physicians, nurses, and staff need to be constantly reminded of the benefits of EHR and need to feel confident that obstacles and barriers are being addressed. It is quite common for clinicians to misinterpret the chaos of implementation as incompetence of implementers and a sign of things going awry. End-users need to experience early and quick wins to maintain their confidence in the implementation process. Implementations that failed due to incorrect execution of this factor were more likely to assume that the benefits were self-evident and did not need to be sold or project champions were entirely absent from the implementation process (Chiang & Starren, 2002).

Early planning strategies encompasses early and extensive planning on how computers will be introduced and implemented into the organization. It is concerned with foreseeing and predictive risks and problems that may arise and planning for them. Plans for acquiring appropriate experts and support personnel to field concerns, anticipation of problems and development of plans to solve them, plans for process and workflow redesign, training plans and planning for the technology deployment are all required to ensure a successful implementation. Use of *early planning strategies* increases the likelihood of success by 10-fold [95% CI 1.8 to 56, p = 0.009]. Given the large number of factors that need to go right in the implementation phase and given that those factors are also potential points of failure, *early planning strategies* are crucial to the successful implementation of an EHR into actual practice. Unsuccessful project managers did not plan for unexpected contingencies. Given the fast-paced, mission critical environment of healthcare, there is typically very little time or patience to deal with technology problems. Successful project managers made sure that a multi-disciplinary team was on-site or readily available during the early weeks of implementation to quickly manage problems that arose. Problems that arise during implementation are likely to span multiple disciplines, such as a hardware problem that exacerbates an existing process problem, causing chaos to ensue. If the problem is not fixed quickly, users are forced to go back to their old processes. If this is allowed to last too long, clinicians lose confidence in the implementers and will not go back to using the new technology (Chiang & Starren, 2002; Lawler, 1993). Quick, on-site support is crucial at these junctures.

Technology usability appears to be a very important factor, with a 96-fold [95% CI 9 to 999, $p < 0.00001$] increase in likelihood of success for overall system design including hardware and software and the system selection at the outset. Conversely, technology usability issues are ostensibly blamed for most failures, partial failures or even hiccoughs in implementation. This is likely to be an over-estimate of the actual impact of technology fit to the organization as it is easy for an organization to blame the system instead of pointing to themselves as the cause of implementation problems, but clearly the perception of its importance is high. New EHR technology will be implemented better if it is easy to use thereby helping derive its purported benefit, especially if it's real benefit closely fits end-user expectations. Essentially the EHR must perform as advertised and be a good match to the needs of the organization, without disrupting workflow and time to complete task expectations, and organizational culture so much that the organization cannot adapt to this change (Ash et al., 2003; Berg, 2001; Delone et al., 2003; Heeks, 2006; Kushniruk & Patel, 2004). The technology usability factor has two aspects to it. Initially, it is the organization's and stakeholder's perception of how usable the technology is and whether it will meet the needs of the end-users. This is modeled in Davis' technology acceptance model (TAM) (Davis & Wilder, 1998). Later, as the technology is implemented, the actual usability and fit within the organization becomes a crucial factor. Many implementations failed to make the transition from perceived usability to actual usability (Lawler, 1993; Massaro, 1993; Tonnesen et al., 1999). Most partial failures languish in a situation where the technology only partially supports the strategic and operational requirements of the organization—stuck in a limbo not of their own making (Aarts & Berg, 2004; Chiang & Starren, 2002; Poon et al., 2003; Tonessen et al., 1999; Wager et al., 2001; Williams, 2002). The reasons for failure in this factor can be attributed to: (1) a flawed EHR selection process that did not engage the appropriate stakeholders whose input was crucial to ensuring a good fit of technology to users (Massaro, 1993); (2) poor mapping between functionality of the software and needs of the organization (Aarts & Berg, 2004) and; (3) poor understanding that flaws in acquired technology requires organizational capacity to overcome them (Lawler, 1993).

Data pre-load and integration plays an important part in achieving success with EHR implementations (Ash et al., 2003; Smith, 2003; Townes et al., 2000). Data-preload and integration of systems before providers start to use the system decreases the requirement for initial data entry from previous documentation and from other systems. Getting data from other systems makes it easier for physicians to get started and decreases their on-going charting efforts. Digitization of paper charts into the new system is an example of decreasing the gap between the technology reality ("we allow you to document all encounters, as long as you do it our way") and expectation of end-users ("we need previous records to be easily accessible when we use the system") (Heeks, 2006), resulting in a better fit of the technology to the expectations of the organization. Previously used database formats from legacy systems can be imported into the new system. Effective integration with other systems containing billing, lab results, reporting, scheduling, diagnostic imaging, referrals and reference sources can be achieved (Chin, 2004). Consideration can be given to scanning parts of the previous paper-based record provided the information can be effectively indexed for later retrieval. These integration and pre-load activities increase end user satisfaction and user acceptance of the new system.

Lack of data pre-load and integration can lead to duplicate paper and electronic documentation which leads to inefficiency, risk to patient safety and a cognitive burden which is difficult to overcome for most clinicians (Keshavjee et al., 2001).

In summary, the goals of the pre-implementation phase are to assist the clinicians within the organization to make the necessary mental and attitudinal changes to implement the EHR technology. This phase uses the EHR selection process as the central activity through which the transformation occurs and which leads to the selection of a particular software solution which will be implemented. At the end of this phase, the organization and its users are confident that the technology is usable and that it will meet their needs, they have a clear understanding of the risks and benefits associated with their choice of EHR software and have begun the planning process to take the organization into the implementation phase.

Implementation Phase

In the implementation phase the work of EHR activation begins. This is the true test of an organization's preparations made in the pre-implementation phase, and of the overall match of these success factors to the nature of its EHR implementation.

Workflow redesign speaks to the relationship between human factors, how people work, and technology. Critical to successful implementation is the fit of staff and physician work flow to that of the EHR functionality and usability design constrictions (Smith, 2003). If the EHR software fits into clinician workflow then it is more likely to be accepted (Wager et al., 2001). It is well documented that redesign of business process is important for technology to deliver on its promise. Automation of poor workflows only leads to faster chaos—an undesirable outcome (Keshavjee et al., 2001). Workflow redesign is a highly specialized field and requires skilled practitioners to guide clinicians in a process through which they can achieve superior productivity in their work. It is the role of the technology to support and enable the new, more efficient workflows to be implemented. Implementers who correctly executed *workflow redesign* experienced 36-fold [95% CI 4 to 333, p = 0.002] increases in the success of their implementations.

Training, implementation assistance and *feedback and dialogue*, all had relatively modest impacts on the success of implementations of between five and nine-fold. Proper *training* (nine-fold increase [95% CI 1.6 to 48, p = 0.013]) supports the smooth transition to a paperless patient care system. Hands on training sessions immediately prior to going live has great significance for accelerating the implementation and user acceptance of the new system (Halley et al., 1996; Swanson et al., 1997; Wager et al., 2001). Training of the end users on EHR should be both initial and on-going, as it is not possible to learn all the features of the EHR software during initial training. Many functions of an EHR are only used once a physician has climbed up the steep learning curve of using an EHR.

A successful implementation requires comprehensive *implementation assistance* (five-fold increase [95% CI 1.1 to 23, p = 0.037]) to be responsive to solving technical problems quickly. In addition, end-users need assistance in making system improvements and modifications and making necessary changes such as developing custom templates, forms and shortcuts (Miller & Sim, 2004; Swanson et al., 1997). Quick and competent support can come from a variety of resources. A strong vendor partnership (Swanson et al., 1997), the presence of "super-users" (Chin, 2004; Keshavjee et al., 2001; Pizziferri et al., 2005; Wager et al., 2001) and "bridgers" (Chin, 2004) and on-site technical teams can contribute significantly to provide proper assistance on time. EHR implementations are dynamic processes which evolve as learning occurs and new problems and opportunities are discovered. End-users who are learning while continuing to provide patient care require additional support to ensure a smooth transition to using technology in their practices.

Feedback and dialogue (nine-fold increase [95% CI 1.6 to 48, p = 0.013]) is essential for supporting the dynamic EHR implementation process by providing opportunities to end-users for discussing issues and problems, to vent their frustrations, to share problems they are experiencing and to recommend changes to the software or to workflows. This process gives project managers and project champions an opportunity to monitor and track the progress of the implementation and detect and resolve problems before they get out of hand (Ash et al., 2003; Chin, 2004; Swanson et al., 1997; Townes et al., 2000).

EHR implementations must meet requirements for *privacy and confidentiality*. Although this is usually stated as a 'top 3' requirement for clinicians and is an important component of information systems management, it did not achieve statistical significance as being a factor for implementation success (4.70-fold increase [95% CI 0.53 to 42, p=0.165]). It is easy to see that although privacy and confidentiality is unlikely to be a driver of success, its absence could be a factor which prevents success or hastens failure. In any case, no discussion of implementation can be considered complete without mention of privacy and confidentiality.

In summary, the goals of the implementation phase are to assist physicians in making a successful transition from existing paper-based processes to the new electronic process. Barriers to the transition must be quickly resolved lest users revert to previous practices. Ensuring that new workflows are logical and streamlined, that appropriate training has been provided, that users have a forum in which to provide feedback and that they get support in a timely manner is crucial for successful navigation through the implementation phase.

Post Implementation Phase

The goals of the post-implementation phase are to consolidate the gains of the implementation phase and to start the organization along the journey toward meeting the real goals of the organization: improved efficiency and improved patient care. This is done through providing incentives and support to clinicians and providing them with a forum in which to share best-practices and enhance their use of the system.

The post-implementation phase is the culminating activity of an IT implementation initiative (Rosenthal, 2002), but also the start of a new journey toward newer implementation activities (Chin, 2004). Despite very limited discussion in the literature on importance of ***incentives*** in the EHR literature, in our analysis implementation efforts that offer incentives to users were 70 times more likely to succeed [95% CI 7 to 705, $p < 0.001$). The identified benefits of an EHR including improved patient safety (Berner et al., 2006; Hippisley-Cox et al., 2003; Mekhjian et al., 2002), increased income and decreased costs (Cooper, 2004), increased efficiency of care (Hippisley-Cox et al., 2003; Mekhjian et al., 2002; Nordyke & Klikowski, 1998), faster access to clinical information at the point of care and more efficient outcomes assessment (Nordyke & Klikowski, 1998) need to be demonstrated to all users. Most incentives were professional and work related incentives—increased efficiency, better patient care and more professional satisfaction, rather than monetary incentives.

Users groups and *business continuity plans* are two post-implementation phase factors that did not achieve statistical significance as drivers of implementation success. However, as with privacy and confidentiality, they can be interpreted as barriers to success rather than as a driver. Structured interactions of the users by scheduling meetings, *users groups* or discussion platforms provides a forum for ongoing training and facilitates a cooperative dynamic where end users can solve technical problems, write templates, and teach each other about software features (Berner et al., 2006). User groups can produce a greater user acceptance and satisfaction (Smith, 2003). A business continuity plan is also essential where there is provision for data protection and disaster recovery (Swanson et al., 1997).

EHR users require significant amounts of *support*, especially in the early phases after implementation. Myriad questions and issues arise which can lead to disenchantment and disillusionment if not handled appropriately (Keil et al., 1998; Massaro, 1993; Miller & Sim, 2004). *Support* did show some impact on the success of implementation; however the sample size was too small to reliably detect the magnitude of the impact.

Requirements of the new system and structures tend to change continuously even after the completion of the implementation phase. In this context, post-implementation activities are critical for the acceptance of new systems (Kuruppuarachchi et al., 2002) and for allowing the organization to grow and achieve its mission.

Overall, it appears that much of the success of EHR implementations can be explained by activities in the pre-implementation and implementation phase. Only the provision of incentives in the post-implementation phase has a large impact on success of implementations. However, the role of user groups and support should not be underestimated, as these are required for clinicians to meet higher order goals such as chronic disease management, preventive maintenance care and more evidence-based care. Although these higher order clinical goals may not be important to the ‘technological success’ of the project, they are important to help the organization meet its strategic goals for which it implemented the technology in the first place!

CONCLUSION

Despite remarkable advances in EHR, many systems still fall short of performance expectations (Centre for Health Policy and Research, 2006). A growing share of these implementation failures are due to non-technical factors (Clegg et al., 1997). This study has attempted to combine a large and diverse literature into a multi-level multi-dimensional meta-framework of successful implementations of EHR in healthcare organizations. Our meta-framework provides a comprehensive set of factors for assessing the EHR implementation literature. Our systematic review of the literature has provided support for this meta-framework by assessing impact on EHR implementation success.

The limitations of our research come from the relatively poor quality of case reports on EHR implementations. Most articles are written by implementers, not academics, who were probably asked to write about their experiences after a successful implementation. These articles are mostly experience reports, are generally incomplete and probably suffer from recall bias. There is also a publication bias in that the number of articles describing failed implementations is under-represented. Of the 47 articles we reviewed, only 10 described failures. Given the prevalence of failed implementations, we should expect to see many more articles describing failures. In addition, implementations in smaller clinic settings are presently under-represented in the literature and need to be examined and reported upon.

Research aimed at validating this framework should include prospective usage of these factors in an EHR implementation and establishing key outcome measures of overall EHR success.

FUTURE RESEARCH DIRECTIONS

Although, our review affirmed well-described success factors in the literature, they add additional components which model the dynamic and evolving nature of EHR implementations. The complexity and multi-dimensional nature of EHR implementation makes it difficult to match a factor tightly to the phenomena in a real EHR implementation (Berg, 2001). Also, a gold standard model to assess and rate EHR implementations is still needed. We believe that our meta-framework can be used iteratively in future research efforts to refine these matches and design a more standardized framework to evaluate the success of implementations prospectively. Future research could benefit from improved data collection through more precise operational definitions and generation of checklists in an attempt to more precisely identify the presence of certain factors or concepts. Improved hypothesis generation could be achieved again by defining more precise operational definitions of success factors and further identifying component concepts that might be successful and unsuccessful. Further definition could be done of the weighting of different factors as they contribute to implementation success. Finally, knowledge translation and controlled trial research needs to be conducted to translate findings from this study into practical advice for project managers and project champions. The factors identified in this study need to be validated in actual implementations through systematic collection of data on a prospective basis from actual implementations.

ACKNOWLEDGMENT

The authors wish to acknowledge the generous support of CIHR and the CHPSTP project in providing funding and infrastructure to accomplish this research.

REFERENCES

Aarts, J., & Berg, M. (2004). A tale of two hospitals: a sociotechnical appraisal of the introduction of computerized physician order entry in two Dutch hospitals. *Medinfo*, *11*(Pt 2), 999–1002.

Ash, J. S., Sittig, D. F., Dykstra, R. H., et al. (2006). An unintended consequence of CPOE implementation: Shifts in power, control, and autonomy. *AMIA Annual Symposium Proceedings.*

Ash, J. S., Stavri, P. Z., Fournier, L., et al. (2003). Principles for a successful computerized physician order entry implementation. *AMIA Annual Symposium Proceedings* (pp. 36-40).

Aydin, C. E., & Forsythe, D. E. (1997). Implementing computers in ambulatory care: Implications of physician practice patterns for system design. *AMIA Annual Symposium Proceedings,* 677-681.

Bates, D. W., & Atul, A. G. (2003). Improving safety with information technology. *Engl J Med.*, *348*, 2526–2534. doi:10.1056/NEJMsa020847

Berg, M. (2001). Implementing information systems in healthcare organizations: myths and challenges. *International Journal of Medical Informatics*, *64*(2-3), 143–156. doi:10.1016/S1386-5056(01)00200-3

Berner, E. S., & Houston, T. K. (2006). Improving ambulatory prescribing safety with a handheld decision support system: A randomized controlled trial. *Journal of the American Medical Informatics Association*, *13*(2), 171–179. doi:10.1197/jamia.M1961

Bingi, P., Sharma, M. K., & Godla, J. (1999). Critical issues affecting an ERP implementation. *Information Systems Management*, ▪▪▪, 7–14. doi:10.1201/1078/43197.16.3.19990601/31310.2

Buckhout, S., Frey, E., & Nemec, J. (1999). Making ERP succeed: turning fear into promise. *IEEE Engineering Management Review*, 116-123.

Centre for Health Policy and Research. (2006). *Health information technology adoption in Massachusetts: costs and timeframe*. Retrieved March 13, 2006, from www.umassmed.edu/healthpolicy/uploads/eHealthInformation.pdf

Chiang, M. F., & Starren, J. B. (2002). Software engineering risk factors in the implementation of a small electronic medical record system: The problem of scalability. *Proceedings AMIA Annual Symposium* (pp. 145-149).

Chin, H. (2004). The reality of EMR implementation: lessons from the field. *Kaiser Permanente HealthConnect, 8*(4).

Clegg, C., Axtell, C., & Damodaran, L. (1997). Information technology: A study of performance and the role of human and organizational factors. *Ergonomics*, *40*(9), 851–871. doi:10.1080/001401397187694

Collins, P. (1998). Risky business. It takes a 'risk-balanced' team to implement a CPR. *Healthcare Informatics*, *15*(3), 85–88.

Cooper, J. D. (2004). Organization, management, implementation and value of EHR implementation in a solo pediatric practice. *Journal of Healthcare Information Management*, *18*(3), 51–55.

Curtis, W., Hefley, W. E., & Miller, S. (1995). *Overview of the people capability maturity model. Prepared for the USA Department of Defense*. Pittsburgh, PA: Research Access, Inc.

Davis, B., & Wilder, C. (1998). False starts, strong finishes—companies are saving troubled IT projects by admitting their mistakes, stepping back, scaling back, and moving on. *Information Week, November 30*, 41-43.

Delone, W. H., & Mclean, E. R. (2003). The delone and mcLean model of information systems success: A ten-year update. *Journal of Management Information Systems*, *19*(4), 9–30.

Duke Clinical Research Institute. (2005). *FDA public meeting*. Retrieved March 13, 2006, from www.fda.gov/cder/meeting/ICHspring2005/Nahm.ppt

Floyd, S. W., & Wooldridge, B. (1992). Middle management involvement in strategy and its association with strategic type: A research note. *Strategic Management Journal*, *13*, 153–167. doi:10.1002/smj.4250131012

Fui-Hoon Nah, F., Lau, J., & Kuang, J. (2001). Critical factors for successful implementation of enterprise systems. *Business Process Management Journal*, *7*(3), 285–296. doi:10.1108/14637150110392782

Goddard, B. L. (2000). Termination of a contract to implement an enterprise electronic medical record system. *Journal of the American Medical Informatics Association*, *7*(6), 564–568.

Golden, B. R., & Martin, R. L. (2004). Aligning the stars: Using systems thinking to (re)design Canadian healthcare. *Healthcare Quarterly (Toronto, Ont.)*, *7*(4), 34–42.

Hage, J. (1980). *Theories of organizational: Form, process, and transformation*. New York: John Wiley.

Halley, E. C., & Kambic, P. M. (1996). Concurrent process redesign and clinical documentation system implementation: A 6-month success story. *Topics in Health Information Management*, *17*(1), 12–17.

Hauschildt, J. (1999). Promotors and champions in innovations—development of a research paradigm. In K. Brockhoff, A. K. Chakrabarti & J. Hauschildt (Eds.), *The dynamics of innovation—strategic and managerial implications*.

Heeks, R. (2006). Health information systems: failure, success and improvisation. *International Journal of Medical Informatics*, *75*, 125–137. doi:10.1016/j.ijmedinf.2005.07.024

Hippisley-Cox, J., Pringle, M., & Cater, R. (2003). The Electronic patient record in primary care - Regression or progression? A cross sectional study. *British Medical Journal*, *326*, 1439–1443. doi:10.1136/bmj.326.7404.1439

Holland, P., Light, B., & Gibson, N. (1999). A critical success factors model for enterprise resource planning implementation. *Proceedings of the 7th European Conference on Information Systems, 1*, 273-297.

Institute of Medicine. (2001). *Crossing the quality chasm: A new health system for the twenty-first century*. Washington: National Academy Press.

Keil, M., Cule, P. E., Lyytinen, K., & Schimdt, R. C. (1998). A framework for identifying software project risk. *Communications of the ACM*, *41*(11), 76–83. doi:10.1145/287831.287843

Keshavjee, K., Bosomworth, J., Copen, J., et al. (2006). Best Practices in EMR Implementation: A Systematic Review. *iSHIMR Proceedings*, (pp. 233-246).

Keshavjee, K. S., Troyan, S., Holbrook, A. M., & Vandermolen, D. (2001). Measuring the success of electronic medical record implementation using electronic and survey data. *AMIA Annual Symposium Proceedings*, 309-313.

Killing, J. P. (1988). Understanding alliance: The role of task and organizational complexity. In F. Contractor & P. Lorange (Eds.), *Cooperative strategies in international business*. Lexington Books.

Koppel, R., Metlay, J., & Cohen, A. (2005). Role of Computerized Physician Order Entry Systems in Facilitating Medication Errors. *Journal of the American Medical Association*, *293*, 1197–1203. doi:10.1001/jama.293.10.1197

Kotter, J. (1995). Leading change: Why transformation efforts fail. *Harvard Business Review*, (March-April): 59–67.

Krupp, J. (1998). Transition to ERP implementation. *APICS—The Performance Advantage*.

Kukafka, R., Johnson, S. B., Linfante, A., & Allegrante, J. P. (2003). Grounding a new information technology implementation framework in behavioral science: A systematic analysis of the literature on IT use. *Journal of Biomedical Informatics*, *36*, 218–227. doi:10.1016/j.jbi.2003.09.002

Kuruppuarachchi, P. R., Mandal, P., & Smith, R. (2002). IT project implementation strategies for effective changes: A critical review. *Logistics Information Management*, *15*(2), 126–137. doi:10.1108/09576050210414006

Kushniruk, A. W., & Patel, V. L. (2004). Cognitive and usability engineering approaches to the evaluation of clinical information systems. *Journal of Biomedical Informatics*, *37*, 56–62. doi:10.1016/j.jbi.2004.01.003

Laughlin, S. (1999). An ERP game plan. *Journal of Business Strategy*.

Lawler, F. (1993). Implementation and termination of a computerized medical information system–Editorial. *The Journal of Family Practice*, *42*(3), 233–236.

Lorenzi, N., & Riley, R. T. (1995). *Organizational aspects of health informatics: Managing technological change*. New York: Springer-Verlag.

Massaro, T. (1993). Introducing physician order entry at a major academic medical center: Impact on organizational culture and behavior. *Academic Medicine*, *68*(1), 20–25.

Mekhjian, H. S., Kumar, R. R., & Kuehn, L. (2002). Immediate benefits realized following implementation of physician order entry at an academic medical center. *Journal of the American Medical Informatics Association*, *9*(5), 529–539. doi:10.1197/jamia.M1038

Miller, R. H., & Sim, I. (2004). Physicians' use of electronic medical records: Barriers and solutions. *Health Affairs*, *23*(2), 116–126. doi:10.1377/hlthaff.23.2.116

Nordyke, R. A., & Kulikowski, C. A. (1998). An informatics-based chronic disease practice: Case study of a 35-year computer-based longitudinal record system. *Journal of the American Medical Informatics Association*, (5): 88–103.

Oden, H., Langenwalter, G., & Lucier, R. (1993). *Handbook of material and capacity requirements planning*. New York: McGraw- Hill.

Pizziferri, L., Kittler, A. F., & Volk, L. A. (2005). Primary care physician time utilization before and after implementation of an electronic health record: A time-motion study. *Journal of Biomedical Informatics*, *38*, 176–188. doi:10.1016/j.jbi.2004.11.009

Poon, E. G., Blumenthal, D., Jaggi, T., et al. (2003). Overcoming the barriers to the implementing computerized physician order entry systems in U.S. hospitals: Perspectives from senior management. *AMIA Annual Symposium Proceedings,* 975.

Poskela, J., Dietrich, P., Berg, P., et al. (2005). Integration of Strategic Level and Operative Level Front-end Innovation Activities. *IEEE Conference Proceedings*, 197-211.

Roberts, H. J., & Barrar, P. R. N. (1992). MRPII implementation: Key factors for success. *Computer Integrated Manufacturing Systems*, *5*(1), 31–39. doi:10.1016/0951-5240(92)90016-6

Rogers, E. M. (1995). *Diffusion of innovations* (4th ed.). New York: Free Press.

Rosario, J. G. (2000). On the leading edge: Critical success factors in implementation projects. *BusinessWorld*

Rosenthal, D. A. (2002). Managing non-technical factors in healthcare IT projects. *Journal of Healthcare Information Management*, *16*(2), 56–61.

Saleem, J. J., Patterson, E. S., & Militello, L. (2005). Exploring barriers and facilitators to the use of computerized clinical reminders. *Journal of the American Medical Informatics Association*, *12*(40), 438–447. doi:10.1197/jamia.M1777

Schumaker, A. M. (2002). Interorganizational networks: Using a theoretical model to predict effectiveness. *Journal of Health and Human Services Administration*, *25*(3/4), 371–380.

Sherrard, R. (1998). Enterprise resource planning is not for the unprepared. *ERP World Proceedings*. Retrieved January 1, 2007, from http://www.erpworld.org/proceed98

Smith, P. D. (2003). Implementing an EMR system: One clinic's experience. *Family Practice Management*, *10*(5), 37–42.

Somers, T. M., Nelson, K., & Ragowsky, A. (2000). Enterprise resource planning for the next millennium: development of an integrative framework and implications for research. *Proceedings of the American Conference on Information Systems (AMCIS)* (pp. 998-1004).

Studer, M. (2005). The effect of organizational factors on the effectiveness of EMR system implementation—what have we learned? *Electronic Healthcare*, *4*(2), 92–98.

Sumner, M. (1999). Critical success factors in enterprise wide information management systems projects. *Proceedings of the Americas Conference on Information Systems (AMCIS)* (pp. 232-235).

Swanson, T., Dostal, J., & Eichhorst, B. (1997). Recent implementations of electronic medical records in four family practice residency programs. *Academic Medicine*, *172*(7), 607–612.

Tape, T. G., & Campbell, J. R. (1993). Computerized medical records and preventive healthcare: success depends on many factors. *The American Journal of Medicine*, *94*(6), 619–625. doi:10.1016/0002-9343(93)90214-A

Tonnesen, A. S., LeMaistre, A., & Tucker, D. (1999). Electronic medical record implementation: Barriers encountered during implementation. *AMIA Annual Symposium Proceedings* (pp. 624-626).

Townes, P. G., Benson, D. S., & Johnson, P. (2000). Making EMRs really work: The Southeast Health Center experience. *The Journal of Ambulatory Care Management*, *23*(2), 43–52.

Umble, E. J., Haft, R. R., & Umble, M. M. (2003). Enterprise resource planning: Implementation procedures and critical success factors. *European Journal of Operational Research*, *146*, 241–257. doi:10.1016/S0377-2217(02)00547-7

Wager, K. A., Lee, F. W., & White, A. W. (2001). *Life after a disastrous electronic medical record implementation: One clinic's experience.* Hershey, PA: Idea Group Publishing.

Weir, C., Lincoln, M., Roscoe, D., et al. (1995). Dimensions associated with successful implementation of a hospital based integrated order entry system. *Proceedings of AMIA Annual Fall Symposium*, 653-657.

Williams, R. B. (2002). Successful computerized physician order entry system implementation. Tools to support physician-driven design and adoption. *Healthcare Leadership & Management Report*, *10*(10), 1–13.

ADDITIONAL READINGS

Aaronson, J. W., Cassie, D. O., & Murphy-Cullen, L. (2001). Electronic medical records: The family practice resident perspective. *Medical Informatics*, *133*(2), 128–132.

Ash, J. S. Stavri. P. Z., Fournier, L. et al. (2003). Principles for a successful computerized physician order entry implementation. *AMIA Annual Symposium Proceedings* (pp. 36-40).

Ash, J. S., Sittig, D. F., Seshadri, V., et al. (2004). Adding insight: A qualitative cross-site study of physician order entry. *Proceedings of Medinfo* (pp. 1013-1016).

Barlow, S., Johnson, J., & Steck, J. (2001). The economic effect of implementing an EMR in an outpatient clinical setting. *Journal of Healthcare Information Management*, *18*(1), 46–51.

Barrows, R. C., & Clayton, P. D. (1996). Privacy, confidentiality and electronic medical records. *Journal of the American Medical Informatics Association*, *3*(2), 139–148.

Bingham, A. (1998). Cost justification for computerized patient records. *The Journal of Medical Practice Management*, (January/February): 193–198.

Chin, H. L., & Krall, M. (1997). Implementation of a comprehensive computer-based patient record system in Kaiser Permanente's Northwest Region. *M.D. Computing*, *4*(1), 41–45.

Churgin, P. G. (1994). Introduction of an automated medical record at an HMO clinic. *M.D. Computing*, *11*(5), 293–300.

Dansky, K. H., Gamn, L. D., Vasey, J. J., & Barsukiewicz, C. K. (1999). Electronic medical records: Are the physicians ready? *Journal of Healthcare Management*, *66*(6), 454–458.

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly*, *13*(3), 319–339. doi:10.2307/249008

Davis, F. D., Bagozzi, R. P., & Warshaw, P. R. (1989). User acceptance of computer technology: A comparison of two theoretical models. *Management Science*, *35*(8), 982–1003. doi:10.1287/mnsc.35.8.982

Gadd, C. S., & Penrod, L. E. (2001). Assessing physician attitudes regarding use of an outpatient EMR: A longitudinal, multi-practice study. P*roceedings AMIA Annual Symposium* (pp. 194-198).

Hanson, S., & Schutzengel, R. (2004). Pioneers and perseverance: Implementing the HER in physician practices. *Journal of American Health Information Management Association*, *75*(1), 38–43.

Hassol, A., & Walker, J. M. (2004). Patient experiences and attitudes about access to a patient electronic healthcare record and linked web messaging. *Journal of the American Medical Informatics Association*, *11*(6), 505–513. doi:10.1197/jamia.M1593

Holbrook, A., Keshavjee, K., & Troyan, S. (2003). Applying methodology to electronic medical record selection. *International Journal of Medical Informatics*, *71*, 43–50. doi:10.1016/S1386-5056(03)00071-6

Jarvenpaa, S. L., & Ives, B. (1991). Executive involvement and participation in the management information technology. *MIS Quarterly*, *15*(2), 205–225. doi:10.2307/249382

Keshavjee, K. S., Troyan, S., Holbrook, A. M., & Vandermolen, D. (2001). Measuring the success of electronic medical record implementation using electronic and survey data. *Proceedings of the AMIA Symposium* (pp. 309-313).

Maxwell, M. (1999). EMR: Successful productivity tool for modern practice. *Health Management Technology*, *20*(9), 48–49.

Mohd, H., & Mohamad, S. M. S. (2005). Acceptance model of electronic medical record. *Journal of Advancing Information and Management Studies*, *2*(2), 75–92.

Packendorff, J. (1995). Inquiring into the temporary organization: new directions for project management research. *Scandinavian Journal of Management*, *11*(4), 318–313. doi:10.1016/0956-5221(95)00018-Q

Pennbridge, J., & Moya, R. (1999). Questionnaire survey of California consumers' use and rating of sources of healthcare information including the internet. *The Western Journal of Medicine*, *171*, 302–305.

Rind, D. M., & Kohane, I. S. (1997). Maintaining the confidentiality of medical records shared over the internet and the World Wide Web. *Annals of Internal Medicine*, *127*(2), 138–141.

Smith, D., & Newell, L. M. (2002). A physician's perspective: Deploying the EMR. *Journal of Healthcare Information Management*, *16*(2), 71–79.

Wang, S. J., & Middleton, B. (2003). A cost-benefit analysis of electronic medical records in primary care. *The American Journal of Medicine*, *114*, 397–403. doi:10.1016/S0002-9343(03)00057-3

This work was previously published in Human, Social, and Organizational Aspects of Health Information Systems, edited by A. Kushniruk; E. Borycki, pp. 120-138, copyright 2008 by Information Science Reference (an imprint of IGI Global).

Chapter 4.3

Electronic Medical Records:

TAM, UTAUT, and Culture

Ken Trimmer
Idaho State University, USA

Leigh W. Cellucci
Idaho State University, USA

Carla Wiggins
Idaho State University, USA

William Woodhouse
Idaho State University, USA

ABSTRACT

Many policymakers, industry experts, and medical practitioners contend that the U.S. health care system—in both the public and private sectors—is in crisis. Among the numerous policy issues associated with the provision of US healthcare is the call for increased adoption and use of health care information technology (HIT) to address structural inefficiencies and care quality issues [11, p. 33]. This paper reports the first steps in a multi-phased research effort into Electronic Medical Records system adoption. The first two phases of our research applies the Unified Theory of Acceptance and Use of Technology as a lens to interpret the responses of physicians completing their Residency in Family Medicine and the third phase examines the role of organizational culture as a critical variable for effective strategy implementation in the same setting

INTRODUCTION

The 2005 Government Accountability Office (GAO) (2005) report, 21st Century Challenges: Reexamining the Base of the Federal Government, was intended to identify critical issues and potential options for addressing key fiscal challenges facing the federal government; the GAO identified healthcare as one of the most critical issues facing federal policy makers. Among the numerous policy issues associated with the provision of US healthcare is the call for increased adoption and use of health care information technology (HIT) to address structural inefficiencies and care quality issues plaguing the US health care industry (GAO, 2005). Multiple clinical and administrative benefits have been identified with the adoption of HIT generally and EMR systems specifically. Yet the health care industry remains a laggard in IT adoption relative to other industries (Burke, D. E., & Menachemi, N., 2004).

The United States federal government is actively encouraging the development of "a nationwide interoperable health information technology infrastructure that:

a. Ensures that appropriate information to guide medical decisions is available at the time and place of care;
b. Improves health care quality, reduces medical errors, and advances the delivery of appropriate, evidence-based medical care;
c. Reduces health care costs resulting from inefficiency, medical errors, inappropriate care, and incomplete information;
d. Promotes a more effective marketplace, greater competition, and increased choice through the wider availability of accurate information on health care costs, quality, and outcomes;
e. Improves the coordination of care and information among hospitals, laboratories, physician offices, and other ambulatory care providers through an effective infrastructure for the secure and authorized exchange of health care information; and
f. Ensures that patients' individually identifiable health information is secure and protected.

Thus, a key objective of federal policy is to achieve widespread adoption of EMR within the next 10 years (Department of Health and Human Services, 2004).

This paper reports the first steps in a multi-phased research effort seeking to:

- Assess new physician residents' beliefs, attitudes and perceived group norms concerning EMR use within their residency, using UTAUT (Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D, 2003)..
- Identify HIT related education and training provided by medical schools and residency programs, and its impact on future career choices.
- Evaluate the role of culture as a value added support strategy in assessing the match between mission and vision, and organization priorities.
- We employed both qualitative and quantitative data collection and analysis to provide what we believe to be a richer understanding of the role of the Unified Theory of Acceptance and Use of Technology (UTAUT) and the role of culture in the adoption of HIT.

THEORETICAL FRAMEWORKS

The Technology Acceptance Model (TAM) and the Unified Theory of Acceptance and Use of Technology (UTAUT)

TAM has been the dominant theoretical approach for studying individual IT adoption and use and has spawned an incredibly rich and widely cited stream of theoretical and empirical research (Lucas Jr., H. C., Swanson, E. B., & Zmud, R. E., 2007; Benbaset, I., & Barki, H., 2007; Straub Jr., D. W., & Burton-Jones, A., 2007). TAM is an information systems theory that models how users come to accept and use technology: the main dependent constructs are behavior intention to use and system usage. The model suggests that when users are presented with a new technology, a number of factors influence their decision about how and when they will use it, specifically Percieved usefulness and Perceived ease of use (Wikipedia, 2008). TAM is is a derivation of Ajzen and Fishbein's Theory of Reasoned Action (TRA) and assumes that "when someone forms an intention to act, that they will be free to act without limitation (Bagozzi, R. P., Davis, F. D.,

& Warshaw, P. R., 1992). Because new technologies are complex an element of uncertainty exists in the minds of potential users. Attitudes and intentions are formed and these attitudes may be positive or negative about technology use in general and the usefulness and ease of use of a specific technology. Thus, in the real world, there are many constraints that might limit a potential users' freedom to act upon their initial intentions (Bagozzi, R. P. et al., 1992).

The Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D., 2003) is a comprehensive synthesis of TAM and serves as a theoretical lens regarding strategic implementation and adoption of EMR. UTAUT proposes a set of variables that directly influence the outcome variables of Behavioral Intent and Usage of Technology. The theory holds that four independent constructs (performance expectancy, effort expectancy, social influence, and facilitating conditions) are direct determinants of usage intention and behavior (Venkatesh, V., 2003). In addition, each of the direct determinants is mediated by one or more of a set of demographic variables such as, gender, age, experience, and voluntariness of use. Validation of UTAUT in a longitudinal study found it to account for 70% of the variance in usage intention (Venkatesh, V., 2003).

Employing a qualitative research design in the first phase of our research, our objective was to identify key TAM-related beliefs and factors concerning perceived usefulness and perceived ease of use in such a manner as to obtain greater insight into the formation of perceptions or beliefs such that subsequent recommendations (or hypotheses) for design changes for both the IT artifact or the work processes in which the IT artifact is employed might be generated.

Recent studies have highlighted the criticality of physician attitudes and the importance of their support with respect to the effective adoption and use of HIT (Illie, V., Courtney, J. F., & Van Slyke, C., 2007; Lapointe, L., & Rivard, S., 2005; Snyder, K. D., Paulson, P., & McGrath, P., 2005; Kohli, R., & Kettinger, W. J., 2004; Daar, A., Harrison, M. I., Shakked, L., & Shalom, N., 2003; Hu, P. J., Chau, P. Y. K., & Sheng, O. R. L., 2002; Treister, N. W., 1998). Physician resistance to technology adoption is not necessarily unwarranted. Snyder, Paulson and McGrath report that while the time required to perform the tasks of medical technicians may decrease, "the doctor is faced with an increase in his or her workload" (Miles, M. B., & Huberman, A. A., 1994, p. 90). Darr, Harrison, Shakked and Shalom (2003) identified six domains of concern: "managerial implications of the EMR, limits on professional autonomy, impact on communications with colleagues, facilitation of research, legal defense, and influence on the professional hierarchy within the hospital"(2004, p. 353). Kerr, McGlynn, Adams, Keesey and Asch (2004) raised many of the same issues particularly highlighting concerns regarding the impact of technology, i.e., data entry, on the quality of doctor-patient interaction, as well as problems with various perceived restrictions imposed by the system.

Thus the second phase of our inquiry into the adoption of EMR is UTAUT driven. This research's primary focus is on one specific mediating factor of the UTAUT theory: prior experience with EMR. Commonly accepted knowledge posits that "Many medical schools and residency programs do not currently employ or train future physicians to use EMR; training the future medical workforce to rely on EMR… can only serve to accelerate universal EMR adoption" (2004). While it may seem intuitive that prior experience would be positively correlated with use, UTAUT does not predict such a simple, positive, linear relationship. Thus, with UTAUT as our theory base, this quantitative second research step scrutinized the impact of physicians' prior experience with EMR.

Culture as a Value Adding Social Influence

UTAUT posits that social influence is one of the four direct determinants of usage intention and usage behavior. We suggest that culture may be the among the strongest social influences in an organization. "Culture acts as a silent governor" (Wenzel, F. J., 2005, p. 54). When new strategies, such as the implementation and use of new technology, are introduced, the cultural component merits consideration. Most often, one of three tactics are employed: 1) attempts may be made to change the existing organizational culture to match the new strategy, 2) the existing culture may remain and the strategic initiatives try to manage around it, or 3) the strategies may present a good fit with the existing culture (2005).

To elaborate, one way of understanding the culture in a specific health service organization may be made possible by how physicians, managers, and staff answer questions regarding organizational mission and value prioritization (Swayne, L. E., Duncan, W. J., & Ginter, P. M., 2006). The mission of the organization refers to why the organization operates the way it does.

- What is the mission of the organization?
- What are the values associated with the organization?
- What are the high and low priorities within the organization? High priorities are those activities that are in concert with the organizational values and mission. Actions that offer good fit should receive higher priority.

Along with the mission, values, and prioritization in the organization, successful "stories" are repeated to underscore the culture.

The telling of such stories also serves to educate others who work in the organization about its culture. And, through the telling of these successful stories, it becomes part of the cultural history of the organization. The story itself becomes meaningful to the staff members who work there (Higgins, J. M., & McAllaster, C., 2003). Hence, such stories serve as a value adding support strategy and, as a result, encourage additional buy-in from other staff members to continue the culture of quality, and in this specific case, the use of EMR.

Swayne, Duncan and Ginter (2006) propose that a strategic thinking map for value adding support strategies may identify matches (or mismatches) of culture and strategy. The construction of the map is subjective and offers direction during strategic planning; the process offers a way to examine if strategic initiatives are good fits for organizational strategy. In the construction of a strategic map, culture is assessed in terms of its assumptions, values, behavior and norms of the organization (see Figure 1).

The third phase of our inquiry into the adoption of EMR, then, employs a qualitative examination of the social influence of culture. Organizational culture permeates throughout an organization (Swayne, L. E. et al., 2006; McConnell, C. R., 2006; Wenzel, F. J., 2005). This concept of culture influences the way people in an organization do their work, and we suggest, it impacts the an organization's intention to use, and the actual use of, EMR.

THE SITE AND THE THREE PHASES OF RESEARCH

The primary site of all three phases of our work is a Family Medicine clinic (FMED) in the Intermountain West region of the United States. The clinic resides in one of the larger population centers in the state, having a metropolitan area less than 75,000 persons.

The Centricity Physician Office EMR product was obtained via grant funding and data were preloaded into it in Fall, 2004 with initial patients seen using the EMR starting in December, 2004. All patients were seen using the EMR by Spring,

*Figure 1. Strategic thinking map for value adding support strategies for FMED**

Strategy Initiatives: EMR initiative and Quality and Culture Project

Characteristics/Attributes			**Evaluations**	**Support Strategy**
Value adding support strategy	Results of Internal Analysis—What is the Culture at FMED?	Requirements of Selected Strategy (IT Implementation and The Quality as Culture Project)	Comparisons Made Between Strategy and Cultural Fits	Guidance, Ideas Offered
Organizational Culture *Mission* *Values* *Behavior* *Norms*	*Strong culture, focused on technological innovation, effective primary care for the underserved rural population.* *Strong culture, focused on the education of family practice physicians* *Strong culture, focused on learning in University environment.*	*Culture reflects probable IT adoption and use by physicians; continuous learning efforts to be employed; and introduction of projects designed for cutting edge healthcare efforts*	*Culture offers good match. The values and norms need to be maintained for successful implementation.*	*IT—Emphasis on readiness and ability for training efforts; emphasis on listening to physician users' ideas and input regarding EMR* *Leaders—Emphasis on visible communication and behavior supportive of strategy*

**[Adapted from Swayne, Duncan, and Ginter (2006) Strategic Thinking Map Exhibit, p. 411]*

2005, and e-prescribing became available in December 2006. Data are accessible at the clinic via a wireless network and all attendant physicians are provided with notebook computers while on call. The data are also accessible from the nearby hospital, and through secure remote access, off-site. In addition, Laboratory Tests, Radiology, and Pharmacy, including E-Prescriptions, are accessible through the network.

There are eight physicians on the staff at FMED clinic who are also Faculty in the College of Health Professions, Department of Family Medicine at the University with which FMED is affiliated. The FMED practice is structured with physicians functioning as director and associate director, and a Pharm.D. as Director of Research.

The Family Medicine Residency Program is designed to train physicians for successful rural family practice. Six Residents are admitted into the program annually, resulting in eighteen Residents in training each year during the three year program. "Residency is a stage of postgraduate medical training in North America and leads to eligibility for board certification in a primary care or referral specialty. It is filled by a resident physician who has received a medical degree (M.D. or D.O.) and is composed almost entirely of the care of hospitalized or clinic patients, mostly with direct supervision by more senior physicians." (Wikipedia, 2007).

Open Ended Face-to-Face Interviews

To assess residents' beliefs, attitudes and perceived group norms concerning EMR use within their residency, open ended interviews were conducted during Winter 2007, with 7of the 18 residents in the Family Medicine Residency program. We were pleased to achieve a 39% level of participation given the intensive nature of our research interview and the tremendously busy schedule of resident physicians.

Three residents were in their third and final year of residency and two were in each of the first and second years. Three of the residents were female and four were male, two were in their late twenties and 5 were 30 years of age or older, three were international. Four of the residents had no experience with either paper or electronic medical records prior to their admission into the Family Residency program. Two of the residents had previously worked with an EMR. In addition, two of the residents had significant information systems backgrounds, both having worked in support functions prior to obtaining their MDs.

Prior Use Survey

The next phase of this work was a written survey project that was conducted during spring, 2008. Both residents and faculty from the residency described above, and from a sister family practice residency program from across the state, were invited to participate. Questions included in the survey were guided by the findings from the face-to-face interviews discussed above. One hundred percent (100%) of the 15 faculty surveys and seventeen (37%) of the resident surveys were returned. Fourteen of the participants were female, 18 were male, 26 were MDs, 4 were DOs, and 2 indicated they were PAs.

The Quality of Care Project

The Quality as Culture Project was initiated independently by FMED. Each resident is required to partake in a quality project before they leave the residency and to on to their first practice site. The Quality as Culture project reported here focused on documenting and assessing Adult Diabetes Clinical Performance Measures from the Physician Consortium for Performance Improvement (PQRI). This project could not have been undertaken without the use of EMR.

Qualis Health, a private, nonprofit healthcare quality improvement organization with national reputation, recognized FMED in 2008 with its Award of Excellence in Healthcare Quality for its demonstrated leadership and innovation in improving healthcare practices. Qualis Health specifically noted FMED as one of the few clinics in the nation that could readily generate reliable clinic data.

FINDINGS

2007 Face-to-Face Interviews

Performance Expectancy

"Performance expectancy is defined as the degree to which an individual believes that using the system will help him or her to attain gains in job performance" (Venkatesh, V., 2003 p. 447). The seven residents were unanimous in their expectation that adoption of an EMR would enhance their ability to provide medical care. Although we found variance in how each resident used EMR with patients, they consistently commented on the value of having the patient's data available at any time, from either the clinic or hospital.

In addition, residents commented on the value of having standardized data elements in the system as a component of their performance expectation. Although 60% of the patients at FMED see a regular physician, the inherent turnover of residents imposes instability on a long-term physician-patient relationship. Having data standardized facilitates patient care by providing consistent history, diagnosis and treatment information for each patient.

Effort Expectancy

"Effort expectancy is defined as the degree of ease associated with the use of the system." (Venkatesh, V., 2003, p. 450), The seven residents unanimously commented about the accuracy of patient documentation, and the ability to easily locate data. Easy access to lab work, medications, prior visits, history and conditions were all discussed as being benefits of the system, in addition to the data being readable. Electronic prescriptions had recently been added to the functionality of the system and were also mentioned as a system benefit.

Overall, data input was the major problem with the EMR cited by residents. One third year resident commented that "the time it takes to enter all the data makes it difficult to see more patients." Another Resident commented that it "takes too long to wrap-up…there are too many tabs…it would be helpful to enter necessary data on one sheet." Navigation of the system was mentioned as a problem by another of the third year residents. Similar comments were echoed by all the residents, with the exception of a technology savvy resident who had prior experience in systems support and development. This third year Resident commented that he was "adept at the EMR."

Additional drawbacks mentioned included system efficiency and the cumbersome nature of many screens, with some including multiple tabs for basic procedures. Because the residents ideally completed their paperwork between appointments, interruptions were also cited as system drawbacks.

Thus from these face-to-face interviews we found strong evidence in support of TAM. The TAM model positis that performance expectancy and effort expectancy predict behavior intention to use and system usage. The construct of performance expectancy was high for these residents; all agreed that the EMR would enhance the care they provided, primarily because of the increased access to patient data. We also found amply evidence of TAM's other construct, effort expectancy; the residents' primary complaints were about the amount of effort it took to enter information, to navigate the system, and to work through all the tabs when closing one patient's record and moving on to the next.

UTAUT is somewhat more complex in the independent variables that it proposes impact the same dependent variables as TAM: Behavioral Intention and Usage of Technology. The theory holds that four independent constructs (performance expectancy, effort expectancy, social influence, and facilitating conditions) are direct determinants of usage intention and behavior (Venkatesh, V., 2003). In addition, each of the direct determinants is mediated by one or more of a set of demographic variables such as, gender, age, experience, and voluntariness of use.

Social Influence

"Social influence is defined as the degree to which an individual perceives that important others believe he or she should use the new system." (Venkatesh, V., 2003, p. 451). At FMED, the organizational culture indicated an expectation that all residents use the EMR system.

When discussing peer influence, residents consistently stated that some of their peers didn't like the system. It was also discussed that some of the residents take more advantage of the system and were rather proficient with the EMR. The residents commented that peer influence was encouraged regarding screen modifications. One of the 'tech savvy' residents stated that "peers had a big influence on what templates were used".

Facilitating Conditions: Gender, Age, Experience, and Voluntariness of Use

"Facilitating conditions are defined as the degree to which an individual believes that an organizational and technical infrastructure exists to support use of the system" (Venkatesh, V., 2003, p. 453). Broad facilitating conditions existed to access the EMR at FMED. First, all residents had a lightweight portable device with a full screen and touch screen technology, not dissimilar to a clipboard. Second, a wireless network provided access to the system while at either FMED or the adjacent hospital. This allowed them to input data not only in the vicinity of the visitation room, but also anywhere within the facility, at any time. Third, the FMED IT staff provided support services at the home of each Resident to configure them for remote access to the EMR.

We did not observe any significant differences in performance expectations by either gender or age in our 2007 interviews. In addition, we had little variation in the ages of our residents as most were in their late 20s to mid 30s, thus are unable to comment on age as a mediating variable

Technical experience had a definite influence on effort expected and behavioral intention of system use in this study. The two 'tech savvy' residents endeavored to master the system and realized that they had to learn the system either through training or on their own. Because training was mentioned frequently by the residents when discussing their intentions of using the system, it seems that the level and nature of training provided to the residents was a facilitating factor.

Use of the EMR was not voluntary for the residents in this study. There was no other option, therefore all residents, as well as faculty at FMED, used the EMR.

2008 Survey of Residents' Experience with EMR and Future Employment Decisions

This second phase of our research stream is primary focused on one specific mediating factor of the UTAUT theory: prior experience with EMR. Commonly accepted knowledge posits that "Many medical schools and residency programs do not currently employ or train future physicians to use EMR; training the future medical workforce to rely on EMR…can only serve to accelerate universal EMR adoption" Kerr, E. A., 2004). While it may seem intuitive that prior experience would be positively correlated with use, UTAUT does not necessarily predict such a simple, positive, linear relationship.

Use of EMR in Medical School

43.8% of the participants in the 2008 survey process reported using EMR while in Medical School. When broken out between faculty and residents, only one out of the 15 faculty participants (7%) used EMR in Medical School; 13 of the 17 residents (76.5%) used EMR while in Medical School. When asked if the presence or non-presence of EMR had a bearing on their choice of residency programs, 7 of the 13 residents who used EMR in medical school (53.8%) indicated that EMR did influence their choice of residency, all indicating their preference had been for a residency with EMR.

Use of EMR in Family Practice Residency Programs

61.3% of the aggregate used EMR in their residency program. As the residency programs chosen for this pilot study both have adopted EMR, 100% of the resident participants in this study indicated they use EMR in their residency. In comparison, only two of the faculty used EMR while in their residency programs. Of the 19 respondents who indicated that they use, or did use, EMR in their residency programs, 11 (57.9%) report that their residency EMR was very or somewhat user friendly, 2 (10.5%)said it was neither friendly or unfriendly, and 8 (42.1%) indicated their residency EMR was somewhat or very non-user friendly.

Choice of Practice Sites

When asked if the presence or non-presence of EMR had or would influence their choice of first practice sites, 12 in the aggregate (37.5%), nine of which were residents (52.9%) and 3 of which were faculty (20%), indicated that EMR did or would have a bearing on first practices sites. Eleven of these physicians said they preferred practices with EMR, one preferred a practice without EMR. Twenty of the aggregate (62.5%), 8 residents (47%) and 12 faculty (80%), indicated that EMR had, or would have, no impact on choice of first practice sites.

Thus, our 2008 survey of residents and faculty found that though UTAUT predicts a positive relationship between experience with EMR and intention to adopt this technology, for 62.5% of the physicians in this study, that positive relationship may not exist.

The Impact of Culture

Mission, Values, and Priorities

When new strategies are introduced, such as the implementation of EMR or the Quality of Culture initiative at FMED, organization culture must be considered. The success of the use of EMR in the Quality of Culture Project is due, in large part, to its good fit and alignment with FMED's existing organizational culture.

An organization's mission statement embodies the intent and self image of the organization. It delineates the highest goals of the hospital and serves as a road map for strategic direction. Mission and value statements reflect the character, strategic direction, and priorities of the organization (Wiggins, C., Hatzenbuehler, L. C., & Peterson, T., 2008). In specific reference to FMED:

- What is the mission of the organization? FMED's mission is to provide a collegial learning experience through which residents become mature, competent and compassionate family physicians. In an environment characterized by academic, technological and clinical innovation, each learner and teacher is encouraged to pursue a path of individual professional growth and leadership. From public policy advocacy to cutting edge information technology to high-quality, multidisciplinary care for the underserved, we seek and encourage the best in family medicine. At FMED, the mission is to train physicians for successful rural family practice.

- What are the values associated with the organization? FMED's values focus on its being identified as a place where training and learning help to produce a competent and compassionate family physician. Thus, its core activities support the focus on education, learning, and patient centeredness.
- What are the high and low priorities within the organization? High priorities are those activities that are in concert with the organizational values and mission. Actions that offer good fit should receive higher priority. Thus, EMR implementation and quality initiatives offer a good fit with the organizational values at FMED precisely because of its focus on technological innovation to serve patients better. EMR use was mandatory: when the paper file room was cleaned out and changed into office space, it illustrated the high priority placed upon EMR use by FMED.

Organizational Stories

In addition to mission, values, and prioritization, told and retold stories of successes and failures, heroes and villains, underscore culture.

FMED's experiences and the stories that evolved focused on positive patient impacts. FMED physicians commented on the value of EMR adoption in both the 2007 interviews and the 2008 survey. Specifically, the reduction of patient error via e-prescribing, cross checking availability regarding prescription drug behaviors, and the physicians' ability to access patient information from remote computing sites were the most common value added components noted.

FMED physicians interviewed in 2007 and faculty members and residents surveyed in 2008 noted factors that did not add value. These include comments that the software was not user friendly, it was not easy for the physicians to enter data, and that the laptop and the process of data entry created intrusions with patient interaction.

Despite these concerns, nearly unanimous recognition of EMR's value resulted after EMR use was proven to have direct benefits upon patient safety and quality of care. As a case in point, the EMR allowed residents to assess how many female diabetic patients of childbearing age were prescribed potentially teratogenic medications that had high potential for causing birth defects, without documentation of contraceptive counseling. Further, 22% of the population who were prescribed these potentially dangerous medications had been prescribed by a physician outside of FMED. FMED sent a certified letter to these patients strongly recommending that they discontinue the medication and contact their primary care provider. In addition, FMED contacted the primary care providers of these patients and alerted them of the situation.

This story entwined the EMR with FMED's Quality of Culture and was direct evidence that patients' lives were made better because of the EMR and the Quality Project's initiatives. It is important to note that this success story could not have occurred without both the EMR and the Quality project working in tandem.

Leadership Support

Critical to the success of the EMR implementation and the Quality as Culture Project was the role of FMED leaders' support to maintain the culture. To maintain culture, leaders focus on consistent communication, behavior, and evaluation (Swayne, L. E. et al., 2006). At FMED, frequent communication of its priorities existed through IT training efforts and verbal and written communications that underscored the importance of IT implementation for improved patient outcomes. The message was clear: FMED leadership supported the efforts—the IT implementation and Quality as Culture Project were important at FMED.

Strategic Thinking Map

Swayne, Duncan and Ginter's strategic thinking map of value adding support strategies identifies matches (or mismatches) of culture and strategy (Swayne, L. E. et al., 2006).

In the case of FMED, the strategic map was not developed during the strategic planning stage. Rather, we adapted Swayne, Duncan, and Ginter's map to illustrate the match between culture and strategy at FMED. This allows us a method to discuss the importance of culture for strategic success.

FMED's strong organizational culture focused on innovation, effective primary care for the rural patient population, and the education of family practice physicians. EMR implementation and the Quality as Culture Project offered a good fit with the way FMED customarily went about conducting work. Grants were secured to support innovative technological developments such as the EMR; FMED is housed within the University which is a site of continued educational efforts and projects designed for cutting edge efforts. Support strategies and tangential activities that helped ensure success included continuous IT support regarding training and one-on-one guidance. IT personnel paid attention to physician input regarding the set up of forms and data entry. Leaders underscored the importance of the project through behavior that supported the strategy, such as the reduction in patient scheduling for a limited time.

The organizational culture that existed at FMED influenced effective strategic implementation. EMR adoption and The Quality as Culture Project were in sync with the mission and values of FMED.

CONCLUSION

Using UTAUT as a framework for the interpretation of our initial 2007 interview responses from residents provides a lens through which we assessed broad underlying factors for the adoption of EMRs by family practice residents. Residents readily and unanimously agreed that EMRs are beneficial in providing enhanced medical care. The overriding concern voiced by residents, however, was the unfriendliness of the system, represented by requirements to enter excess data and click through multiple forms and screens.

When the respondents of the 2008 survey were asked if the existence of an EMR had or would influence their choice of first practice sites, only 37.5% indicated that EMR did or would have a bearing on first practice sites with eleven of these physicians reporting they preferred practices with EMR, one preferred a practice without EMR. 62.5% indicated that EMR had, or would have, no impact on choice of first practice sites.

Thus, this second phase of our research stream found that though UTAUT predicts a positive relationship between experience with EMR and intention to adopt this technology, for 62.5% of the physicians in this study, that positive relationship may not exist.

Using the concept of organizational culture and assessing its match with strategy, our third phase of research assessing EMR implementation and the Quality of Culture Project at FMED were indeed found to have a good fit with FMED's culture. FMED adopted a three year Quality as Culture Project that focused on the usage of an electronic medical records system that helped create a forum for practice measurement and improvement. The project resulted in FMED's receiving the Award of Excellence from Qualis Health in 2008 as one of the few clinics in the nation that could readily generate reliable clinic data. The match of organizational culture with FMED's mission, values and goals was key for successful strategic achievement.

The residents and EMR at FMED provide an interesting set of conditions that perhaps influence, and certainly warrant, further research. The residents are essentially a cohort group, enabling group dynamics of social influence to impact behavioral intention. In addition, the combination of an organizational culture of quality encouraged and supported EMR implementation and the outcomes evidenced to the residents that they could provide a higher quality of medical care because of the information available with the EMR.

FUTURE RESEARCH

These findings are from the first 3 stages of an on-going stream of research. We find it interesting to note the generally more positive attitudes toward EMRs expressed by this study's participants relative to those presented in others' work. We acknowledge these more positive attitudes may result in part from the fact that EMR capabilities are improving over time, technical competency of several of the respondents, and the degree of participation residents had in configuring the system. Further, the experience of working in an organizational culture that supported HIT may have also added to this positive stance.

TAM and UTAUT have been widely used to study physician's intentions to adopt and use EMR. One of the mediating factors in UTAUT is experience. Our work found that although UTAUT predicted a positive relationship between experience with EMR and intention to adopt this technology, for the population in this study, that positive relationship may not exist. This somewhat unexpected finding requires further investigation in different settings and among different specialties of physicians before any conclusions can be drawn regarding the usefulness or validity of UTAUT and EMR.

Finally, all three phases of our work thus far have been based on one residency and a small sample of family practice residents: caution must be used in generalizing our results to other physicians and other settings. In particular it is important to note that one of UTAUT's mediating variables, voluntariness of use, is not a true variable in our work, in the sense that it is not allowed to vary among our subjects or our research sites. EMR use is required of all residents in all three phases of our research. Indeed, the US federal government intends to require that all healthcare practitioners and facilities use EMR within the next decade, thus any research employing UTAUT to investigate the adoption and use of EMR will soon have the same limitation.

REFERENCES

Bagozzi, R. P. (2007). The legacy of the technology acceptance model and a proposal for a paradigm shift. *Journal of the Association of Information Systems, 8*(4), 244-254.

Bagozzi, R. P., Davis, F. D., & Warshaw, P. R. (1992). Development and Test of a Theory of Technological Learning and Usage. *Human Relations, 45*(7), 660-686.

Benbaset, I., & Barki, H. (2007). "Quo Vadis, TAM? *Journal of the Association of Information Systems, 8*(4), 211-218.

Burke, D. E., & Menachemi, N. (2004). Opening the black box: Measuring hospitial information technology. *Healthcare Management Review, 29*(3), 207-217.

Burrell, G. (1999). Normal science, paradigms, metaphors, discourses and genealogies of analysis. In S. R. Clegg, C. Hardy & W. R. Nord (Eds.), *Handbook of Organization Studies*, (pp. 642-658). Thousand Oaks: Sage.

Daar, A., Harrison, M. I., Shakked, L., & Shalom, N. (2003). Physicians' and nurses' reactions to electronic medical records: Managerial and occupational implications. *Journal of Healthcare Organisations, 17*(5), 349-359.

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly, 13*(3), 319-340.

Davis, F. D., Bagozzi, R. P., & Warshaw P. R. (1989). User acceptance of computer technology: A comparison of two theoretical models. *Management Science. 35*(8)982-1003.

Department of Health and Human Services (HHS). (2004, July). *The decade of information technology: Delivering consumer-centric and information rich health care.* Washington DC: HHS.

Flower, J. (2006). Imagining the future of healthcare. *The Physician Executive, 32*(1), 64-66.

Government Accountability Office (GAO). (2003, October). *Information technology: Benefits realized for selective health care functions* (Tech. Rep. No. GAO-04-224). Washington DC: U.S. Government Printing Office.

Government Accountability Office (GAO). (2005, February). *21st century challenges: Reexamining the base of the federal* Thielst, C. B. (2007). The new frontier of electronic, personal and virtual health records. *Journal of Healthcare Management, 52*(2), 75-78.

Hu,, P. J., Chau, P. Y. K., & Sheng, O. R. L. (2002). Adoption of telemedicine technology by health care organizations: An exploratory study. *Journal of Organizational Computing and Electronic Commerce, 12*(3), 197-221.

Illie, V., Courtney, J. F., & Van Slyke, C. (2007). Paper versus electronic: Challenges associated with physicians' usage of electronic medical records. *In Proceedings of the 40th Hawaii International Conference on System Sciences* (pp. 1-10). Big Island, HI.

Kerr, E. A., McGlynn, E., Adams, J., Keesey, J., & Asch, S. M. (2004). Profiling the quality of care in communities: Results from the community quality index study. *Health Affairs, 23*(3), 247-256.

Klein, H. K., & Myers, M. D. (1999). A set of principles for conducting and evaluating interpretive field studies in information systems. *MIS Quarterly, 23*(1), 67-93.

Kohli, R., & Kettinger, W. J. (2004). Informating the clan: Controlling physicians' costs and outcomes. *MIS Quarterly, 28*(3), 363-394.

Lapointe, L., & Rivard, S. (2005). A multilevel model of resistance to information technology implementation. *MIS Quarterly, 29*(3), 461-491.

Lucas Jr., H. C., Swanson, E. B., & Zmud, R. E. (2007). Implementation, innovation and related themes over the years in information systems research. *Journal of the Association of Information Systems, 8*(4), 206-210.

McGlynn, E. A., Asch, S. M., Adams, J., Keesey J., Hicks, J., DeCristofaro A. et al. (2003). The quality of health care delivered to adults at the United States. *New England Journal of Medicine, 348*(26), 2635-2645.

Miles, M. B., & Huberman, A. A. (1994). *An expanded Sourcebook: Qualitative Data Analysis* (2nd Edition). Thousand Oaks, CA: Sage.

Pierce, M. E. (2005). Convergence of the health industry. *Leadership in Health Services, 18*(1), 22-31.

Snyder, K.D., Paulson, P., & McGrath, P. (2005). Improving processes in a small health care network: A value mapping case study. *Business Process Management Journal, 11*(1), 87-99

Stake, R. E. (1994). Case Studies. In N. K. Denzin & Y. S. Lincoln (Eds.), *Handbook of Qualitative Research* (pp. 236-247). Thousand Oaks: Sage.

Straub Jr., D. W., & Burton-Jones, A. (2007). Veni, Vidi, Vici: Breaking the TAM logjam. *Journal of the Association of Information Systems, 8*(4), 223-229.

Thielst, C. B. (2007). The future of healthcare technology. *Journal of Healthcare Management, 52*(1), 7-9.

Thielst, C. B. (2007). The new frontier of electronic, personal and virtual health records. *Journal of Healthcare Management, 52*(2), 75-78.

Treister, N. W. (1998). Physician acceptance of new medical information systems: The field of dreams. *The Physician Executive, 24*(3), 20-25.

Tsoukas, H. (1989). The validity of ideographic research explanations. *Academy of Management Review, 14*(4), 551-561.

Venkatesh, V., Davis, F. D., & Morris, M. G. (2007). Dead or alive? The development, trajectory and future of technology adaptation research. *Journal of the Association of Information Systems, 8*(4), 267-286.

Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User acceptance of information technology: Toward a unified view. *MIS Quarterly, 27*(3), 425-478.

Wikipedia.org. June 14, 2007 http://en.wikipedia.org/wiki/ Medical_residency,

Yin, R. K. (1994). *Case Study Research: Design and Methods*, Second Edition. Thousand Oaks, CA: Sage.

Higgins, J. M., & McAllaster, C. (2003). If you want strategic change, don't forget to change your cultural artifacts. *Journal of Change Management, 4*(1), 63-73.

McConnell, C. R. (2006). *Umiker's Management Skills for the New Health Care Supervisor*, Fourth Edition. Boston, MA: Jones and Bartlett.

Menachemi, N., Saunders, C., Chukmaitov, A, Matthews, M., & Brooks, R. (2007). Hospital adoption of information technologies and improved patient safety: a study of 98 hospitals in Florida. *Journal of Healthcare Management, 52*(6), 398-410.

Possner, B. Z., Kouzes, J. M., & Schmidt, W. H. (1985). Shared values make a difference: an empirical test of corporate culture. *Human Resource Management, 24*(3), 293-309.

Swayne, L. E., Duncan, W. J., & Ginter, P. M. (2006). *Strategic Management of Health Care Organizations*, Fifth Edition. Malden, MA: Blackwell.

Thielst, C. B., & Gardner, J. H. (2008). Clinical documentation systems: another link between technology and quality. *Journal of Healthcare Management, 53*(1), 5-7.

Wenzel, F. J. (2005). Governance Organizational Models and Issues. In F. J. Wenzel & J. M. Wenzel (Eds.), *Fundamentals of Physician Practice Management*. (pp. 43-58). Chicago: Health Administration Press

Wiggins, C., Hatzenbuehler, L. C., & Peterson, T. (2008). Hospital Missions and the Education of our Future Health Care Workforce. *The Journal of Allied Health, 37*(3), 132-6.

Wikipedia.org. November 14, 2008 http://en.wikipedia. org/wiki/Technology_acceptance_model

This work was previously published in International Journal of Healthcare Information Systems and Informatics, Vol. 4, Issue 3, edited by J. Tan, pp. 55-68, copyright 2009 by IGI Publishing (an imprint of IGI Global).

Chapter 4.4

Perceptions of an Organizing Vision for Electronic Medical Records by Independent Physician Practices

John L. Reardon
University of Hawaii, USA

ABSTRACT

Adoption and usage rates of healthcare information technology (HIT) in general and electronic medical records (EMR) in particular are below expectations even though both show potential to help solve pressing problems plaguing the U.S. healthcare system. This research explores the role an organizing vision (OV) (Ramiller & Swanson, 2003) plays in shaping independent physician practices' (IPP) perceptions of EMRs and hence their interest in adopting and using the technology. This paper reports on an OV for EMRs by using a mail survey of IPPs and uses factor analysis to examine structural properties and content of the OV among the practices. Contributions to theory include exploring the applicability of Ramiller and Swanson's (Ramiller & Swanson, 2003) OV on HIT innovations in healthcare research. Contributions to practice include empowering HIT decision makers with a model for addressing the introduction of a technology innovation (EMR) into an independent physician practice.

INTRODUCTION

The Advanced Technology Program (ATP) of the National Institute of Standards and Technology (NIST) promotes using information technology (IT) systems in the healthcare industry as a means to deliver substantial cost savings, to improve the quality of healthcare, and to capture global market share of new and improved products and services (NIST, 2005); the Institute of Medicine (IOM) highlighted IT as integral to improving healthcare (IOM, 2001); and, the U.S. Government in general has promoted increased use of health information technology (HIT) (WHSOU, 2008, 2007) and in particular has outlined a plan that seeks to ensure that most Americans have electronic health records (EHR) by the year 2014 (WHSOU, 2006, 2005, 2004). In addition, Health and Human Services (HHS) Secretary Mike Leavitt recently described how electronic medical records (EMR) can help change the macroeconomics of the way small physician practices are reimbursed thereby facilitating improvement in the delivery of healthcare (Burda, 2008).

Despite these high expectations for the value of IT in healthcare, HIT use in the U.S. is low in the sheer number of adopters as well as in the extent of actual use (Poon et al., 2006; Johnson, Pan, & Middleton, 2002). Studies from the Center for Studying Health System Change (HSC) show wide variation in IT adoption across physician practices, particularly by physician practice setting, size, and specialty. That is, in the 2004 to 2005 timeframe, U.S. physicians in traditional practice settings i.e., primarily solo or relatively small group practices where the vast majority of Americans receive care, reported that their practice generally confined IT use to five clinical function areas: obtaining treatment guidelines (65%), accessing patient notes (50%), writing prescriptions (22%), exchanging clinical data with other physicians (50%), and exchanging information with hospitals (66%) (Cory & Grossman, 2007). Since only those physicians with access to IT for all five of these clinical activities are considered to have an EMR the issue of adopting an EMR based on lack of support is an important issue for small practices. That is, typically the highest levels of IT support for patient care are found in staff- and group-model health maintenance organization (HMO) practices, followed by medical school faculty and large group practices (Johnson, Pan, & Middleton, 2002).

In particular, the adoption and use of EMRs by independent physician practices is well below expectations. For example, in a random survey of nonfederal, office-based physicians providing direct patient care, Burt et al. (2007) found that just 24% of physicians used EMRs in their office-based practices; in a survey of primary care physicians, Menachemi and Brooks (2006) found that 24% overall reported electronic health record (EHR) use in the office; and, in a national, representational survey of physician practices Gans et al. (2005) found that just 14% of practices overall used EMRs. In addition, whereas recent estimates of EMR adoption indicate that the actual number of adoptions has increased from about 105,000 physicians to 130,000 physicians, this increase still represents just approximately 20% of the overall general physician population (iHealthBeat, 2005).

This apparent variation in IT adoption in general and low EMR adoption in particular across the community of independent physician practices, provides a fertile opportunity for research, from both theoretical and practical perspectives. This paper thus reports on a survey of the perceptions of EMRs by independent physician practices by extending the theoretical model of organizing visions as developed by Ramiller and Swanson (2003). That is, Swanson and Ramiller (1997) posit that a diverse inter-organizational community creates and employs an organizing vision of an information system innovation that is central to its early, as well as later, diffusion. In this context, an organizing vision is a 'focal community idea for the application of information technology in organizations' (Swanson & Ramiller, 1997, p. 460). By utilizing the theoretic concept of an organizing vision for IT innovations (Ramiller & Swanson, 2003; Swanson & Ramiller, 2004, 1997) this paper analyzes how small physician organizations perceive the discourse surrounding EMRs in terms of interpretability, plausibility, importance, and discontinuity with existing clinical and administrative practices and technologies. In the next sections of this paper the organizing vision concept and its applicability to EMR adoption is outlined. Next, survey method and findings are described. Finally, a discussion of the implications and future steps in this research are presented.

LITERATURE REVIEW

Electronic Medical Record

In terms of managing information resources in healthcare, the U.S. Health and Human Services Department defines health information technology (HIT) as the comprehensive management of medical information and its secure exchange between health care consumers and providers (HHS, 2008). An electronic medical record (EMR) is a specific example of a HIT that is a computer-based record containing health care information (Tang & McDonald, 2001). This record may contain some, but not necessarily all, of the information that is in an individual's paper-based medical record. Although EMR is the term used signifying the artifact in this study, the concept of a computer-based (or electronic-based) record to manage healthcare information comes by many names depending on specific functional components. In addition, all comprehensive EMR's share several common traits: they all contain large data dictionaries that define their contents; all data are stamped with time and date so that the record becomes a permanent chronological history of the patient's care; the systems have the capability to display data in flexible ways, such as flow sheets and graphical views; and, they have a query tool for research and other purposes (Dick, Steen, & Dether, 1997).

Study Rationale and Significance

There are few theory-based research studies in the area of IT in healthcare (Chiasson & Davidson, 2005) and virtually no theory-based research studies on the process of adoption and assimilation of complex IT in the small organization setting (Lee & Xia, 2006). In addition, most HIT studies, theory based or otherwise, have examined large organizations such as hospitals (Garrets & Davis, 2006; Ash, Gorman, Seshadri, & Hersh, 2002; Doolan & Bates, 2002; Schubart & Einbinder, 2000) or have examined perceptions and use of HIT at the individual-level (Dykes, 2006; Blumenthal et al., 2006; Chau & Hu, 2002). A review of the literature indicates that there are virtually no theory based HIT studies at the small physician organization level. It is thus unclear if theories developed at the large organizational level or at the individual level apply equally well at the small organizational level.

Prominent specific factors contributing to low EMR adoption rates in small, independent physician practices include cost, lack of financial incentives, and an immature EMR software market (Ash & Bates, 2005). Likewise, beyond the apparent adoption of EMRs, actual use of EMRs in clinical practice is of concern because little is known about why some physician practices ultimately use an EMR successfully, despite high barriers to adoption and assimilation, while others do not (Ash & Bates, 2005). It is evident that unless IT applications are effectively assimilated into small physician practices in ways that improve overall healthcare, benefits such as decrease in errors, increase in cost savings, and better results in clinical outcomes will be limited to mere incremental, automation improvements (Broder, 2005). Therefore, a better understanding of those factors that facilitate or hinder the adoption and assimilation of EMRs in physician practices is a key to achieving substantial healthcare improvement though HIT.

The issue here is to select those theories or models that enhance our understanding of EMR adoption and assimilation patterns. To that end, the unit of analysis in this study is the independent physician practice as an organization and not the physician as an individual adopting a technology innovation. As such, an individual-based method of analysis such as the Technology Acceptance Model (TAM) (Venkatesh, Morris, Davis, & Davis, 2003) would be less useful than an organizational-based one as an EMR is an organization-wide system. That is, although the physician-owner of a practice may serve as the key decision-maker in the adoption of IT, it is not feasible that this one individual would adopt and use an EMR but associated professional and administrative staff would not, or visa versa. Therefore, the adoption and use of an EMR is best considered an organization-based decision and not an individual-based one.

The problem here is that determining just how an organization i.e., independent physician practice, goes about developing a collective understanding of an IT innovation such as an EMR is not an easy task to accomplish. An organization requires help in reconciling different interpretations and conceptualizations of the innovation that may be held by members of the organization. It is suggested that by employing the theoretical model of an organizing vision (Ramiller & Swanson, 2003), a relatively small, independent physician practice may reconcile the varied individual meanings and invented or contrived ideas surrounding an innovation. The physician organization can then better position itself to decide if adoption and use of the innovation is truly in the organization's best interests.

Organizing Visions of IT Innovation

Individuals and organizations often first learn about an innovation such as an EMR through a community-wide discussion and discourse before an adoption and use decision is made. Swanson and Ramiller (1997) posit that a diverse, inter-organizational community creates an organizing vision (OV) of an information system innovation through its community-wide discussion and discourse, and that this vision is important to early, and late diffusion of the information system. Furthermore, Swanson and Ramiller (1997) define an OV as the focal community idea for the application of information technology in organizations. This focal community coalesces in the inter-organizational field. As such, the OV becomes the community's vision for organizing in a way that embeds and utilizes new IT in organizational structures and processes (Swanson & Ramiller, 1997).

The concept of an OV thus helps to explain how information system innovations originate, develop, and diffuse over time, across firms and industries. This vision serves key functions in interpretation, legitimation, and the organization and mobilization of economic roles and exchanges. In essence, a community's discourse serves as the developmental engine for an OV. Within this community additional factors such as business commerce, the IS practitioners' world view, the motivating business problem or objective, the core technology, and material processes of adoption and diffusion help to provide the discourse with its content, structure, motivation, and direction.

A key aspect of an OV is that it has a "career" over which it varies substantially in visibility, prominence, and influence. For example, previous OV research was used to identify and characterize new types of information systems such as application services provisioning (ASP) and customer relationship management (CRM). To illustrate, Currie (2004) found that over time the initial discourse surrounding the OV of ASP was replaced by skepticism and distrust as powerful institutional interests in the form of leading technology firms, industry analysts, and IT consultancies were ultimately unsuccessful in their attempts to disseminate ASP across wider business and not-for-profit IS user communities. Currie's research indicates that a process-oriented analysis of how OVs are interpreted, legitimized, and mobilized is critical to understanding and explaining how underdevelopment of an OV at an early stage may inhibit its later adoption and institutionalization. Likewise, Firth (2001) used the analysis of the OV as a tool to trace the diffusion of a CRM system as an IS innovation and found that by creating, participating, and being influenced by the CRM discourse, managers do not operate in a vacuum when they consider whether to adopt and implement a CRM system. These studies are of value because they illustrate that even as an OV helps shape how managers think about the future application and practice in their field, the OV nonetheless still struggles to achieve ascendancy in the overall community (Swanson & Ramiller, 1997).

Swanson and Ramiller (2004) address this struggle to achieve ascendancy by positing that different types of organizations will respond differently to an OV. For example, some organizations respond "mindlessly" to join the "bandwagon" to adopt an innovation whereas other organizations more purposefully evaluate the innovation's appropriateness for their own situation. Swanson and Ramiller (2004) also suggest organizations respond differently at different stages in the OV "career." That is, organizations may be more inclined to accept an innovation uncritically in the early stages, when little is known about the innovation, especially so if the OV is powerfully presented in the discourse community. To illustrate, in an exploratory study of the structural aspects of organizing visions, Ramiller and Swanson (2003) investigated how information systems (IS) executives responded to OVs that are in different career stages. By using field interviews and a survey Ramiller and Swanson identified four dimensions of executive response that focused on an organizing vision's *interpretability*, *plausibility*, *importance*, and *discontinuity*.

Interpretability reflects how intelligible and informative the executive found the representations of the OV in its associated public discourse. Interpretability revolves around such aspects as clarity, consistency, richness, and balance. *Plausibility* focuses on distortions in the discourse, emphasizing in particular the burdening of the OV with misunderstandings, exaggerations, and misplaced claims. Items contributing to plausibility are suggestive, on one hand, of honest confusion and basic lack of knowledge and, on the other hand, of the calculative and even deceptive exploitation of the OV. *Importance* brings together a diverse set of judgments. That is, importance implies the power of influencing or the quality of having evident value either generally or in a particular relation and often by merely existing. Importance is further categorized into three sub-dimensions *business benefit*, *practical acceptance*, and *market interest*. Business benefit concerns a "bottom line" understanding i.e., to what extent does the innovation contribute to a value chain or return on investment? Practical acceptance concerns an innovation that may be characterized more by technology push, than by need pull. That is, whether the innovative concept transfers well to practical application may still be an open question thus undermining the sense of its basic importance. As such, the vision may be a "hard sell" to management, and its practical acceptance may be weak. Market interest concerns the extent to which market signals are substantively informative such that a relative lack of market interest may reflect real and persistent problems of practical acceptance. In essence, the notion that an innovation is or is not worthy of the community's interest, and accordingly its attention, is fundamentally tied to the vision's received importance. Finally, *Discontinuity* consists of two concepts: conceptual discontinuity i.e., how great a departure from existing ideas and notions of existing technologies does the OV pose; and structural discontinuity i.e., how much difficulty is entailed in implementing the new innovation. These four dimensions thus form the underlying structure of an OV and are examined in this study.

By taking a comparative approach, Ramiller and Swanson's (2003) study offers several grounded conjectures concerning the career dynamics of an OV. For example, Conjecture 5 states: "Supporters and detractors will not differ from the community's majority, on the average, in their evaluation of the discontinuity of the organizing vision" (Ramiller & Swanson, 2003, p.36). This is of value because for a managerial decision maker, an IS executive in their case, the findings point the way to a more proactive, systematic, and critical stance toward innovations that can place the executive in a better position to make informed adoption decisions. Likewise, an understanding of the OV surrounding EMR technology may help place the physician practice in a better position to make informed EMR adoption and use decisions. Also, if policy makers such as government officials, professional associations, and healthcare organizations who want to promote EMR adoption understand how physicians perceive the OV surrounding EMRs, they can then take steps such as general education and directed continuing medical education (CME) to better effect such promotion. In addition to policy makers vendors can also better understand how to promote products. Additional resources such as consultants and implementation guides that are mobilized through the OV may similarly provide substantial benefit from which organizations may draw as they undertake adoption and assimilation of the complex organizational technology.

The potential benefits of EMR adoption, there is some common knowledge and trade press level coverage of purported barriers to EMR adoption such as initial cost of investment, return on investment, and decrease in productivity (Havenstein, 2006), but much less scientific examination into those barriers. Since adopting and assimilating EMR technology in an independent physician practice is an important undertaking, it is imperative that the decision to adopt adequately address such issues as investment costs, operational and procedural changes, and market support. When the innovation is new, or when the adopter population is not familiar with the innovation, community-level discourse about the innovation serves an important role in informing and persuading potential adopters on such issues. In the case of EMRs, although the technology has been available for some time the rate of adoption remains low among small independent physician practices (Callahan, 2007). This paper suggests that the OV for EMRs also contributes to the low rate of adoption. As a first step in investigating this possibility, this study explores organizational decision-makers' perceptions of the EMR OV using Ramiller and Swanson's (2003) institutional reception variables of interpretability, plausibility, importance, and discontinuity in independent physician practices.

RESEARCH METHOD

To empirically evaluate independent physician practices' reception of the OV for EMRs, a mailed survey following procedures outlined in Dillman (2000) was conducted to include the following major steps: a brief pre-notice letter; an initial questionnaire; a thank you and reminder postcard; a replacement questionnaire; and, a final contact. The mailing list for an independent physicians association with approximately 780 physician members was used. The endorsement of the association's leadership and their sponsorship of the survey helped assure a good response rate as physicians are typically noncompliant to surveys (Olson, Schneiderman, & Armstrong, 1993). The unit of analysis in this study is the physician organization; therefore it was determined that although the association is overwhelmingly made up of solo practitioners the 780 individual physician members were grouped into 567 separate independent practices (organizations). To determine which physicians practice together as a single organization, information in the practice association databases (for example, the same address and phone number), online sources of licensing information, and calls to office staff to verify practice arrangements were used. Membership in these 567 clearly distinct and separate physician practices ranged from a minimum of just one physician to a maximum of 18 physicians with an average practice size of two physicians. Overall practice sizes (consisting of physicians and staff members) ranged from a minimum of two (just the physician and a staff member) to a maximum of 54 (physicians and staff members) with an average overall size of six members. As surveys were uniquely addressed to the practice and each physician member was identified as belonging to just one unique practice organization there were no cases of double counting of results.

Over the course of mailings to the 567 physician organizations, 302 or 53% were not returned, 54 or 10% were returned but respondents declined to participate, 32 or 6% were marked by the U.S. Post Office as "return to sender" (due to reasons such as retired, deceased, moved out of state etc.), and 179 or 32% were returned apparently complete to use for analysis. Out of the 179 returned and apparently complete 15 were deleted due to partial responses, ambiguous responses, or other reasons. The resulting 164 responses or 29% were utilized for this analysis in a confirmatory factor analysis to determine the extent to which the OV perceptions of interpretability, plausibility, importance, and discontinuity affect the perceptions of EMR technology by small, independent physician practices.

Of the physicians responding to the survey, the majority (63%) of physicians operates an urban practice (in Honolulu), 26% operate suburban practices, and 11% operate rural practices (on neighbor islands or rural parts of Oahu). About 23% operate more than one office location or work in a clinic as well as in their own office(s). The majority (57%) have patient panels of less than 4000, indicating both the small size of practices and the predominance of solo practices. Respondents covered a wide range of medical specialties with most in general practice, family practice, internal medicine, or pediatrics. This distribution of practice demographics is consistent with the overall make-up of the independent physician association membership.

The OV items used in this study were adapted from Ramiller and Swanson (2003) by placing them in the context of healthcare in general and EMR technology in particular. A draft of the survey was discussed with a number of healthcare experts to elicit feedback on wording and format. The healthcare experts included the executive director of the independent physicians association; the Chair, Care Improvement Committee of the independent physicians association; members of the Health Information Management Systems Society (HIMSS), Hawaii Chapter; a registered nurse familiar with HIT and EMRs; and, a colleague who had prior research and publication experience in HIT and EMRs. Comments and suggestions from these individuals contributed to updating the survey with respect to improving survey question wording and formatting issues. A comparison of questions as originally used in the Ramiller and Swanson (2003) factor analysis and as adapted for this paper is illustrated in the Appendix.

A copy of the updated draft of the survey was subsequently administered to two practicing independent physicians (results from these two physicians were not included in the survey results) where additional feedback was obtained to include the approximate time to complete the survey. In particular, the two physicians were asked to help support the development of the survey by accomplishing the following:

Complete the survey as they would if the answers affected their unique independent practice (not as an individual and not as a staff member of a Hospital or other large scale healthcare institution);

Identify any questions that were so ambiguous or nebulous that they needed rewording;

Write-in questions or comments that they felt were important to include but were not addressed in the given survey question format;

Provide feedback with respect to the overall appropriateness of the types of questions, number of questions, and approximate survey length i.e., time to complete the survey

Feedback from the individuals identified above were subsequently incorporated into the final version of the survey

FINDINGS

In this section the results of the survey of physicians' perceptions of the EMR organizing vision and findings from a confirmatory factor analysis are presented. In addition, content validity was maximized using an iterative process in developing the questionnaire. Prior use of the OV dimensions and subsequent experts' opinions in the development stage of the survey helped to refine the questionnaire. Also, validity and reliability were strengthened by using an extensive literature review of surveys in healthcare in general and prior OV research in particular to help develop the wording of the questionnaire and by perfecting the questionnaire using feedback from the two physicians identified earlier. For example, previously validated instruments concerning various aspects of EMR adoption and use were reviewed such as: attitudes toward implementation of an EMR (Jacob, 2003); effects on patient care (Marshall & Chin, 1998); measurement of physicians' use of, knowledge about, and attitudes toward computers (Cork, Detmer, & Friedman, 1998); EMR use and outpatient encounters (Gadd & Penrod, 2001, 2000; Penrod & Gadd, 2001); users vs. nonusers of EMRs (Loomis, Ries, Saywell, & Thakker, 2002); and, family practice residents perspective on use of EMRs (Aaronson, Murphy-Cullen, Chop, & Frey, 2001). Reviewing these previously validated instruments helped with rewording the original questions used by Swanson and Ramiller (2003) to the wording of the questions used in this study (see Appendix).

Factor Analysis

Confirmatory factor analysis (CFA) requires *a priori* designation of plausible factor patterns from previous theoretical or empirical work. These plausible alternative models are then explicitly tested statistically against sample data (Comrey & Lee, 1992). As such, following prior exploratory factor analysis work of Ramiller and Swanson (2003) and using communality estimates of one, a principal axis factor analysis was run using SPSS (version 14) to determine the legitimacy of the underlying structure of the OV model based on eighteen OV items. Responses to items 2, 4, 6, 7, 11, and 13 were reverse-coded (rc) prior to conducting the factor analysis so that the item under study would contribute in a consistent positive way to the survey coding category with which it was initially associated.

Table 1 presents the detailed results of the factor analysis. Anti-image, KMO, Bartlett's test of sphericity, and a scree plot were obtained and Varimax was used for the group method. These selections were used to produce a solution using principal axis factoring extraction, which was then given a Varimax rotation. Eigenvalues of the correlation matrix were obtained in both table and scree plot form. Consistent with the research model and prior OV research by Ramiller and Swanson (2003), a four factor solution was chosen for analysis. The Kaiser-Meyer-Olkin Measure of Sampling Adequacy measured 0.829, relatively high, so a factor analysis is indeed useful with the data. Bartlett's test of sphericity in this case was Sig. = 0.000, so the variables in this study are related and therefore suitable for structure detection.

In this analysis four factors in the initial solution have eigenvalues greater than 1 and together accounted for almost 56% of the variability in the original variables and this indicates that four latent influences are associated with the data. The Extraction Sums of Squared Loadings indicates the variance explained by the extracted factors before rotation such that the cumulative variability explained by the requested four factors in the extracted solution is about 44%, a difference of 12% from the initial solution. Thus, 12% of the variation explained by the initial solution is lost due to latent factors unique to the original variables and variability that simply cannot be explained by the proposed factor model. Cronbach's alpha in

Table 1. Rotated factor matrix

OV Variable	Question	Factor 1	Factor 2	Factor 3	Factor 4
Interpretability	1 Useful information on what EMRs can do is easy to come by.	0.240	0.129	0.080	**0.679**
Interpretability	2 Finding a good balance of information on the pros and cons of EMRs is difficult. [rc]	-0.187	0.596	0.015	0.245
Interpretability	3 Key players in physician professional associations (AMA, AAFP, etc) have been heard loud & clear concerning EMRs.	0.303	-0.021	-0.029	0.435
Interpretability	4 There are aspects of EMRs that you cannot easily grasp. [rc]	0.004	**0.622**	0.086	0.122
Plausibility	5 EMRs will be adopted and used by independent physician practices faster than many people seem to think.	0.534	0.100	0.033	-0.076
Plausibility	6 A lot of what I've heard about EMRs seems like exaggerated claims. [rc]	0.217	**0.630**	0.227	-0.131
Plausibility	7 What EMRs really consist of is widely debated. [rc]	0.130	0.550	0.305	-0.053
Importance_BB	8 EMRs offer a tremendous opportunity to deliver value to a practice.	**0.791**	0.030	0.280	0.268
Importance_BB	9 EMRs make doable some wonderful things that were previously only dreamed of.	**0.692**	-0.012	0.065	0.278
Importance_BB	10 A practice that waits too long to use an EMR is going to fall behind its peers.	**0.722**	0.159	0.075	0.058
Importance_PA	11 The push for EMRs comes mainly from parties with something to sell. [rc]	0.163	0.509	0.271	0.020
Importance_PA	12 EMRs are solutions that have found the right problems to solve.	**0.601**	0.219	0.122	0.251
Importance_PA	13 EMRs don't transfer well to the real world. [rc]	0.204	0.454	0.402	0.029
Importance_MI	14 The health care market still has a considerable interest in EMRs.	0.489	-0.134	-0.057	0.062
Discontinuity	15 EMRs call for a fundamentally different way of thinking about a private practice from clinical perspectives.	0.202	-0.261	-0.193	-0.208
Discontinuity	16 EMRs seem to require some kind of health information technology wizard to get it all to work out. [rc]	0.042	-0.383	**-0.675**	-0.048
Discontinuity	17 Using EMRs basically turns a private practice upside down.	-0.180	-0.224	**-0.697**	-0.047
Discontinuity	18 Complexity of running a private practice decreases significantly when an EMR is implemented.	0.385	0.141	0.254	0.240

continued of following page

Table 1. continued

BB=Business Benefit PA=Practical Acceptance MI=Market Interest	Extraction Method: Principal Axis Factoring. Rotation converged in 9 iterations.	

this study measured 0.698 and is considered acceptable at the general level of 0.70 (rounded).

Interpretation of Factors

In essence, a factor analysis seeks to answer two basic questions: How many underlying variables, or factors, are there? What are the factors? (Kerlinger & Lee, 2000, p. 828). In general the data analyzed here support the findings outlined in Ramiller and Swanson (2003) of four factors. In particular, in selecting a threshold value of 0.600 for factor loading criterion, *Interpretability* reflects how intelligible and informative the independent physician practice finds the representations of the OV. As Table 1 indicates, *interpretability* seems to correlate with Factor 4 and with item 1 with factor pattern coefficient of 0.679.

Plausibility complements interpretability. That is, both support qualities of the community discourse that builds and sustains the OV. The difference is that interpretability concerns the intelligibility and informativeness of the discourse whereas plausibility focuses on distortions in the discourse. Plausibility further emphasizes the burdening of the OV with misunderstandings, exaggerations, and misplaced claims. As Table 1 indicates, *plausibility* seams to correlate with Factor 2 and with item 6 with factor pattern coefficients of 0.630.

Importance brings together a diverse set of judgments exemplified by the three sub-dimensions of *business benefit*, *practical acceptance*, and *market interest*. As Table 1 indicates, *importance* seams to correlate with Factor 1 and with items 8, 9, 10, and 12 with factor pattern coefficients of 0.791, 0.692, 0.722, and 0.601, respectively.

Discontinuity consists of two dimensions. *Conceptual Discontinuity* indicates how great a conceptual departure does the OV pose to the independent physician practice whereas *Structural Discontinuity* indicates how difficult would it be for the independent physician practice to actually implement the technology. As Table 1 indicates, *discontinuity* seams to correlate with Factor 3 with items 16 and 17 with factor pattern coefficients of -0.675 and -0.697.

In general, a simple or clean factor structure is evident when each item in a factor analysis loads highly on one factor and lowly on other factors. Discounting for the 0.600 threshold value for factor loading criterion and utilizing a 0.400 threshold, clearly the data here suggest that the OV construct of *interpretability* appears to load on both Factors 2 and 5; *plausibility* appears to load on both Factors 1 and 2; *importance* appears to load on Factors 1, 2, and 3; and, *discontinuity* appears still to load on just Factor 3. This less than pure factor structure may be explained by the fact that this survey was the first attempt at applying the OV to a healthcare information technology innovation. As such, subsequent research may yield a simpler, or cleaner, factor structure.

Descriptive Analysis of the Survey

For each of the 18 OV Likert scale-based items (Babbie, 2005) used in the survey, the corresponding OV dimension, number, and percent of respondents are indicated in Tables 2 thru 5.

Table 2. Survey items on Interpretability **(***numbers vs. % where 1=strongly disagree vs. 7=strongly agree and status with respect to basic premise of the item i.e., disagree, neutral, or agree)*

ITEM (QUESTION NUMBER AND STATEMENT)	**STATUS**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Total**
1 Useful information on what EMRs can do is easy to come by.		8%	9%	23%	**26%**	18%	12%	5%	100%
Mean 3.9 Median 4 Mode 4 Disagree 65 v. Agree 57	Disagree	13	14	38	**42**	29	20	8	164
2 Finding a good balance of information on the pros and cons of EMRs is difficult. [rc]		5%	5%	15%	18%	24%	**26%**	7%	100%
Mean 4.6 Median 5 Mode 6 Disagree 41 v. Agree 93	Agree	9	8	24	30	39	**43**	11	164
3 Key players in physician professional associations (AMA, AAFP, etc) have been heard loud & clear concerning EMRs.		9%	16%	24%	**27%**	15%	5%	4%	100%
Mean 3.5 Median 4 Mode 4 Disagree 80 v. Agree 39	Disagree	14	27	39	**45**	24	8	7	164
4 There are aspects of EMRs that you cannot easily grasp. [rc]		7%	5%	15%	18%	18%	**23%**	13%	100%
Mean 4.5 Median 5 Mode 6 Disagree 46 v. Agree 89	Agree	12	9	25	29	30	**38**	21	164

Table 3. Survey items on Plausibility **(***numbers vs. % where 1=strongly disagree vs. 7=strongly agree and status with respect to basic premise of the item i.e., disagree, neutral, or agree)*

ITEM (QUESTION NUMBER AND STATEMENT)	**STATUS**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Total**
5 EMRs will be adopted and used by independent physician practices faster than many people seem to think.		13%	18%	18%	**24%**	12%	12%	4%	100%
Mean 3.5 Median 4 Mode 4 Disagree 80 v. Agree 45	Disagree	21	30	29	**39**	20	19	6	164
6 A lot of what I've heard about EMRs seems like exaggerated claims. [rc]		3%	6%	12%	**27%**	26%	18%	9%	100%
Mean 4.5 Median 5 Mode 4 Disagree 35 v. Agree 85	Agree	5	10	20	**44**	42	29	14	164
7 What EMRs really consist of is widely debated. [rc]		2%	5%	10%	**39%**	21%	13%	9%	100%
Mean 4.5 Median 4 Mode 4 Disagree 29 v. Agree 71	Agree	4	8	17	**64**	35	21	15	164

Table 4. Survey items on <u>*Importance*</u> **(***numbers vs. % where 1=strongly disagree vs. 7=strongly agree and status with respect to basic premise of the item i.e., disagree, neutral, or agree)*

ITEM (QUESTION NUMBER AND STATEMENT)	STATUS	1	2	3	4	5	6	7	Total
8 EMRs offer a tremendous opportunity to deliver value to a practice.		7%	8%	10%	13%	**25%**	24%	13%	100%
Mean 4.6 Median 5 Mode 5 Disagree 41 v. Agree 101	Agree	11	13	17	22	**41**	39	21	164
9 EMRs make doable some wonderful things that were previously only dreamed of.		4%	7%	5%	13%	**31%**	28%	11%	100%
Mean 4.9 Median 5 Mode 5 Disagree 27 v. Agree 115	Agree	7	11	9	22	**51**	46	18	164
10 A practice that waits too long to use an EMR is going to fall behind its peers.		8%	13%	16%	15%	**23%**	16%	9%	100%
Mean 4.2 Median 4 Mode 5 Disagree 61 v. Agree 79	Agree	13	21	27	24	**38**	26	15	164
11 The push for EMRs comes mainly from parties with something to sell. [rc]		3%	4%	12%	**26%**	19%	24%	12%	100%
Mean 4.7 Median 5 Mode 4 Disagree 32 v. Agree 89	Agree	5	7	20	**43**	31	39	19	164
12 EMRs are solutions that have found the right problems to solve.		5%	9%	21%	**29%**	23%	12%	1%	100%
Mean 4.0 Median 4 Mode 4 Disagree 58 v. Agree 59	Neutral	9	14	35	**47**	37	20	2	164
13 EMRs don't transfer well to the real world. [rc]		6%	12%	18%	**26%**	16%	16%	6%	100%
Mean 4.0 Median 4 Mode 4 Disagree 60 v. Agree 62	Neutral	10	20	30	**42**	26	26	10	164
14 The health care market still has a considerable interest in EMRs.		2%	1%	2%	13%	26%	**43%**	13%	100%
Mean 5.4 Median 6 Mode 6 Disagree 8 v. Agree 134	Agree	3	1	4	22	42	**70**	22	164

Table 5. Survey items on <u>*Discontinuity*</u> **(***numbers vs. % where 1=strongly disagree vs. 7=strongly agree and status with respect to basic premise of the item i.e., disagree, neutral, or agree)*

ITEM (QUESTION NUMBER AND STATEMENT)	STATUS	1	2	3	4	5	6	7	Total
15 EMRs call for a fundamentally different way of thinking about a private practice from clinical perspectives.		6%	12%	18%	23%	**24%**	12%	5%	100%
Mean 4.0 Median 4 Mode 5 Disagree 60 v. Agree 67	Agree	10	20	30	37	**40**	19	8	164
16 EMRs seem to require some kind of health information technology wizard to get it all to work out. [rc]		4%	12%	15%	13%	**30%**	18%	8%	100%
Mean 4.4 Median 5 Mode 5 Disagree 52 v. Agree 91	Agree	7	20	25	21	**49**	29	13	164
17 Using EMRs basically turns a private practice upside down.		5%	15%	**21%**	21%	19%	11%	7%	100%
Mean 3.9 Median 4 Mode 3 Disagree 69 v. Agree 61	Disagree	9	25	**35**	34	31	18	12	164
18 Complexity of running a private practice decreases significantly when an EMR is implemented.		12%	18%	18%	**25%**	16%	10%	1%	100%
Mean 3.5 Median 4 Mode 4 Disagree 78 v. Agree 45	Disagree	19	30	29	**41**	26	17	2	164

That is, item number 1 “Useful information on what EMRs can do is easy to come by” falls under the Interpretability OV dimension. This OV item yielded 42 or 26% of respondents indicating neither disagreement nor agreement and 38 or 23% indicating somewhat agree. In addition, Tables 2 thru 5 also indicate an overall general summary measurement of respondents’ status with respect to the basic premise of the item i.e., disagree, neutral, or agree. To illustrate, with respect to item number 1 under interpretability, respondents generally disagree that useful information on what EMRs can do is easy to come by. That is, discounting the 42 neutral responses of choice #4, there were 65 disagree responses (sum of choices #1, #2, and #3) versus 57 agree responses (sum of choices #5, #6, and #7) yielding a slight overall disagreement with the premise of item number 1. Likewise, for item number 2, respondents agree that finding a good balance of information on the pros and cons of EMRs is difficult; for item number 3 respondents disagree that key players in physician professional associations (AMA, AAFP, etc) have been heard loud & clear concerning EMRs; and, for item number 4, respondents agree that there are aspects of EMRs that you cannot easily grasp. These results are important because they are consistent with prior research in that physician practices identified the following variables as sources of information when conceptualizing the EMR: relying on a uniform set of sources to obtain information on EMRs; reviewing the literature; attending conferences or trade shows; consulting respective specialty societies (e.g., AAFP); speaking with peers and colleagues; and visiting independent or reference sites (Rippen, 2006).

With respect to plausibility, respondents generally disagree that EMRs will be adopted and used by independent physician practices faster than many people seem to think; agree that a lot of what they've heard about EMRs seems like exaggerated claims; and agree that what EMRs really consist of is widely debated. These results are consistent with prior research in that physician practices identified a lack of robust empirically derived evidence on the costs and benefits associated EMR adoption and existing cost-benefit studies based on simulation models that rely on expert opinion and extrapolation from literature sources as reasons to doubt the plausibility of EMR success (Rippen, 2006).

With respect to the business benefit of importance, respondents to this survey agree that in theory EMRs offer a tremendous opportunity to deliver value to a practice, that EMRs make doable some wonderful things that were previously only dreamed of, and that a practice that waits too long to use an EMR is going to fall behind its peers. These results are of value because they are consistent with prior research in terms of perceptions of business variables in the adoption and implementation of EMRs. For example, Rippen (2006) found that for small physician offices, major perceived barriers to EMR implementation include lack of capital investment, maintenance costs, complex contracts, and lack of time whereas major perceived benefits to EMR implementation include improved charge capture, reduced transcription costs, reduced staff expenses, and increased revenues. With respect to practical acceptance of importance, respondents to this survey agree that the push for EMRs comes mainly from parties with something to sell. However, respondents are neutral about EMRs as solutions that have found the right problems to solve and their transfer to the "real world." These results are significant because they are consistent with prior research in terms of experience in actual practice with respect to EMR adoption. For example, Cimono et al. (1999) identified issues of cognitive overload, disorientation, and blind acceptance of information and recommendations from an EMR as barriers to effective adoption. With respect to the market interest of importance, respondents to this survey agree that the health care market still has a considerable interest in EMRs. This result is important because it is consistent with prior research as indicated by the level of general interest in the physician community in wireless access to EMRs. That is, a Medical Records Institute survey indicates increased use of WiFi, WWAN (digital and analog), and WPAN wireless connectivity, with WiFi most used (Medical Records Institute, 2007).

With respect to discontinuity, respondents agree that EMRs call for a fundamentally different way of thinking about a private practice from clinical perspectives and that EMRs seem to require some kind of health information technology wizard to get it all to work out but disagree that using EMRs basically turns a private practice upside down or that complexity of running a private practice decreases significantly when an EMR is implemented. These findings are supported by prior research that indicates that the combination of increasingly sophisticated functionality, including improved user-interfaces, increasing numbers of successful implementations, growing consumer expectations for information accessible via computer-based systems, and increased physician (i.e., end-user) awareness of functionality and benefits must occur before more widespread adoption of EMRs will take place (Meinert, 2005).

Interpretation of Survey Items

With respect to interpretability, item responses indicate that stakeholders (i.e., governmental agencies, insurance companies, software vendors, training companies, and professional organizations etc.) need to do a better job at presenting the representations of the EMR before an independent physician practice would find the OV clear, consistent, rich, and balanced enough to adopt an EMR.

For example, the U.S. Government could provide more support to the independent physician practice other than merely stating that by computerizing health records, dangerous medical mistakes can be avoided, costs can be reduced, and care can be improved (WHSOU, 2004). Likewise, insurance companies could do more to better present the overall benefit to physicians of using an EMR as many physicians perceive the practical benefits of using an EMR favor insurance companies and not the physician practice (Guadagnino, 2005).

Results also indicate that stakeholders need to do a better job at communicating the apparent validity (plausibility) of the EMR concept before a practice would find the misunderstandings and exaggerations of the OV minimized enough to adopt an EMR. Whereas results indicate that physician practices basically find the OV influential (important), results are some-what mixed on discontinuity. That is, the OV poses a significant conceptual departure from existing mental schemas, and respondents are split on how much difficulty the OV suggests in actually adopting an EMR.

Additionally, although the physician practices surveyed appear to find EMRs important, stakeholders need to do a better job increasing physician practice perceptions of interpretability and plausibility while decreasing discontinuity. That is, a key aspect of an OV is the career over which it varies substantially in visibility, prominence, and influence. The data here suggest that the concept of an OV is still in the process of shaping the opinions of the key IT decision maker in independent physician practice organizations. That said the data do help to clarify the extent to which an OV on EMR technology has attained importance in this physician community. In fact, it is suggested that as the career of the OV progresses to a point of strongly positive perceptions held by physician practices then many of the apparent barriers to adoption and assimilation of EMRs would dissipate and more physician practices would ultimately adopt and use an EMR.

LIMITATIONS OF CURRENT RESEARCH

Dillman (2000) cites four sources of survey error: measurement, sampling, coverage, and nonresponse. Measurement error is the result of poor question wording or questions presented in a way that either inaccurate or un-interpretable answers are obtained. By obtaining feedback on survey questions from professionals in the field such as physicians and other healthcare professionals it is believed that the potential for measurement error has been reduced.

Sampling error is the result of surveying only some, but not all, elements of the survey population. The unit of analysis in this research was the independent physician practice in one state in the United States. Physicians in Hawaii may differ in significant ways from physicians in other states, such as ethnic makeup of the population and percentage of small practices. The state has approximately 4,000 practicing physicians. Approximately 780 of these physicians belong to the independent physicians association (IPA) surveyed. This IPA is not representative of all physicians in Hawaii, but it is believed that this group is typical of the adopter population in this study.

Coverage error is the result of not allowing all members of the survey population to have an equal or known nonzero chance of being sampled for participation in the survey. All IPA member contact information was available for use and given that only 32 out of 567 surveys, or 6%, were returned by the U.S. Postal Service as “return to sender” it is believed this return rate limits the potential for coverage error.

Non-response error is the result of individuals who respond to the survey who are different from sampled individuals who did not respond, in a way relevant to the study. It was not possible to assess demographic differences within the practice association among respondents and non-respondents. The rate of EMR adoption reported by the respondents (24%) suggests a slight bias towards EMR adopters, compared to national surveys of EMR adoption rates. Thus, the data may present a more positive reception for the EMR OV.

In addition, the survey asked that the physician most responsible for making decisions concerning the IT used in the practice complete the survey. At the end of the survey a question asked who actually completed the survey. Response categories and corresponding number of respondents are: physician (149), nurse (1), office manager (9), office staff member (2), IT staff member (1), and other (2). Following up with those practices where a practice member other than a physician completed the survey, responses indicated that each such practice discussed the survey with the physician members so the responses on the survey are considered representative of the views of the physician members and hence the organizations. In addition, in no instance were multiple surveys submitted by a single practice as each individual member and each practice grouping were clearly identified prior to mailing of the survey and each survey was numbered to indicate recipient. Finally, confirmatory factor analysis results should be taken with a grain of salt (Dillman, 2000) as the criteria used to evaluate overall goodness-of-fit and model design are relative, not absolute--there simply are really no well-defined cutoff values for evaluating model data fit or even the existence of higher-order constructs.

FURTHER RESEARCH

It is suggested that the OV for EMRs is a work in progress in motivating the physicians sampled in this study to overcome their hesitance to adopt in the face of very practical barriers like up-front investment costs (Groves, 2007). The 18 item survey developed in this research may be useful for additional assessments of physicians' perceptions of EMR technology and to evaluate whether the "career" of the EMR OV is progressing towards greater acceptance or is declining towards skepticism i.e., as measured by degree of agreement or disagreement with the various OV questions. In addition, further refinement of the questions may be needed to produce a more factorially pure model. That is, the questions used for this survey were adapted from Ramiller and Swanson (2003) as the Appendix illustrates. Those original questions were developed by Swanson and Ramiller for information technology managers and general information technologies i.e., computer-aided software engineering (CASE), client-server computing, and electronic commerce. As the present survey concerns a health information technology, the EMR, and as the present survey was directed at non-information technology managers i.e., physician practices, it is suggested that perhaps some of the questions may not translate very well to the healthcare setting. It could turn out that questions concerning cost to include acquisition and on-going maintenance, workflow performance, and treatment outcomes might weigh more heavily than those questions as posed in the current research. Further exploration of these issues might yield a better crafted survey in which to elicit perceptions of an OV for EMRs by physician practices.

Despite some shortcomings in the survey items themselves, overall survey results are expected to be useful in the next steps of investigating the adoption and assimilation of EMRs by small independent physician practices. That is, a logical next step is to consider whether the physicians' reception of the EMR OV predicts the likelihood of actually adopting an EMR. This may be accomplished in two ways. First, an analysis indicating if a positive perception along any of the OV dimensions is significantly associated with the organization's decision to adopt an EMR. Further research could indicate if there is a significant relationship between an OV dimension and a practice's adoption of an EMR. Second, further analysis may reveal if any of the OV dimensions is associated with the physician's stage of assimilation i.e., actual use, of an EMR. To illustrate, assimilation may be defined as a scale from awareness, thru interest, active investigation, and preliminary adoption, to full assimilation (Fichman & Kemerer, 1997; Cooper & Zmud 1990; Meyer & Goes, 1988; Ettlie, 1980). Identifying a scale of assimilation is important because one needs to differentiate between the mere adoption of a technology and the actual use of that technology. For example, Fichman and Kemerer (1999) developed a general operational measure derived from the difference between cumulative IT acquisition and deployment patterns to introduce the concept of *assimilation gap* i.e., the difference between mere IT acquisition and actual deployment of that IT. Fichman and Kemerer observed that cumulative adoption patterns vary depending on which event in the assimilation process, acquisition or deployment is considered the actual adoption event. This concept of assimilation gap suggests that although 20% of the overall general physician population in the U.S. may have indicated they have acquired EMRs (iHealthBeat, 2005), this does not necessarily imply widespread assimilation as there is no research (theory-based or otherwise) indicating to what extent actual deployment of EMRs has occurred. Therefore, the concept of assimilation gap is of value because there is the danger that mere EMR adoption statistics might equate to deployment thereby yielding an incorrect and inaccurate picture of overall EMR system usage.

Finally, although this research suggests that the analysis of the perception of the EMR OV provides useful insight into the perceptions of EMRs among small physician practices, it is recognized that many other factors are also influential. For example, additional research may investigate whether small practices differ significantly in terms of their ability to overcome the learning barriers that EMR adoption represents, and if so, whether the development of community resources can assist physician practices that are not as adept as the minority of practices that have successfully integrated EMR use into their clinical practices. It is believed that the EMR OV may play a role in this process, as the community discourse represents an important resource of composite learning and experience with EMR implementation developed within the discourse community.

CONCLUSION

In the U.S., there is increasing regulatory and economic pressure on healthcare providers to adopt health information technologies to address such issues as cost, quality and access to healthcare. It is believed that the adoption of health information technology in general and electronic medical records in particular by small physician practices is a key step to achieving such goals. However, potential adopters have been slow to embrace EMRs (Havenstein, 2006; Loomis, 2002). This research used a survey of physician members of an independent physicians association. The target sample was representative of independent physician practices in the state. Individuals from this group responded to a questionnaire adapted from prior organizing vision research (Ramiller and Swanson, 2003). Confirmatory factor analysis was applied to the resulting data set and yielded a four factor model consisting of interpretability, plausibility, importance, and discontinuity and results are consistent with prior organizing vision research by Ramiller and Swanson (2003). A descriptive analysis of these four constructs indicates that the organizing vision for EMRs is still working its way through the target population. That is, for interpretability, although respondents agree that finding a good balance of information on the pros and cons of EMRs is difficult and that there are aspects of EMRs that you cannot easily grasp, respondents disagree that useful information on what EMRs can do is easy to come by and that key players in physician professional associations (AMA, AAFP, etc) have been heard loud & clear concerning EMRs. For plausibility, respondents agree that a lot of what has been heard about EMRs seems like exaggerated claims and that what EMRs really consist of is widely debated, respondents disagree that EMRs will be adopted and used by independent physician practices faster than many people seem to think. For importance, although respondents agree that EMRs offer a tremendous opportunity to deliver value to a practice, that EMRs make doable some wonderful things that were previously only dreamed of, that a practice that waits too long to use an EMR is going to fall behind its peers, that the health care market still has a considerable interest in EMRs, and that the push for EMRs comes mainly from parties with something to sell, respondents are neutral that EMRs are solutions that have found the right problems to solve and that EMRs don't transfer well to the real world. For discontinuity, although respondents agree that EMRs call for a fundamentally different way of thinking about a private practice from clinical perspectives and that EMRs seem to require some kind of health information technology wizard to get it all to work out, respondents disagree that using EMRs basically turns a private practice upside down and that complexity of running a private practice decreases significantly when an EMR is implemented. Overall, results are significant because they illustrate that the perceptions of the organizing vision for EMRs are not quite yet fixed. That is, the notion that an organizing vision's career is by turns ascendant and descendant is tied to the level and tenor of the discourse surrounding it. In addition, an organizing vision's career is tied to a particular level of maturity i.e., a youthful and undeveloped vision may or may not achieve ascendance, whereas a older and established vision, once having achieved ascendance, ultimately faces decline. Against this broader life cycle, an organizing vision may also undergo smaller fluctuations in prominence i.e., multiple ups and downs, over its career (Ramiller & Swanson, 2003, p. 16).

In essence, results from this study address one aspect of the ways in which small physician practices respond to a community discourse, or organizing vision, related to EMRs. Empirical findings suggest that, among physicians surveyed, EMRs are now perceived as an important innovation for physician practices, but questions about the interpretability, plausibility and discontinuity of this innovation remain. It is hoped that this research contributes in practical ways to the effective utilization of IT in healthcare settings and to the refinement of theory-based information systems research applied in the healthcare industry.

REFERENCES

Aaronson, J. W., Murphy-Cullen, C. L., Chop, W. M., & Frey, R. D. (2001) Electronic medical records: the family practice resident perspective. *Family Medicine*, *33*(2), 128-32.

Ash, J. S., & Bates, D. W. (2005). Factors and Forces Affecting EHR System Adoption: Report of a 2004 ACMI Discussion. *Journal of the American Medical Informatics Association*, *12*(1), 8-12.

Ash, J. S., Gorman, P. N., Seshadri, V., & Hersh, W. R. (2002). Computerized physician order entry in U.S. hospitals: results of a 2002 survey. *Journal of the American Medical Informatics Association*, *11*(2), 95-99.

Babbie, E. R. (2005). *The Basics of Social Research*. Belmont, CA: Thomson Wadsworth, Publishers.

Broder, C. (2005). Speaker: Practice redesign, technology should go together. *Healthcare IT News*, April 4, 2005.

Burda, D. (2008).Transcript of Roundtable Discussion with Mike Leavitt, *Modern Healthcare*, May 12. Retrieved May 12, 2008, from http://modernhealthcare.com

Burt, C. W., Hing, E., & Woodwell, D. (2007). Electronic medical record use by office-based physicians: United States, 2005. *U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Health Statistics*, Hyattsville, MD. Retrieved February 27, 2007, from http://www.cdc.gov/nchs/products/pubs/pubd/hestats/electronic/electronic.htm

Callahan, J. (2007). EMR for the Small Practice: The EMR Conundrum. *MediNotes Corporation.* Retrieved April 13, 2008, from http://www.medinotes.com/content/pdf/whitepapers/The5CriticalSteps_FINAL0707.pdf

Chau, P. Y. K., & Hu, P. J. H. (2002). Investigating healthcare professionals' decisions to accept telemedicine technology: an empirical test of competing theories. *Information & Management*, 39(4), 297-311.

Chiasson, M., & Davidson, E. (2005). Taking industry seriously in information systems research. *MIS Quarterly*, *29*(4), 591-605.

Cimono, J. J., Teich, J. M, Patel, V. L., & Zhang, J. (1999). What is Wrong with EMR? (Panel Proposal). *American Medical Informatics Association*. Retrieved August 24, 2008, from http://acad88.sahs.uth.tmc.edu/research/publications/EMR.pdf.

Comrey, A. L., & Lee, H. B. (1992).*A first course in factor analysis*. 2nd Edition, Lawrence Erlbaum Associates, Publishers.

Cooper, R. B., & Zmud, R. W. (1990). Information technology implementation research: a technological diffusion approach. *Management Science*, *36*(2), 123-139.

Cork, R. D., Detmer, W. M., & Friedman, C. P. (1998). Development and initial validation of an instrument to measure physicians' use of, knowledge about, and attitudes toward computers. *Journal of the American Medical Informatics Association*, *5*(2), 164-176.

Cory, C., & Grossman, J. M. (2007). Clinical information technology adoption varies across physician specialties. *Center for Studying Health System Change*, Data Bulletin No. 34, September.

Currie, W. L. (2004). The organizing vision of application service provision: A process-oriented analysis. *Information and Organization*, *14*, 237-267.

Dillman, D. A. (2000).*Mail and Internet Surveys – The Tailored Design Method*. 2nd Edition, John Wiley & Sons, Inc.

Doolan, D. F., & Bates, D. W. (2002). Computerized physician order entry systems in hospitals: mandates and incentives. *Health Affairs*, *4*(21), 180-188.

Dykes, P. (2006). The impact of health information technology on the role of nurses & interdisciplinary communication final results/findings - survey result (3/1/2006). *Healthcare Information and Management Systems Society Analytics*, LLC, Chicago, IL. Retrieved February 27, 2007 from http://www.himss.org/ASP/ContentRedirector.asp?ContentID=65652.

Ettlie, J. E. (1980). Adequacy of stage models for decisions on adoption of innovation. *Psychological Reports, 46*, 991-995.

Fichman, R. G., & Kemerer, C. F. (1999). The illusory diffusion of innovation: an examination of assimilation gaps. *Information Systems Research*, *10*(3), 255-275.

Fichman, R. G., & Kemerer, C. F. (1997). The assimilation of software process innovations: an organizational learning perspective. *Management Science, 43*(10), 1345-1363.

Firth, D. R. (2001). The organizing vision for customer relationship management. *Proceedings of the 7th Americas Conference on Information Systems (AMCIS),* (pp. 834-840).

Gadd, C. S., & Penrod, L. E. (2001). Assessing physician attitudes regarding use of an outpatient EMR: a longitudinal, multi-practice study. *Proceedings of the American Medical Informatics Association Symposium*, (pp. 194-8).

Gadd, C. S., & Penrod, L. E. (2000). Dichotomy between physicians' and patients' attitudes regarding EMR use during outpatient encounters. *Proceedings of the American Medical Informatics Association Symposium*, (pp. 275-9).

Gans, D., Kralewski, J., Hammons, T., & Dowd, B. (2005). Medical groups' adoption of electronic health records and information systems. *Health Affairs*, *24*(5), 1323-33. Retrieved February 27, 2007, from http://www.himssanalytics.org/docs/WP_EMR_EHR.pdf

Groves, B. (2007). Physicians find cost a barrier to digitizing records. *EmpowerMed – EMRinsight*. Retrieved August 24, 2008, from http://emradvice.wordpress.com/2007/02/14/physicians-find-cost-a-barrier-to-digitizing-records/

Guadagnino, D. F. (2005) Growth of electronic medical records. *Physician's News Digest*, Retrieved August 18, 2008, from http://www.physiciansnews.com/cover/505.html

Havenstein, H. (2006).Costs slow adoption of E-health record systems. *Computerworld*, June 12.

Health and Human Services (HHS) (2008). Retrieved May 14, 2008, from www.hhs.gov/healthit

iHealthBeat. (2005). Study: Barriers to EMR Adoption Remain. *California Healthcare Foundation*, April 19.

Institute of Medicine (IOM) (2001). *Crossing the Quality Chasm: The IOM Health Care Quality Initiative*. The National Academies Press, Washington, D.C.

Jacob, D. (2003). *Adaptation of an instrument to measure attitudes toward the implementation of an electronic medical record*. A Thesis, Oregon Health & Science University, School of Medicine.

Johnston, D., Pan, E., & Middleton, B. (2002). Finding the value in healthcare information technologies. *Center for IT Leadership*, Partners HealthCare, Boston, MA.

Kerlinger, F. N., & Lee, H. B. (2000). *Foundations of Behavioral Research*, 4th Edition, Harcourt College Publishers.

Loomis, G. A. (2002). EMRs: Still not ready for prime time. *iHealthBeat*, California Healthcare Foundation, October 07.

Loomis, G. A., Ries, J. S., Saywell, R. M. Jr., & Thakker, N.R. (2002) If electronic medical records are so great, why aren't family physicians using them? *Journal of Family Practice, Jul, 51*(7), 636-41.

Marshall, P. D., & Chin, H. L. (1998) The effects of an electronic medical record on patient care-clinician attitudes in a large HMO. *American Medical Informatics Association Symposium*.

Medical Records Institute (2007). Medical Records Institute's Ninth Annual Survey of Electronic Medical Records Trends and Usage 2007. Retrieved August 24, 2008, from http://www.medrecinst.com/MRI/emrsurvey.html

Meinert, D. (2005). Resistance to Electronic Medical Records (EMRs): A Barrier to Improved Quality of Care in Issues. In B. Cohen (Ed.), *Informing Science and Information Technology*. Retrieved August 02, 2008, from http://proceedings.informingscience.org/InSITE2005/I41f100Mein.pdf

Menachemi, N., & Brooks, R. G. (2006). EHR and other it adoption among physicians: results of a large-scale statewide analysis. *Journal of Healthcare Information Management*, *20*(3), 79-87.

Meyer, A. D., & Goes, J. B. (1988). Organizational assimilation of innovations – a multilevel contextual analysis. *Academy of Management Journal* 31(4), 897-923.

National Institute of Standards and Technology (NIST) (2005). http://www.atp.nist.gov/atp/focus/iifhc.htm, Retrieved April 24.

Olson, L., Schneiderman, M., & Armstrong, R. V. (1993). Increasing physician survey response rates without biasing survey results. *Proceedings, SRMS, American Statistical Association*, (pp. 1036-1041).

Penrod, L. E., & Gadd, C. S. (2001). Attitudes of academic-based and community-based physicians regarding EMR use during outpatient encounters. *Proceedings of the American Medical Informatics Association Symposium*, (pp. 528-32).

Poon, E. G., Jha, A. K., Christino, M., Honour, M. M., Fernandopulle, R., Middleton, B., Newhouse, J., Leape, L., Bates, D. W., Blumenthal, D., & Kaushal1, R. (2006). Assessing the level of healthcare information technology adoption in the United States: a snapshot. *BMC Medical Informatics and Decision Making*, *6*(1).

Ramiller, N. C., & Swanson, E. B. (2003). Organizing visions for information technology and the information systems executive response. *Journal of Management Information Systems*, *20*(1), 13-50.

Rippen, H. (2006). Summary of the Findings Assessing the Economics of EMR Adoption and Successful Implementation in Physician Small Office Settings. Office of the Assistant Secretary for Planning and Evaluation, Health and Human Services. *Retrieved December 17, 2006, from www.hhs.gov/healthit/ahic/materials/meeting10/ehr/Rippen.ppt*

Schubart, J. R., & Einbinder, J. S. (2000). Evaluation of a data warehouse in an academic health sciences center. *International Journal of Medical Informatics*, *60*(3), 319-333.

Swanson, E. B., & Ramiller, N. C. (2004). Innovating mindfully with information technology. *MIS Quarterly*, *28*(4), December, 553-583.

Swanson, E. B., & Ramiller, N. C. (1997). The organizing vision in information systems innovation. *Organization Science*, *28*(5), 458-474, Sept-Oct.

Tang, P. C., & McDonald C. J. (2001). Computer-Based Patient-Record Systems. In E. H. Shortliffe, L. E. Perreault, G. Wiederhold, & L. M. Fagan (Eds.), *Medical Informatics - Computer Applications in Health Care and Biomedicine* (pp. 327-358). Springer-Velag, NY.

Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User acceptance of information technology: Toward a unified view. *MIS Quarterly*, *27*(3), 425-478.

WHSOU - White House State of the Union (2008). Retrieved April 23, 2008, from http://www.whitehouse.gov/stateoftheunion/2008

WHSOU - White House State of the Union (2007). Retrieved April 23, 2008, from http://www.whitehouse.gov/stateoftheunion/2007

WHSOU - White House State of the Union (2006). Retrieved February 3, 2005, from http://www.whitehouse.gov/stateoftheunion/2006

WHSOU - White House State of the Union (2005). Retrieved February 3, 2005, from http://www.whitehouse.gov/stateoftheunion/2005

WHSOU - White House State of the Union (2004). Retrieved December 2, 2005, from http://www.whitehouse.gov/stateoftheunion/2004

APPENDIX: COMPARISON OF SURVEY QUESTION CONSTRUCTION

Ramiller & Swanson (2003)	**Survey**
Interpretability	
1 Good information on ___ is hard to come by.	1 Useful information on what EMRs can do is easy to come by.
2 Finding a good balance of different perspectives on the ___ concept has proven difficult.	2 Finding a good balance of information on the pros and cons of EMRs is difficult. [rc]
3 Key players in the industry are yet to be heard from concerning ___.	3 Key players in physician professional associations (AMA, AAFP, etc) have been heard loud & clear concerning EMRs.
4 There are aspects of ___ that you can't really get your fingers on.	4 There are aspects of EMRs that you cannot easily grasp. [rc]
Plausibility	
5 ___ is not going to happen as fast as many people seem to think.	5 EMRs will be adopted and used by independent physician practices faster than many people seem to think.
6 A lot of what I've heard about ___ seems like hype.	6 A lot of what I've heard about EMRs seems like exaggerated claims. [rc]
7 What ___ really consist of is widely debated.	7 What EMRs really consist of is widely debated. [rc]
Importance	
8 ___ offer a tremendous opportunity to deliver business value.	8 EMRs offer a tremendous opportunity to deliver value to a practice.
9 ___ make do-able some wonderful things that were previously only dreamed of.	9 EMRs make doable some wonderful things that were previously only dreamed of.
10 The company that waits to do ___ is going to fall dangerously behind.	10 A practice that waits too long to use an EMR is going to fall behind its peers.
11 The push for ___ is coming mainly from parties with something to sell.	11 The push for EMRs comes mainly from parties with something to sell. [rc]
12 ___ is a solution still looking for the right problems to solve.	12 EMRs are solutions that have found the right problems to solve.
13 ___ doesn't transfer well to the real world.	13 EMRs don't transfer well to the real world. [rc]
14 The market has lost interest in ___.	14 The health care market still has a considerable interest in EMRs.
Discontinuity	
15 ___ calls for a fundamentally different way of thinking.	15 EMRs call for a fundamentally different way of thinking about a private practice from clinical perspectives.
16 ___ seems to require some kind of wizard to get it all to work out.	16 EMRs seem to require some kind of health information technology wizard to get it all to work out. [rc]
17 Doing ___ basically turns an organization upside down.	17 Using EMRs basically turns a private practice upside down.
18 Complexity increases significantly when you undertake ___.	18 Complexity of running a private practice decreases significantly when an EMR is implemented.

Note: Under the Ramiller & Swanson questions the "___" represents the following IT: CASE, client-server, and E-commerce.

This work was previously published in International Journal of Healthcare Information Systems and Informatics, Vol. 4, Issue 3, edited by J. Tan, pp. 16-37, copyright 2009 by IGI Publishing (an imprint of IGI Global).

Chapter 4.5

Providing Telemental Health Services after Disasters:

A Case Based on the Post-Tsunami Experience

Shashi Bhushan Gogia
S.A.T.H.I, AMLA MEDIQUIP and Indian Association for Medical Informatics, India

ABSTRACT

The role of information technology (IT) in managing disasters is increasingly being recognized. The Healing Touch project was started after the tsunami disaster in Tamilnadu to address the healthcare needs of the survivors through IT. Specifically, it provided mental health support to the victims near their place of residence. This project has been different from other telemedicine projects because:

- It was sponsored and managed entirely by NGOs.
- The local community and local NGOs were directly trained to manage there own health problems after the natural disaster.
- Success was linked to the intensive pre and post execution work done.

We believe that preparation and involvement of people is the key to success in most IT projects. Some problems we faced were related to a general lack of awareness and nonpenetration of IT in the community we served. If people are using IT in their day to day work, adoption of telemedicine and other e-services will be far simpler after a disaster.

DOI: 10.4018/978-1-60566-064-6.ch016

BACKGROUND

"E-Health will completely change health care," says Kendall Ho, who heads the U21 committee (http://www.innovations-report.com/html/reports/medicine_health/report-50033.html) for e-health. "It is one of the fastest-growing fields of health care today, giving undreamt-of opportunities for us to spread our medical knowledge to the whole world."

SATHI is a nongovernment organization (NGO) based in New Delhi and consists of experts from the fields of health, IT, and telecommunications. They provide consultancy services in the fields of telemedicine and healthcare informatics. Their members (see Acknowledgments for a list of the key persons) contribute to the projects on a voluntary basis, whereby SATHI tries to reimburse the actual costs incurred in managing the project. The idea of such varied professionals joining together was mooted in the realization that, at least in India, current practices and efforts in promoting telehealth and related services had not been very successful. SATHI felt that such technology showed great promise, but was providing less than desired outcomes. Important related aspects to this technology such as change management and capacity building and so forth were lacking. Probably a different approach was required.

SATHI was registered in 2004. The current report pertains to the very first project assignment of SATHI. It was named Healing Touch (Gogia & Surwade, 2006)

The Technology

The dictionary definition of *telemedicine* is the use of telecommunications technology to provide, enhance, or expedite healthcare services, as by accessing off-site databases, linking clinics or physicians' offices to central hospitals, or transmitting x-rays or other diagnostic images for examination at another site. *E-health*, however is a much more encompassing term. This has been defined by World Health Organization (WHO) as:

> *The delivery of healthcare services, where distance is a critical factor, by all healthcare professionals using information and communication technologies for the exchange of valid information for diagnosis, treatment and prevention of disease and injuries, research and evaluation, and for the continuing education of healthcare providers, all in the interests of advancing the health of individuals and their communities.*

Telemedicine was initially conceived to provide healthcare to space travelers, thereafter to extending healthcare facilities for the geographically hard-to-reach and the underserved, literally providing a virtual doctor to places where a physical presence is a problem. With time, telemedicine is becoming more widespread, less costly, and new applications are emerging. The technology has moved from expensive room-sized systems to the desktop personal computer, and now further to the Internet, as well as mobile phones and palm tops.

Healthcare in India

India, with its large population (1029 million in 2001), has vastly varied terrains. The range consists of deserts, coastal regions, tropical jungles, islands, and mountains (CIA, 2001). Roads and physical reach are a problem in many areas. 72.2% of India's population is rural (United Nations Economic and Social Commission for Asia and the Pacific, 2000), and this population is supplied by less than 30% of medical professionals. The ratio for specialized medical care is worse with less than 4% of specialists serving in rural areas.

Even while healthcare in India is free and the responsibility of the state, over 70% of the population prefers to pay for treatment as the actual availability of the facilities leaves much to be desired. To service this demand, rural areas are filled with healthcare workers without adequate training as most doctors having better qualification are unwilling to work in such places. There is a lack of adequate facilities for them to satisfactorily practice to the level of training imparted to them. Good schools for their children as well as social and entertainment facilities matching the standards of living which they are used to are also lacking.

While actual healthcare expenditure in India constitutes 5.2% of GDP (gross development product), as compared with 2.7% in China (WHO World Health Report, 2000), it is widely believed that it can go up to 15% of the budget of most families. In rural areas, much of the expenditure is wasted on the transportation to the nearest healthcare facility. Bringing down transportation costs, including the time wasted for travel, is the real boon which telemedicine can provide. Traditionally, in India any sick person is accompanied by three or four persons when he goes to a hospital. Thus, the time off work for them is an additional hidden cost.

Though not widely publicized, we have come to know that China has been doing teleconsultations for a long time mostly through telephone as well as other means using experts in the cities and a wide network of less qualified barefoot doctors present in the community (Dr. B.S. Bedi, personal communication, 2006). Telemedicine as a concept was designed to take care of health problems of space travelers (Garshnek, 1991) and first applied in a disaster situation after the Mexico earthquake (Garshnek & Burkle, 1999).

Setting the Stage

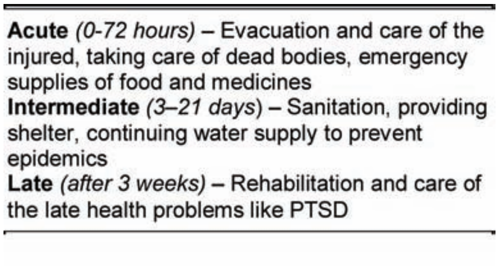
Telemedicine is a generic term but comes in various streams:

- **Between patient and doctor** which generally means a direct virtual consultation by the patient or his relative through e-mail or telephone.
- **Between a general practitioner** or any healthcare provider which could be an untrained village health practitioner or nurse (as the setting in this case) *and an expert*/specialist who happens to know more about a particular problem (see below).
- **Between specialists**. These are online discussion forums and user groups. The Association of Plastic Surgeons of India (APSI) runs an active discussion group (plastic_surgery@yahoogroup.com) where difficult and interesting cases are presented and the ensuing discussion helps the members to manage the patients with similar problems better.
- **Through e-learning programs**. Training and skill upgrading of healthcare workers can be provided online. Joshi (in press) cites that his organization provides education and training to parents on how to take care of spastic as well as disabled children.
- **Through home telemedicine**. Many gadgets are available which can monitor the elderly and infirm for problems and provide timely reminders for taking medicines.
- **By telerobotic surgery**, and so on,

The stream with the most relevance to developing countries is through improving the skills of any local healthcare practitioner with the expert. The average individual goes to her nearest medicine man whenever unwell. Generally, in India, for persons in rural areas and other far-flung places, the healthcare provider would be untrained and practicing medicine as per the family occupation or after working as an apprentice with a doctor for some time in a town.

80–90% of diseases are known to be self limiting or treatable by simple measures. However, since one would have taken advice, credit is provided to the health provider from whom the advice was taken, irrespective of whether the improvement was a result of, or in spite of, the advice. Thus, over time, faith, respect, and fame of varying degrees is achieved by any healthcare service provider whatever the qualification. Ensuring a licensing regime for such untrained persons is difficult to achieve due to the lack of suitable alternatives. However, in such a scenario, persons who have a genuine problem will suffer due to a delay in treatment and, occasionally, inappropriate treatment. A consultancy with the trained persons can help the local practitioner decide on what is to be done: Is local treatment possible?, its specifics, and if not, where and how to shift (Gogia, 2002). Each teleconsultation becomes an opportunity to interact with the specialist to learn more about the problem at hand and upgrading one's knowledge.

Figure 1. Phases of healthcare response after disasters; Use of IT can improve the outcome in all three.



Acute *(0-72 hours)* – Evacuation and care of the injured, taking care of dead bodies, emergency supplies of food and medicines
Intermediate *(3–21 days)* – Sanitation, providing shelter, continuing water supply to prevent epidemics
Late *(after 3 weeks)* – Rehabilitation and care of the late health problems like PTSD

The Tsunami Disaster

The worldwide response to the tsunami disaster on December 26, 2004 resulted in a massive outpouring of personnel, materials, and funds. Healthcare was felt as a primary need for the survivors.

Management of disasters is broadly categorized into four phases: preparedness, mitigation, response, and recovery (Warfield, 2007). The phase immediate after the disaster is the response phase which can be further subclassified (see Figure 1).

After any natural or man-made disaster, supplies, food, and so forth can be moved to the affected area, but disease and healthcare needs require specialized care which in most cases mean a reverse transfer.

Citing his experience after the Kashmir Earthquake of 2005, Patoli (2006) found telemedicine to be an effective method of helping the healthcare aspects of disasters. It can provide the specialists virtually to the affected area(s), overcoming time and geographical barriers. However, most studies in telemedicine in general and specifically in disasters have concentrated on the technology rather than the implementation. Shifting from a normal physical healthcare provision to a virtual availability is a significant change. This requires following change management principles and the key to SATHI's approach to this project.

Schiesser (2002) defines Change Management as "a process to control and coordinate all changes to an IT production environment."

Box 1. Telemedicine processes

There are two main forms of teleconsultations, the most common called **Store and Forward** technology.

In this, all medical records are stored electronically in a local database. On need for opinion, patients' records with all images and reports are transmitted normally during the night or hours of low telecommunication demand, although with current available technology of high speeds, such a restriction may be superfluous.

The other type is **Real Time** where dynamic active video conferencing or live data transfer takes place.

In a normal teleconsultation, a combination is used per need. Data are transferred beforehand and appointment set for a live session. In this, speech and eye contact for the patient provided online and reports are reviewed. Some questions are asked for clarification or even a possible online clinical examination may be done. Examples would be skin lesions sent through a digital or the VC camera, listening to heart sounds by using a digital stethoscope, asking the patient to walk, and so forth.

Thereafter, the patient may be asked to do some tasks as explained by the specialist or further tests may be requested. After that, the patient maybe provided a prescription online.

A referring doctor or the patient is then informed on what to do. Telecounseling, especially for psychiatric cases, is possible through VC.

Sometimes the patient may be asked to come to the expert center for a procedure. An appointment is given and problems and means of transfer explained. In emergency situations, preparations are made for receiving the patient.

According to Wikipedia (2007), change management is responsible for managing change process involving:

- Hardware
- Communications equipment and software
- System software
- All documentation and procedures associated with the running, support, and maintenance of live systems.

As will be shown later, this was the route SATHI followed and some of the problems faced were due to lack of maintenance support, failing hardware and software as well absent communication links—factors which were beyond our control or not managed well due to our inexperience in properly dealing with vendors, and so on.

Telemedicine is yet to be regarded as a primary tool in the management of disasters. However, many e-health experts (e.g., Mathew, 2004) have emphasized that IT will and can help disaster management, but much preparatory work is required.

While worldwide telemedicine programs have increased in number in hospitals, academic departments, managed care organizations, homes, schools, prisons, and so on, in India most efforts were limited to government organizations, the most prominent being ISRO (Indian Space Research Organization). Most of these efforts were to provide teleconsultations to persons in far-flung places However, the rural community, the one desperately in need of quality care, has so far been unable to reap the benefits. A perusal of the above Web site has shown that most linkages are

Box 2. List of activities performed by SATHI (further details in full text)

- **Preliminary planning** and design of project.

- Preliminary visit to the project area consisting of a **needs assessment survey**. This helped to identify the health problems faced by the survivors. An evaluation of the existing health system was also done for adequacy and possible areas of reinforcement.

A personal visit and interview of the identified NGOs who were potential partners, both in periphery as well as expert end, was done alongside with discussions with government functionaries.

These interviews were accompanied with **concept marketing and orientation** of the persons interviewed. A look into connectivity needs and how they could be fulfilled. Based on the visit report, the project was redesigned and a formal order the systems (hardware and software) was placed.

- **Create MOUs**. These were between the various identified partners of the project meaning OXFAM, SCARF, and other local NGOs.

- **Install the systems** in the identified locations. **Training** of the local persons who will manage the sessions, on how identifying the problem cases, running the systems, conducting the sessions, troubleshooting, and so on. Test sessions were held before a formal launch under SATHI's supervision as well as an engineering representative from the vendor.

- **Streamlining** of the project included setting and fine tuning protocols for identified problems and setting up the time table for the consultations, which was called TCS (telemedicine consultation session) time table.

- **Feedback** was obtained on a regular basis with reporting mechanisms in place.

- Outcome analysis, done by an outside agency, was planned at the outset as this was to be a pilot.

between district hospitals with referral hospitals. The tsunami had affected areas largely at the village and block level where any health services let alone technology was simply unavailable.

The tsunami disaster spurred SATHI, like many other organizations, to reach out to help those affected. With a basic guiding principle that "More people die of after-effects of natural disaster than the disaster itself," SATHI felt that telemedicine can and should provide a solution to control the "disaster after the disaster" through efficiency and greater reach of the health services on offer. SATHI offered its services to various organizations, stating that SATHI could provide data collection services as well as help in improving the health status in a sustainable manner. It received support from OXFAM Trust India, the Indian branch of OXFAM International wherein the SATHI would be providing consultancy to manage healthcare in the relief centres run by OXFAM and its sister organizations. OXFAM was also concerned with the mental affects of disasters having experienced during their rehabilitation efforts in previous disasters (Sharma, 2002).

SATHI was fortunate to get funding for the project with a relatively free hand. The project was to be treated as pilot which could show sustainability of telemedicine along with providing some immediate gains to the tsunami victims, an attempt to showcase the use of IT in healthcare after disasters.

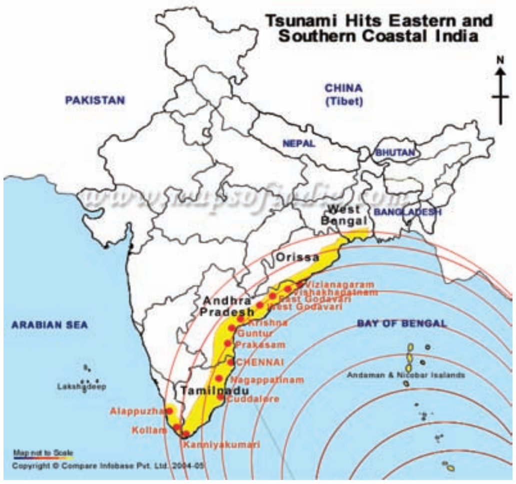
CASE DESCRIPTION

A summary of the procedures that follows is listed in Box 3.

Once the MOU was signed, a detailed plan to execute the project was drawn out. Preliminary discussions were done between OXFAM as well as the possible vendors of the hardware and software. BSNL (Bharat Sanchar Nigam Limited), the local telephone service provider in the area of concern, was identified as the resource for connectivity.

The **needs assessment** was done through a personal field visit to the affected areas in the second half of January 2005. This consisted of a survey of the affected areas where we analyzed the location-specific health needs and available health services provisions directly by the government or camps run by other NGOs. Our emphasis was to look for and thereon fill the gaps, if any. (Figure 2)

Figure 2. Map of areas affected by the Tsunami. Chennai was our main centre



Simultaneously, meetings were held with local NGOs to assess their willingness as well as capabilities to do the tasks required. Availability of connectivity was to be at a level which could ensure video conferencing (VC).

Box 3. IDSP program

The IDSP program is a World Bank funded project where the local health care workers collect door to door data pertaining to disease incidence and health status and then upload to a central server via a satellite link from the district centre. Nagapattinam district, after the tsunami, was the very first place to launch this program.

The needs assessment survey showed that as far as healthcare was concerned, the first and second phases of the disaster were well managed by the government and supporting NGOs in the areas visited (parts of Pondicherry and Nagapattinam district of Tamilnadu). Epidemiology and disease surveillance had already been activated in the entire district. This was part of an Integrated Disease Surveillance Program (IDSP) run by National Institute of Communicable Diseases (NICD), a central government organization.

However, a need for mental health support was found due to a high incidence of a sense of loss and bewilderment among the survivors who continued to be gripped with fear and a sense of shock. They were anxious, depressed, displaced from their homes, and had lost their family members and loved ones. Most were too frightened to rejoin their regular occupation of fishing. Alcoholism was rampant as well as mass panic reactions; we experienced one ourselves where we found the entire populace, vehicles, and even animals running away form the coast at a time of a particular high tide (see Box 4).

The people were ignorant about the tsunami: What was it? Will it strike again? How will we be prepared? How will we cope with its after effects?

The occurrence of this problem was articulated by WHO (The Hindu, 2005). Steps taken by the government for upgrading of mental health of the victims were found to be inadequate as well as wrongly directed. There was a mismatch between needs and services with an inadequate number of mental health specialists. A high incidence of stress and fatigue among relief workers with no community participation was also found.

As per the WHO reports, following disasters, 80–90% of the population have a lowered mental health status, a situation which would improve in most. However, 4–5% would be serious cases requiring specialist help. PTSD (post-traumatic stress disorder) and other serious mental problems manifest a few weeks after the disaster and the effects can last for up to 1–2 years in some cases.

The problem was in identifying the exact victims who would require specialized medical help. This meant a virtual door-to-door search on a repeated basis. Telemedicine was thought to be the right solution to these problems since it would allow the specialist to train the health workers, who being in the community could organize such searches better and on a continual basis to identify this 4–5%. This would ensure access to specialists' services for the real victims and would also ensure quality. Since health workers might themselves be affected, one could not rely on them alone without external specialist help.

The Healing Touch was conceptualized after the above assessment. Possible solutions were analyzed and specifics of the telemedicine network planned. Various possible additional partners and stakeholders were identified and an advocacy and orientation plan rolled out. This included concept

Box 4. Panic reaction in Vellangani

The village of Vellangani is a religious tourist spot with an ancient church on the sea coast. This church was flooded during the tsunami. During our visit there, we were at a villagers' residence around a kilometer from the coast. At around 5:00 p.m., we heard a loud noise outside and suddenly we were confronted by the entire population of the village, people, vehicles, and even animals running further inland yelling "*Thaneer Thaneer*" (Tamil for "water, water"). The most vivid image was of two teenage girls panting and running with eyes popping out.

The reason was later found to be a high tide.

We were told that such panic reactions had become a regular phenomena. Although the panic lasted only a few minutes, it was this single moment that made us decide to provide mental health support to the affected population.

marketing and social mobilization of additional NGOs and those who could contribute specialized mental health support.

Once the partnering NGOs were identified and found agreeable, Memoriam of Understandings (MOUs) between the various stakeholders, between OXFAM and local NGO, as well as between various NGOs themselves, were drafted and presented for formal signature.

During preliminary discussions, SATHI had planned for and thereby placed an initial order for complete telemedicine systems, with peripherals like scanners and the like. On reassessment, mental health support was found to be the sole healthcare requirement with all other healthcare needs of the tsunami victims already being well provisioned for by the government and other agencies. Disease surveillance was well in progress through IDSP. Thereby, the planned epidemiology module was found unnecessary. With funding becoming a problem, orders for the entire set of add-on peripherals like an ECG machine and scanner and other equipment were also shelved. A limited scope meant a more focused approach with a decreased need for orientation and capacity building. Thus, finally VC and basic data collection through an EMR (electronic medical record) module were selected as the components to be used.

The following were provided at each location:

1. Pentium II PC with Windows 2000 as OS and standard hardware prevalent at that time:
    - 256 MB RAM
    - 40 GB hard disk
    - External modem
    - Printer
2. Video-conferencing equipment was provided by the systems vendor which consisted of:
    - Add on VC card to the above PC
    - PC based VC camera
    - Multimedia speakers
    - PC microphone
    - Telephone type handset
3. EMR software was provided as part of the system. The entire system was a stand-alone self sufficient plug and play type, the vendor also sent its own engineer to train the community workers for usage.
4. USB (universal serial bus) and other relevant ports were provided for connectivity through external devices, modem, and ethernet card.
5. Regular power was a problem so a UPS (Uninterrrupted Power Supply) was provided. Option of a generator was left to the local NGO managing the system.

Connectivity add-ons were to be provided as per local availability. Possibilities were:

- **Satellite,** which could provide mobile connectivity and could reach all possible areas. Free satellite connectivity daily for one hour was promised for a month or so along with the relevant hardware (INMARSAT) through the equipment vendor who happened to have a relevant tie up with European Space Agency for the same. However, it did not happen as trials by them regarding VC had not been very successful with the INMARSAT equipment in a separate project in Sri Lanka. The only local provider of satellite connectivity was ISRO. After disappointment with INMARSATs, we petitioned ISRO, but could not get the requisite linkages. The quoted cost of satellite connectivity (Rs 60/approximately US $1.33 per minute as per 2005 currency rates) was a limiting factor. Connectivity costs were to be managed by the local NGO.
- **ISDN** (integrated switching data network) was found to be the low cost option wherein the average per minute cost was one local phone call (less than one U.S. cent per minute for every 64 Kbps connectivity). 128 Kbps was felt to be adequate for video

conferencing. ISDN connectivity, although promised by the local telephone company at all possible locations, was found to have limitations and could not be used wherever we desired. There were some limitations: The regional telephone exchange had to be electronic and capable of providing ISDN services, and the final location should require less than 2.5 Kms of wiring from the regional exchange. At some places, the exchange itself had been flooded. Therefore, provision of any land line service was expected to take time.

Table 1. Implementation details of various locations for the Healing Touch Project

Location	*Reasons*	*Outcome and Remarks*
Tharangammbadi	Largest rehabilitation colony in affected area with over 1000 families Local Taluk hospital in midst of rehabilitation colony Support from local NGO available (PEDA) Willing staff and doctors in the hospital	The first peripheral location where the equipment was installed. Local staff and doctors both from the Taluk (community) hospital as well as PEDA were trained. Later connectivity by ISDN was not found possible as the local exchange was too old. Attempts for reaching though satellite were also unsuccessful for reasons cited above. Finally the equipment was shifted out.
SCARF Chennai (Expert service provider)	Reputed mental health facility Voluntary organization already working in providing support to the Tsunami victims Willing and ample support from the director (Dr. R. Thara) and staff IT aware and knowledgeable staff No language problems	Equipment and staff were trained within a day of installation. This was in late February 2005. ISDN connectivity was provided on demand. SCARF sent its doctors and staff for its initial orientation and training to all peripheral locations. They have been a major contributor to the success of the program.
Dharmakulam	Support from local NGO (ISED) Part of affected area Connectivity possible	It was initially planned to install in the local government health facility (Thiruvengadu) but that was too far from the affected area. Thereafter a room was taken on rent near the affected area in Dharamkulam village near Poompuhar a noted tourism centre of Tamilnadu. ISDN connectivity took a long time and finally was made available only in May 2005. This centre has been successfully working since then. The mental needs are over after 79 teleconsultation sessions and 249 patients seen over 6 months. Two possible suicides have reportedly been prevented.
Kariakal	Support from local NGO (PEDA) Good connectivity options	Equipment promised for Tharangambaddi was eventually shifted here with management by the same local NGO. However, the decision to shift was taken late, as there had been hope of getting satellite connectivity through INMARSATs or ISRO in the previous location. Equipment and connectivity became available only by February 2006. This centre has been successfully working since then (see enclosed case report).
Seradure Village	Deeply affected area Supporting staff and orientation provided in the government health centre	Could not find a suitable local NGO to manage the project.
Kalpakkam, Akaripettai and many others	Affected area Exchange has ISDN capability	Late decision and funding limited though local NGOs were identified for some of these locations.
Sundaram Medical Foundation (SMF) (Expert Service Provider)	Super specialty medical facility in Chennai Works in close alliance with SCARF No language problems	Decision to limit the project as a pilot Consultations for nonmental health needs could be done by the doctors traveling to the SCARF centre nearby in the absence of their own telemedicine unit.
Various places in Nagapattinam	These were possible partners of the project for the expansion which did not take place.	Planned for mobile connectivity wherein a van hired or owned by the NGO would travel to the location at a fixed time and provide consultancy. Lack of satellite linkages shelved this approach.

- **Dial-up networking,** though possible at all places, was found to provide inadequate bandwidth as video conferencing was an essential component.
- **Mobile** connectivity was again found to provide inadequate bandwidth.
- **Broadband** Internet through ADSL (asynchronous digital subscriber link) was not yet prevalent in the affected areas, except in Chennai.
- **WiMax** similarly has still not become prevalent widely.

Finally, ISDN was decided to be the connectivity option of choice as it was the cheapest, could support video conferencing, and was available albeit at select locations. An application was placed with BSNL, the company providing telephone and ISDN services locally. Though connectivity on demand had been promised in view of the scale and emergent nature of the problem, actual delivery was delayed by a few months.

SATHI ascribed the delay to a poor initial understanding of the above requirements. In one place, considered ideal for provision of telemedicine services (Tharangammbadi), the equipment could not be utilized and had to be shifted elsewhere as ISDN connectivity was not possible. Associated training of personnel and preparation of the site got wasted (see Table 1).

The network provided counseling (through video conferencing for the victim) in the presence of the health worker. Individual and group sessions were possible. No traveling was required by the victims. The local volunteers were responsible for identifying the possible members of the community who required support after a short training course by a personal visit of the expert team to the field. A time and date for the counseling sessions was set and the volunteers held responsible for providing continuous learning and supervision on the job as well as on the spot.

A teleconference based training module was developed by SATHI. This was used for the orientation of the community health workers and experts. Hard copies were also made available for review. These were based on WHO recommendations with some separate guidelines for relief workers themselves affected directly or indirectly by the disaster.

Experts from SCARF, on their own, had arranged to travel to the affected areas before the start of the project to familiarize themselves with the persons whom they would be meeting through VC. The local volunteers were trained to identify mental health problems in the community and how to bring the more affected to the telecentre for direct teleconsultations with the experts. Initial sessions were managed in the presence of our representative or the engineer installing the systems. Later, on the job and continuous training using an innovative interactive and participatory training methodology supported through audiovisuals was made possible through VC.

Since SATHI is based in New Delhi, far from the affected area, the experts traveled to the affected area for planning and implementation spending over 40 days for the project planning and implementation. Many activities and online discussions took place later through VC from its office with the project partners at the peripheral as well as expert locations.

*Box 5. Health systems in Indi*a

In India the health system is structured according to the Bhore Committee report (1948) wherein the basic health services are provisioned at the primary, or community, level through PHCs (primary health centres) and their subcentres who refer, if required, to the secondary level (district and Taluk hospitals) and thereafter for specialty services to the tertiary level (medical colleges and tertiary care hospitals in select locations).

Since SATHI could only offer occasional and limited help after the initial orientation and installation, it can be said that the project has been conceptualized and managed by the community itself. Being operable at the village level, it integrated well with the present health system in India (see Box 5) both vertically (i.e., across the primary, secondary, and tertiary care providers) as well as horizontally (i.e., among the networked units). It turned out to be an empowering exercise for the community and an exemplary partnership between the government, NGOs, as well as community and development support agencies.

Telemedicine enabled the affected people and community to reach out and to articulate their needs. The affected persons participated in interactive sessions with experts and enabled healthcare service provider to be need specific. It strengthened the healthcare delivery system and increased the efficiency of service provider by allowing wider coverage.

The Project Cycle

The tsunami disaster occurred on December 26, 2004. The project was conceptualized in January 2005. All initial processes, identification of stakeholders, operators, locations, and so forth were ready by mid-February 6–7 units were planned in the periphery and one in the centre. SCARF (Schizophrenia Research Foundation), a psychiatric care centre in Chennai, was identified as the expert or central unit, which would provide mental health support.

This selection was based on the aspects of willingness to do voluntary work, familiarity with the local (Tamil) language, as well as proximity to the affected areas. SATHI tried to ensure that in case of need, actual transfer for the more serious cases and continued care through the same facility would be possible.

Units in the periphery were to be located in various places depending on:

- The percentage of the population affected by the tsunami.
- Motivation level and capability of the local NGOs. In this, their motivation and initiative was assessed along with the ability to run the system. They had to have access to or in possession of a room at least 10 feet by 10 feet with relevant furniture for housing the telemedicine facility. Access to government channels if using government facilities IT skilled personnel capable of running and troubleshooting the equipment were required. Adequate financial capability with a willingness to pay the day to day running costs of the staff and connectivity was essential.
- Proximity of the proposed location to the exchange (to allow ISDN connectivity).

The units were to be located in the Primary Health Centre or a government hospital in the tsunami affected area and run by the health workers with supervision and support by local NGOs. Funding support for the machines as well as for maintenance and connectivity for the first 6 months was assured by the funding organization. Alternatively, as stated above, if the NGO had enough funds and their own doctors, they were invited to run it fully themselves.

A review of the decided locations and there eventual outcome is hereby listed in Table 1.

Thus, in summary, the project could not start until middle of May 2005 due to the reasons outlined above and summarized below:

- **Funding** was slow. It was never fully released.
- **New type of technology**, so there were doubts about the project. Some senior functionaries in the funding organization were not in favor. SATHI being a recently registered organization, its capabilities were felt to be suspect by some. Delays meant that continues retraining of volunteers was

required. With delayed funding which was cut short, the expansion plan was delayed and had to be shelved ultimately. By the time it was actually released (October 2005), many earmarked places had already lost interest and some of the need for mental health support had decreased.

- **Connectivity** took too long. In Chennai connectivity was provided in a day in early February 2005. In the periphery, the regional office was around 100 Kms from the coast. Though orders were placed for ISDN lines in February, the lines were not made available until May. Reasons for nonrelease of the connectivity (see above) were understood only following a personal visit from a SATHI representative to the regional office during mid-April 2005 in what was its fourth visit. Thereafter, the location plans were changed but it still took a month more for starting the sessions.

Currently, there are three systems, two in the periphery and one in the centre (SCARF). At all these places, connectivity has been established and the system are up and running. Initially, there used to be thrice weekly sessions wherein patients—those felt to be most affected—were asked to come to the local telemedicine centre by the specially trained community health workers. These patients were seen online by doctors from SCARF and counseling was done; medicines prescribed by the doctors online were provided to the patients by the attending volunteers; a separate stock of medicines used was kept locally as no chemists were available in the periphery.

The patients in Dharmakulam and surrounding areas requiring mental health support have been largely treated. Volunteers from here are now asking for online treatment for other specialties like general medicine, cardiology, and so on.

An evaluation has been done independently by OXFAM. This was by Mr. Saharaj Louis and submitted in May 2006. The summary of his findings have been listed in Box 6.

Current Status and Outcomes

A model telemedicine network has been developed. The design of this model is specific to the needs and integrates the service providers with field level facilitators.

The capacity of the field level NGOs has been built in terms of the operation of the telemedicine network and skills to conduct counseling sessions at the community level.

A unified approach to respond to the disaster situation with application of the communication technology and network of health and other professionals has been developed. This would enable reducing the response time to future disasters. Professionals as well as a service providers' network will be available in future.

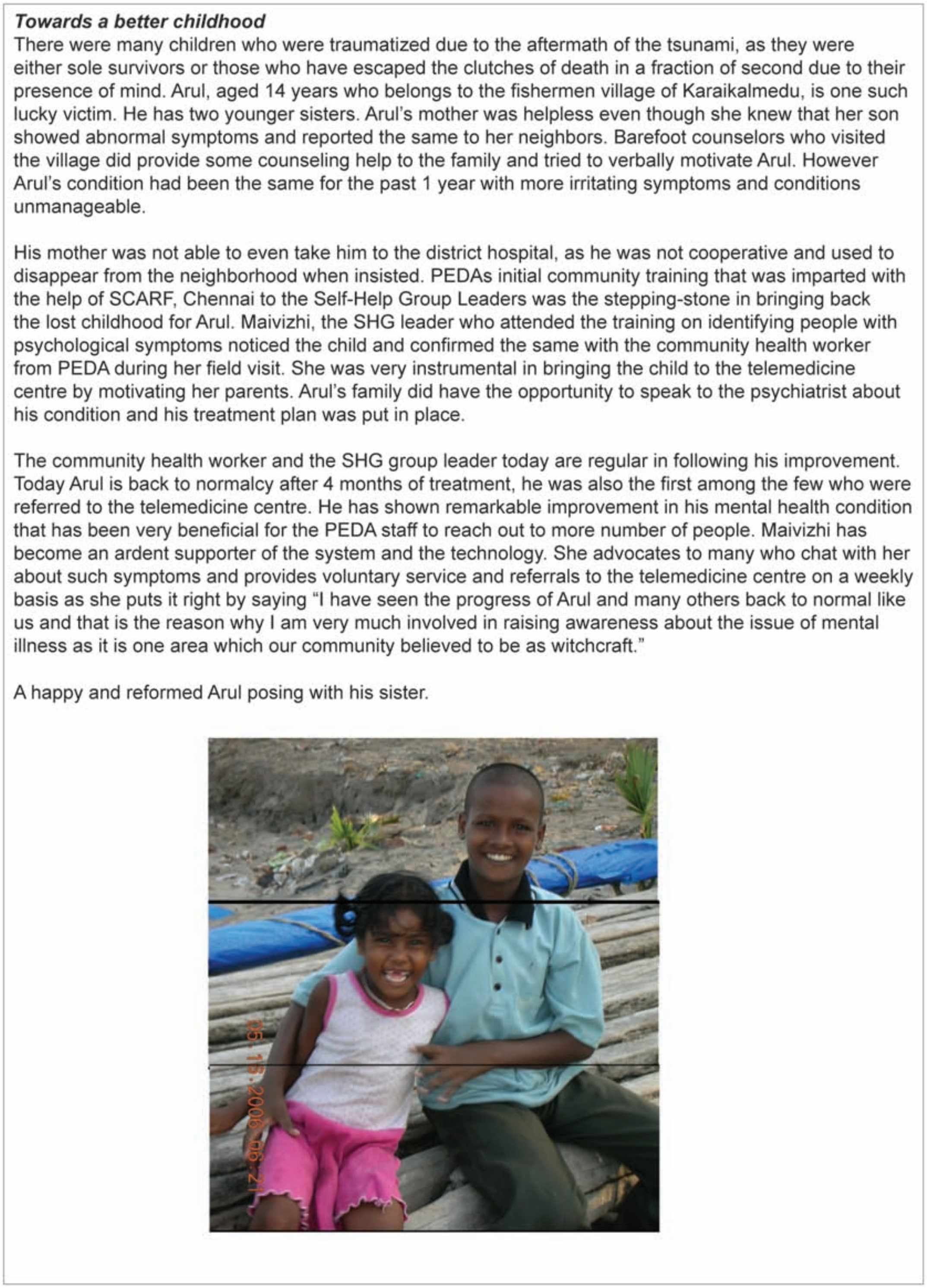
The project has contributed to defining the modalities for disaster response.

A parallel attempt of using IT to improve disaster preparedness has been recommended. This includes making available IT facilities in many areas so that trained persons are readily available as well as a national database of the population,

Box 6. Quotations from evaluation report. Courtesy of OXFAM

"Telemental Health is economically viable" "This project has indeed provided a working model to provide quality mental health care to the rural population. Further use of Telemedicine as a tool to cater to the health needs of the communities has improved availability, reduced cost and improves health outcomes at large" "Community empowered to seek the mental health care using telemedicine network providing access to specialists" "Significant local capacity built ensuring sustainability of service delivery system. Community Mental Health volunteers trained, Local facilitating NGO's capacity built" "In general, acceptance of Telemedicine by the public and patients is far higher than the physicians"

Figure 3. Case report from our project. Courtesy of OXFAM



Towards a better childhood

There were many children who were traumatized due to the aftermath of the tsunami, as they were either sole survivors or those who have escaped the clutches of death in a fraction of second due to their presence of mind. Arul, aged 14 years who belongs to the fishermen village of Karaikalmedu, is one such lucky victim. He has two younger sisters. Arul's mother was helpless even though she knew that her son showed abnormal symptoms and reported the same to her neighbors. Barefoot counselors who visited the village did provide some counseling help to the family and tried to verbally motivate Arul. However Arul's condition had been the same for the past 1 year with more irritating symptoms and conditions unmanageable.

His mother was not able to even take him to the district hospital, as he was not cooperative and used to disappear from the neighborhood when insisted. PEDAs initial community training that was imparted with the help of SCARF, Chennai to the Self-Help Group Leaders was the stepping-stone in bringing back the lost childhood for Arul. Maivizhi, the SHG leader who attended the training on identifying people with psychological symptoms noticed the child and confirmed the same with the community health worker from PEDA during her field visit. She was very instrumental in bringing the child to the telemedicine centre by motivating her parents. Arul's family did have the opportunity to speak to the psychiatrist about his condition and his treatment plan was put in place.

The community health worker and the SHG group leader today are regular in following his improvement. Today Arul is back to normalcy after 4 months of treatment, he was also the first among the few who were referred to the telemedicine centre. He has shown remarkable improvement in his mental health condition that has been very beneficial for the PEDA staff to reach out to more number of people. Maivizhi has become an ardent supporter of the system and the technology. She advocates to many who chat with her about such symptoms and provides voluntary service and referrals to the telemedicine centre on a weekly basis as she puts it right by saying "I have seen the progress of Arul and many others back to normal like us and that is the reason why I am very much involved in raising awareness about the issue of mental illness as it is one area which our community believed to be as witchcraft."

A happy and reformed Arul posing with his sister.

NGOs, healthcare facilities, and so forth, which can quickly set up a response team.

FUTURE CHALLENGES

Funding has been a problem for most healthcare IT projects as the outcomes of previous ventures had been disappointing.

Excessive promotional efforts by vendors used to result in far higher allocation for the technology itself rather than its implementation. Technology however, contributes only 20% to the success of any new technology project; 75% depends on proper implementation (i.e., change management) and 5% on luck (Karthikeyan, personal communication, 2006).

The role of IT in managing healthcare has been recognized but implementation has been a problem. A proper response requires a cultural change and availability of software and hardware at all and especially the disaster prone ones who are running the systems as part of daily routine. Once they are trained, getting such systems to work in emergencies will not require the massive orientation and marketing exercise that SATHI had to do.

Acknowledgment

- **Members of SATHI (**http://www.sathi.org**)** The actual work and field trips were done by Dr. S.B. Gogia (the current author) and Dr. M.R. Surwade.
  Dr. Vidya Surwade, Ms. Arun Rekha, Mr. Ramesh Verma, Dr. Sanjay Bedi, Dr. Lazar Mathew, Dr. R.S. Tyagi and Prof. Sneh Bhargava helped in the background work, administrative assistance, and assessments.
- **The OXFAM Team (**http://www.oxfamint.org.in**)** Ms. Gurinder Kaur, then Executive Director
  Ms. Meetha Parti
  Ms. Madhushree Bannerjee
  Mr. Manishi Chandra
  Ms. Shubhangi Sharma
  Others
- **SCARF** (http://www.scarfonline.org) Schizophrenia Research Foundation, Anna Nagar Chennai, the *expert* service provider
- **PEDA** (Peoples Education Development Association, Karaikal, Pondicherry), the NGO working in Kariakal
- **ISED** (Institute for Social Education and Development, Chennai and Thiruvengadu), the NGO working in Dharmakulam
- **Other NGOs** were involved in the discussions
- **Tamilnadu Government**
  Dr. R. Damodharan (then Deputy Directory of Health Services, Nagapattinam District)
  Dr. Supriya Sahu (then Joint Secretary of Health, Tamilnadu state)
- **Vendors of the Equipment**
  Ms Online Infocomm, Ahmedabad, India
  Ms I-Diagnosis, Ahmedabad, India
- **Mr. Saharaj Louis** for photographs and quotations (Box 6) as well as the submitted case report (Figure 3)

REFERENCES

U21 and the World Health Organization. *E-health is a global revolution for the poor populations of the world.* Retrieved June 7, 2008, from http://www.innovations-report.com/html/reports/medicine_health/report-50033.html

CIA. (2001). *The world factbook 2001*. Washington, DC: Office of Public Affairs.

DECU. (a unit of ISRO) describing ISRO Telemedicine Projects. Retrieved June 7, 2008, from http://www.isro.org/decu/projects/indextele.htm

Dictionary, F. The. Retrieved June 7, 2008, from http://www.thefreedictionary.com/telemedicine

Garshnek, V. (1991). Applications of space communications technology to critical human needs: Rescue, disaster relief, and remote medical assistance. *Space Communications*, *8*, 311–317.

Garshnek, V., & Burkle, F. M. (1999). Applications of telemedicine and telecommunications to disaster medicine: Historical and future perspectives. *Journal of the American Medical Informatics Association*, *6*(1), 26–37.

Gogia, S. B. (2002). *Towards a national telemedicine network.* Paper presented at the 1st National Conference of Telemedicine Society of India at SGPGI, Lucknow, India.

Gogia, S. B., & Surwade, M. R. (2006). *Healthcare technology aspects of disaster management*. Paper presented at the 2nd Global E Health Conference, New Delhi. Retrieved June 7, 2008, http://openmed.nic.in/1774/01/telmedtsunami.pdf

Hindu, The (Chennai ed.). (2005, January 21). p. 5.

Joshi, G. A. (in press). Role of ICT in disability rehabilitation in rural environment. In *IT and Indian rural healthcare.* Macmillan India.

Louis, S. (2006). *Project Healing Touch: Telemedicine healthcare for tsunami survivors in TamilNadu evaluation report.* (Private publication commissioned by OXFAM Trust, excerpted with permission)

Mathew, D. (2004). Information technology and public health management of disasters: A model for South Asian countries. *Prehospital and Disaster Medicine*, *20*(1), 54–60.

Patoli, A. Q. (2006). Role of telemedicine in disaster management. *E Health International Journal*, *2*(2), 34.

Schiesser, R. (2002). *IT systems management.* Prentice Hall. ISBN 0-13-087678-X.

Sharma, R. (2002, February 2). Gujarat earthquake causes major mental health problems. *BMJ (Clinical Research Ed.)*, *324*(7332), 259. doi:10.1136/bmj.324.7332.259c

United Nations Economic and Social Commission for Asia and the Pacific (ESCAP). (2000). *Asia and the Pacific in figures 2000*. UN Statistics Division.

Warfield, C. *The disaster management cycle.* Retrieved June 7, 2008, from http://www.gdrc.org/uem/disasters/1-dm_cycle.html

WHO World Health Report. (2000). *Health systems: Improving performance*. WHO.

Wikipedia. (2007). Change Management. Retrieved June 7, 2008, from http://en.wikipedia.org/wiki/Change_Management_(ITIL)

This work was previously published in Cases on Managing E-Services, edited by A. Scupola, pp. 238-252, copyright 2009 by Information Science Reference (an imprint of IGI Global).

Chapter 4.6

Planning and Control and the Use of Information Technology in Mental Healthcare Organizations

I.J. Baars
Maastricht University, The Netherlands

G.G. Van Merode
Board of Maastricht University Medical Center & Maastricht University, The Netherlands

INTRODUCTION

Demand for mental healthcare increases. Simultaneously, the need for more patient oriented processes increases and the market develops towards more competition among providers and organizations. As a result of these developments, mental healthcare organizations are becoming more aware of efficiency and effectiveness. Often, they choose to transform to more process oriented organizations, which require changes in planning and control systems and information technology (IT). However, little is known about the required planning and control systems and IT for mental healthcare.

We argue that IT for planning and control of mental healthcare organization needs to be adaptive and support short term planning. IT has to be adaptive to be able to support first and second order control which is needed for planning and control of mental healthcare processes. Short term planning or reactivity is needed to deal with stochasticity and variability as present in mental healthcare. These subjects are further described in the background.

This article reports the results of two studies on the use of standard care processes and IT for planning and control of mental healthcare processes. The results give insight in the needed functionalities of IT and planning and control of mental healthcare processes. The first study is a case study in a center for multidisciplinary (mental) youth care. This center implemented care programs and an automated planning tool. We studied the success of this implementation and particularly the fit between the care programs and the planning tool. In the second study we studied the characteristics

DOI: 10.4018/978-1-59904-687-7.ch021

Table 1. Control models

Control model condition	Unambiguous objectives	Measurable output	Known effects	Repetitive activities
Routine control	+	+	+	+
Expert control	+	+	+	-
Trial and error control	+	+	-	+
Intuitive control	+	+	-	-
Judgmental control	+	-	+/-	+/-
Political control	-	+/-	+/-	+/-

+ = condition is present
- = condition is not present

of ambulant mental healthcare processes and the actual and preferable use of planning and control models and IT.

BACKGROUND

Mental healthcare is often multidisciplinary and includes several professionals, disciplines, and departments within one or more organizations which all need to be planned and controlled. Consequently, the object of control is mainly professionals and patients, but also resources like rooms. We define planning as the determination of what should be done and control as the process that assures that the planned results are obtained (Van Merode, Groothuis, & Hasman, 2004).

According to Hofstede (1981), the way non-profit organizations, such as mental healthcare organizations, can be planned and controlled depends on the type of processes. The type of process can be determined by answering the following questions: is the output measurable? Are the objectives unambiguous? Are the effects of management interventions known? And, can the activities be repeated? The type of processes determines the control model and instruments (e.g., protocols, case management and budgeting) that can be applied.

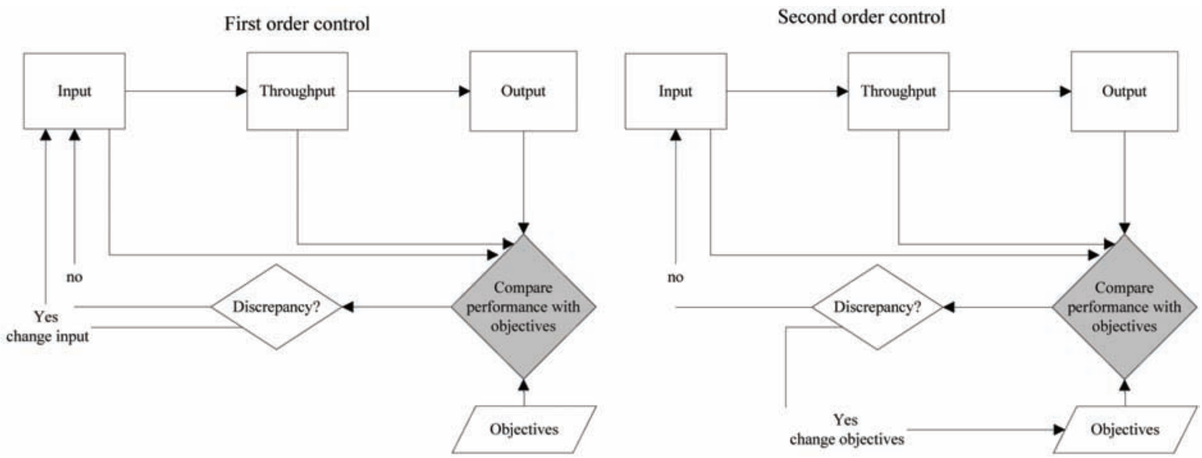
Hofstede (1981) defines six different control models, as shown in Table 1. The more standardized, well-defined, and structured the processes are, the more routine control can be used.

A mental healthcare organization consists of various processes. These processes are possibly different and thus need different control models. To select a control model that best suits a situation, processes have to be analyzed. Especially the distinction between routine and less routine processes is important here.

Routine processes can use standards and can be controlled by routine control or, when the activities cannot be repeated, by expert control. For routine control, and marginally for expert control and trial-and-error control, models that compare automatically what actually happens with the standards about what should happen apply. These models use feedback for control. The feedback from relevant indicators provides information that can be compared with targets. A number of care processes can be coordinated to a large extend by planning and control integrated in one system and by providing feedback from control to planning (Hofstede, 1981; Van Merode, Groothuis et al., 2004; Van Roth & Van Dierdonck, 1995). Moreover, for intuitive and judgmental and political control only vague models exist (Hofstede, 1981).

An example of control by feedback in mental healthcare is a protocol for the process of the treatment of depression. This protocol describes that the target of the indicator “number of sessions” is

Figure 1. First and second order control



15. If a patient receives 17 instead of the targeted 15 sessions, this is evaluated. Several actions can be undertaken to meet the target of 15. One such an action is adapting the input of the process so that the 15 sessions are not exceeded. This is first order control (Figure 1).

A problem with first order control can be that the aim becomes to keep the activity on target at any cost. To overcome this problem, a second order feedback loop that can periodically adjust the targets of the first order feedback loop is necessary (Figure 1). A second order feedback loop provides information (e.g., by new insights or outcome of evaluations) that enables decisions on the appropriateness of the target. By means of a second order feedback loop, the interventions of the first order loop can be overruled. With that, the targets of the process can be adapted so that the outcome better fits the targets. In our example of 15 sessions where the output did not meet the target of 15 sessions, the target of the standard can be changed to, for example, 17 sessions. An advantage of second order feedback is that it can cover more complex organizational control situations. Furthermore, variability and stochasticity can be accounted for with a second order feedback loop.

Information Technology for Planning and Control

Planning and control by feedback on performances can be supported by IT. IT provides the backbone for collecting, compiling, and utilizing information on patients, activities, methods, costs, and results (Porter & Olmsted Teisberg, 2006). Because of the multidisciplinary care and the involvement of several professionals, disciplines, and departments that need to be planned and controlled, a central automated system for planning and control might be needed. In industry Enterprise Resources Planning systems are often used for this purpose. Enterprise Resource Planning (ERP) systems attempt to integrate all corporate information in one central database, and information can be retrieved from many different organizational positions and in principle they allow any organizational object to be made visible (Dechow & Mouritsen, 2005).

Likewise, for healthcare, ERP systems can integrate many functions such as patient scheduling, human resource management, workload forecasting, and management of workflow (Jenkins & Christenson, 2001). However, when implementing ERP systems in an organization, several implementation and structural problems can occur, for example, ERP may not fit the structure of the organization.

Implementation and structural problems may occur in healthcare because ERP systems require fixed, deterministic processes and ignore alternative processes (Van Merode, Groothuis et al., 2004). But in healthcare, stochasticity (e.g., patients not showing up) and variability (e.g., demands for care differ between several individual patients) exist. Because of the existence of stochasticity and variability, a more reactive decision making technology or short term planning systems as, for example, Advanced Resource Planning (ARP), better suit the less deterministic processes (Vandaele & De Boeck, 2003; Van Merode, Groothuis et al., 2004). Another possibility for planning and control in mental healthcare is to physically separate deterministic processes suitable for ERP from nondeterministic processes requiring a more reactive decision making, or short term planning, technology.

PLANNING AND CONTROL AND THE USE OF IT IN MENTAL HEALTHCARE ORGANIZATIONS

To study the possibilities of planning and control and the use in mental healthcare organizations, we performed two case studies. Here we present the results of these two case studies.

Case 1: Planning Tool and Care Programs

In the multidisciplinary youth (mental) healthcare center, processes were standardized by care programs. The aim of the care programs was to plan processes more efficient and effective, and also to improve the patient-oriented way of working. A care program is defined as a framework with which organizations, professionals, and patients should comply and it is used to get a patient-oriented organization of a well described target group. It integrates the activities between different disciplines, professionals, and departments and indicates the way the care should be given, by which professional, in which setting, and with what frequency (Berg, Schellekens et al., 2005).

Care programs consist of several standardized modules. The planning of a care program, that is, which modules will be performed, is done based on the demand of the patient. Further, for planning and control of the activities of a module, each module contains a Bill of Resources (BOR), which is described in the protocol of the module.

A BOR is derived from a Bill of Materials that is used by ERP systems. However, mental healthcare includes more than materials such as professionals and patients. Therefore, the use of a BOR is more appropriate for healthcare organizations (Van Roth & Van Dierdonck, 1995). In the center, a BOR defined the location, type of activity, professional, and patient.

Because of the multidisciplinary care, the coordination of the care programs was complex. Automated support might reduce this complexity. Therefore, IT, that is, the planning tool, was used for planning and control of activities of patients and professionals. The planning tool was a software application, intended to support working with care programs. The features of the care programs, such as the involvement of several professionals and departments and the standardization of modules, require certain functionalities of the planning tool. The planning tool contained the following functionalities: a BOR to plan activities, an event handler to react to ad hoc changes by revising timetables and re-arranging activities, an electronic organizer, and a control function for process control by first order feedback and second order feedback.

To test the functionalities in relation to the care programs, the planning tool was tested in a pilot. The evaluation of the pilot was done with a document analysis, interviews with all those involved, and analysis of e-mails to and from the planning tool helpdesk.

The results of the evaluation show that the fit between the standardized care programs and the planning tool was insufficient. The main cause was the noncompliance of the professionals with the standard modules because they feared inflexibility in performing their activities due to the standardization and first order control. However, the professionals did have some flexibility in planning. They could use the event handler to react to ad hoc situations and they had the possibility to deviate from the standards to react to variability which is second order control. But the results show that the flexibility possibilities were not known and not used by the professionals.

As the results illustrate, the characteristics of care processes and the functionalities of IT must fit to function. In this case, the IT demands a certain amount of standardization while in daily practice the professionals require flexibility in performing their activities. Therefore standardization and flexibility have to be balanced. Because the professionals did not comply with the standard modules of the care programs, and did not know of, or use, the possible flexibility, we do not know for sure that the care programs and the IT did not fit. It seems also due to implementation problems of the IT and care programs that professionals did not comply and did not have knowledge about the possibilities of second order control.

Professionals do need some planning freedom to be able to react to the present variability and stochasticity. A planning and control system, including the IT, need to support this in an efficient way. In the second case study, we studied the actual use and the possibilities of a planning and control model which is based on performance measurement and second order feedback.

Case 2: Optimizing Planning and Control in Ambulant Mental Healthcare Centers

Due to increasing competition in mental healthcare, planning and control based on performances is needed. Therefore routine control is necessary and processes have to fulfill the characteristics as described by Hofstede (1981). But as shown in the evaluation of the planning tool, also flexibility in planning is needed.

The case study of four ambulant mental healthcare centers presents information about characteristics of their processes and the planning and control models as used. These results are used for recommendations that can guide mental healthcare organizations in their planning and control and the use of IT. These are presented in the conclusion.

In this case study, we first described the present processes by using process mapping techniques. Next, we assessed these processes on the uncertainty of demand, supply, and the service process itself, complexity of coordination, and staff inflexibility. These three factors determine the efficiency and adaptation possibilities of a process (Van Merode, Molema, & Goldschmidt, 2004). These factors incorporate the conditions of Hofstede's (1981) model.

The results of this study showed that most of the processes were not planned and controlled in a consistence way. Three of the four ambulant mental healthcare centers hardly used performance indicators to monitor the processes. The uncertainty and complexity were high and instruments, like protocols or IT, to decrease the unnecessary uncertainty and complexity were hardly used. One center did use care programs. However, the opportunities for planning and control of these care programs were not used to their full extent. Besides, a planning and control system based on feedback did not exist. This center had the most extended IT software. Nevertheless, this software was not used to monitor the results of the processes with performance indicators. Therefore, planning and control based on feedback was not performed. IT use for planning and control was very minimal in all four centers.

FUTURE TRENDS

In mental healthcare organizations, we mainly see two developments. The first is that many mental healthcare organizations continue in their old ways in organizing their care, that is, that no standards or IT are used. However, a second development is that, because of growing attention for more efficiency in mental healthcare, more and more mental healthcare organizations standardize their processes by, for example, the introduction of care programs.

Standardization can be very fruitful in decreasing unnecessary uncertainty in care processes. However, mental healthcare organizations often do not change their organization structure simultaneously with the introduction of care programs. Additionally, IT with planning and control functionalities is underused. The use of IT for integrated planning and control will probably increase. But, what we observe in somatic healthcare is that (standard) ERP packages are implemented while they do not suit the situation. These ERP systems are often implemented without a change in organization structure. By the lack of the fit between the organization, processes, and ERP systems, this can result in many problems. New, adaptive, software is there but is not successful.

As we claimed in the introduction, first and second order control should be supported by IT. Therefore IT has to be adaptive and support short term planning or reactive decision making. However, mental healthcare organizations are not yet interested in this kind of technology. In the future, mental healthcare organizations consider IT more to profit from care programming and, as a result, work more efficient and effective.

CONCLUSION

Mental healthcare organizations are on their way to more efficiency in their processes; yet IT is still underused for planning and control.

As shown in the first case study, processes and IT must fit. In this center, the organization thought that planning and control was possible with routine control supported with information technology. The care programs met the conditions for first order control and second order control. However, in the pilot it did not work out as intended.

In the second study, we observe that almost no use is made of possibilities of standardization and feedback for control purposes. Moreover, IT is hardly used for planning and control purposes. As a result, the ambulant mental healthcare centers miss the possibility to direct the outcome of processes to a certain target, and efficiency is not optimal. As a result, the centers miss the opportunities to be competing on the (regulated) market.

The results emphasize the need to carefully consider process characteristics before introducing a planning and control system. Careful consideration is needed to avoid type I and type II errors. Type I errors occur when opportunities for routine planning and control (with standardization and IT) are not used by management. However, some processes are not deterministic and cannot be controlled with routine models. When they are controlled with routine models anyway, type II errors occur. To avoid either type I or type II errors, a fit between standardization and flexibility has to been found. Hofstede (1981) states that type I errors often occur in not-for-profit organizations because the concern for cost and effectiveness is often missing. However, mental healthcare is subject of social and political developments resulting in the need to be more aware of efficiency and effectiveness. Therefore we assume that type II errors may occur in future more often.

The results also show the necessity of balancing between process standardization and the flexibility of the working practice. Routine models can be applied for processes in mental healthcare in certain circumstances. Nevertheless, routine models need to use second order control because not all activities can be planned in advance due to variability and stochasticity. This balance between standardization and flexibility has to be considered carefully before fully implementing care programs and a central planning and control system integrated in IT. To be able to balance between flexibility and efficiency by means of care programs, the organization structure also has to be changed and IT has to be adaptive.

We recommend the following to develop more efficient processes in mental healthcare organizations. First, performance indicators should be developed to be able to compete in the (regulated) market. Simultaneously, time horizons should be distinguished in which planning and control on several different levels (e.g., establishing different care programs by board 3 years, planning of professional 6 weeks) can be defined. Next, processes need to be distinguished on uncertainty and complexity of the process. The difference in characteristics of a process (more or less routine) decides on the possibility of standardizing processes. After that, the processes that satisfy the possibilities for routine control need to be standardized and a BOR should be described. For the actual control on performances, a system based on first order control and second order control must be developed and adaptive IT that supports short term planning or is reactive is needed to support the planning and control.

The use of these recommendations helps in finding a balance between standardization, use of IT, and flexibility. In addition, IT interacts with the social system and the working practice and, therefore, it is necessary to tailor both. However, it is a process of trial and error and therefore requires adaptive IT.

REFERENCES

Berg, M., & Schellekens, W. (2005). Bridging the quality chasm: Integrating professional and organizational approaches to quality. *International Journal for Quality in Health Care*, *17*(1), 75–82. doi:10.1093/intqhc/mzi008

Dechow, N., & Mouritsen, J. (2005). Enterprise resource planning systems, management control and the quest for integration. *Accounting, Organizations and Society*, *30*, 691–733. doi:10.1016/j.aos.2004.11.004

Hofstede, G. (1981). Management control of not-for profit activities. *Accounting . Organizations and Society: An International Journal Devoted to the Behavioural Organizational & Social Aspects of Accounting*, *6*, 193–211.

Jenkins, E. K., & Christenson, E. (2001). ERP (enterprise resource planning) systems can streamline healthcare business functions. *Healthcare Financial Management*, *55*(5), 48–52.

Porter, M. E., & Olmsted Teisberg, E. (2006). Redefining healthcare. *Creating value-based competition on results.* Boston, MA: Harvard Business School Press.

Van Merode, F., Molema, H., & Goldschmidt, H. (2004). GUM and six sigma approaches positioned as deterministic tools in quality target engineering. *Accreditation and Quality Assurance*, *10*, 32–36. doi:10.1007/s00769-004-0876-0

Van Merode, G. G., Groothuis, S., & Hasman, A. (2004). Enterprise resource planning for hospitals. *International Journal of Medical Informatics*, *73*(6), 493–501. doi:10.1016/j.ijmedinf.2004.02.007

Van Roth, A., & Van Dierdonck, R. (1995). Hospital resource planning: Concepts, feasibility and framework. *Production and operations management, 4*(1), 2-29.

Vandaele, N., & De Boeck, L. (2003). Advanced resource planning. *Robotics and Computer-integrated Manufacturing*, *19*, 211–218. doi:10.1016/S0736-5845(02)00081-9

KEY TERMS AND DEFINITIONS

Adaptive Information Technology: Information Technology that can be adapted to changing circumstances in finding a balance between processes and IT.

Care Program: A care program is a framework where organizations, professionals, and patients should comply with and is used for patient-centered organization of a well described target group. It integrates the activities between different disciplines, professionals, and departments (Berg, Schellekens et al., 2005).

Control: The process that assures that the planned results are obtained.

Enterprise Resource Planning System: Enterprise Resource Planning systems attempt to integrate all corporate information in one central database, and information can be retrieved from many different organizational positions and in principle they allow any organizational object to be made visible (Dechow & Mouritsen, 2005).

Feedback: Information about the output is fed back to the input.

Planning: Determination of what should be done.

Reactive Decision Making: Decision making based on reacting to unexpected situations due to variability and stochasticity.

Short Term Planning: Planning on short terms with data about monthly, daily, and hourly demand and meaning full statistical distributions to be able to deal with stochasticity and variability.

This work was previously published in Strategic Information Technology and Portfolio Management, edited by A. Tan; P. Theodorou, pp. 394-401, copyright 2009 by Information Science Reference (an imprint of IGI Global).

Chapter 4.7

The Use of Information and Communication Technologies for Health Service Delivery in Namibia:

Perceptions, Technology Choices, and Policy Implications for Sub-Saharan Africa

Meke I. Shivute
Polytechnic of Namibia, Namibia

Blessing M. Maumbe
Eastern Kentucky University, USA

ABSTRACT

Information and communication technologies (ICT) have transformed health service delivery (HSD) in developing countries although the benefits are not yet fully understood. This chapter examines the use of ICT for HSD in the Namibian context. To obtain insights into the extent and degree of the current ICT uses, the chapter begins by mapping a HSD landscape for Namibia. The reported ICT use patterns are based on a primary survey of 134 patients and key informant interviews held with 27 health service providers (HSPs) in Khomas and Oshana regions of Namibia. The results from the survey indicate that Namibian patients use diverse range of ICT to access health services including the traditional television and radio, and the more modern mobile phones and computers to a limited extent. HSPs reported the growing use of ICT in various functional areas such as admissions, clinical support, family planning, maternity, and emergency services. The chapter identifies key challenges and policy implications to enhance the uptake of ICT-based health services in Namibia. The relatively high penetration rates of traditional ICT such as televisions and radios coupled with a growing use of mobile phones presents new alternative opportunities for expanding HSD to Namibian patients in remote settings. The chapter will benefit HSP and patients

DOI: 10.4018/978-1-60566-820-8.ch012

as they decide on affordable technology choices; and policy makers as they design interventions to stimulate the use of ICT in HSD in Namibia. The results provide key insights for other Sub-Saharan African countries contemplating ICT integration in health services.

INTRODUCTION

Information and communication technologies (ICT) have transformed the way health services are delivered in today's global society Sargeant (2005:305). For any society, however, it is important to understand how ICT are being deployed to support the delivery of health services to patients. In the case of Namibia, health service providers (HSP) in both the private and public health sectors must have the capability to use ICT as this will subsequently influence how they deliver services to their patients in the future. On the other hand, patients too, need to use relevant ICT to support and improve their access to health services. This chapter, therefore, examines the landscape for health service delivery (HSD) in Namibia. The Namibia Health Service Delivery Landscape (NHSDL) provides key insights and a better understanding of the current utilization and the future potential for ICT applications in health service delivery (HSD). The proposed NHSDL provides a comparative assessment of the emerging ICT use patterns in both rural and urban areas in Namibia. Patient's views and perceptions about ICT applications in HSD are described. Furthermore, the chapter highlights some considerations for improving access to ICT by both rural and urban-based patients in Namibia.

Namibia's health sector is distinctive and different from other sub-Saharan countries. What makes Namibia's HSD unique is the critical role that missionaries have consistently played in health care provision. Health services in Namibia are supplied by the government, missions and private providers (Namibia, Ministry of Health and Social Services, 2004b:5). The HSD system comprises two main components: a *public* and *private* health services sector (El Obeid Mendlsohn, Lajars, Forster and Brule, 2001:1). The government of Republic of Namibia (GRN) through the Ministry of Health and Social Services (MOHSS) supplies public health services, while the private health services are offered by private practitioners, hospitals and clinics. Mission health services are subsidized by the MOHSS and include hospitals, health centers and clinics. Mission health facilities are considered key part of the public health services.

In view of the fact that the healthcare sector is one of the fastest growing industries in the service sector, stakeholders in healthcare will be forced to make some adjustments to reposition themselves for the future. Those health service providers (HSP) that fail to introduce the necessary changes arising from increased use of ICT will either become obsolete or less competitive in the long-run. As a developing country, Namibia is confronted with the global competitive issues and this serves as a further motivation for this study. A competitive health service sector will play a major role in the GRN effort to meet the challenges of the Millennium Development Goals (MDGs).

Namibia is among the leading countries in Sub-Saharan Africa that have made significant strides in using ICT to transform government service delivery. Hesselmark & Miller (2002:40) indicates that Namibia's infrastructure has tremendously improved in the twelve years after independence, the number of telephone lines has doubled, the mobile network covers most of the population, the Internet can be accessed throughout the country, and 600 leased lines are in operation. Hesselmark & Miller (2002:40) further adds that ICT competence is widespread and that several large companies in the modern sector operate sophisticated enterprise software.

According to the MOHSS, Namibia has implemented a computerized health information system (HIS) that is currently being used in the public sector (Namibia, MOHSS, 2004a:26).

Given new and emerging changes taking place in ICT provision, MOHSS is revising the current HIS with the view to modernize it and make it more efficient. The newly established Ministry of Information and Communication Technology has assumed the responsibility for (i) the overall national ICT policy development functions and (ii) establishment of a legal framework for the ICT industry (Namibia, 2008). The use of telephones, faxes, emails and Internet in the health sector is becoming widespread. However, there is need to assess the extent and degree to which the modern ICT are used to support HSD in Namibia's public and private health sector. Given the foregoing, the specific objectives of this chapter are to:

i. Describe Namibia's health service delivery landscape (NHSDL).
ii. Examine existing ICT uses in Namibia's health sector and identify major constraints in health service delivery (HSD).
iii. Discuss ICT policies and their implications for health service provision.
iv. Recommend measures to enhance the uptake of ICT in HSD in Namibia.

The rest of the chapter is organized as follows: the next section provides a review of the literature and that is followed by a brief description of the research methods in section 3. Section 4 presents the results of the patient survey and health service provider key informant interviews and that is followed in section 5 by a brief discussion of the policy implications and future directions. Section 6 concludes our chapter with suggestions for future studies.

LITERATURE REVIEW

The Use of ICT in Health Service Delivery (HSD) in Developing Countries

ICT has the potential to radically change the way health services are delivered to patients and improve the quality of these services by providing easy access to health care information in developing countries especially in Sub-Saharan Africa. The benefits of ICT as a technique to improve the quality of health services is widely acknowledged worldwide and health institutions are striving to identify ways to deliver their services efficiently and effectively (Hjelm, 2005; Chandrasekhar, 2001). The benefits of telemedicine (i.e. ICT applications in HSD) have been summarized as improved access to information, provision of new healthcare services, improved access to existing service, increase in care delivery, improved professional knowledge, better quality control of screening programs, and reduction in health care costs (Hjelm, 2005). The effective use of ICT can help overcome geographic isolation for the populations that live in remote rural areas, as it facilitates access, dissemination, utilization and exchange of information on combating debilitating diseases such as malaria, tuberculosis and HIV/AIDS (Yamuah, 2005:1). A study in a remote north-west district of Russia reported that a Mobile Telemedicine Unit with endoscopy, electrocardiography and digital photography capability was used for emergency and screening purposes (Uldal, et al, 2004). Mobile ICT is important in reaching patients in remote rural locations without access to primary care facilities. In Cameroon, mobile phones helped medical residents from University Cameroon deployed in remote villages reduce their isolation and maintain contact with mentors during their rural training (Scott.et. al., 2005).

Chandrasekhar (2001:851) explains that ICT has the potential to be used as a mechanism to increase the transparency and efficiency of governance, which in turn would improve the availability and delivery of health services. The author argues that the potential of ICT in the health sector can be that of acting as mediatory role between the HSP and beneficiary (i.e. patients). In the mediatory role, ICT is used as a medium to deliver health services to patients or can be used as tool to organize information more efficiently and effectively. Yamuah (2001:2) identifies similar benefits, which include the use of ICT to facilitate communication between different levels of delivery units (e.g. district hospitals, health centers, clinics and referral hospitals). At the referral level there is added value through effective resource management and planning, efficiency in processing transactions, and access to more reliable information. Health professionals would have the advantage of effectively and efficiently sharing the information with other health professionals (Yamuah, 2001:2). ICT such as email, telephone or mobile technologies facilitate communication between two or more health professionals by sharing information on various diseases that may afflict the patients.

In developing countries, innovative uses of ICT involve the dissemination by medical experts of disease surveillance, disease treatment, and disease control interventions which saves the patient both time and monetary costs in the form of transportation charges. Such advances in telemedicine allows for the exchange of health information and delivery of health care across distances by using telecommunications (Rao, 2001:223). With the growth of telemedicine, patients can have their regular consultations with medical specialists across a distance and they do not have to travel long distances for such health services. Zolfo & Lynene (2008), explain how telemedicine is being used in remote areas to assist physicians in clinical support and mentoring. A study conducted in Tanzania to investigate the use of ICT tools such PDA's to assist members of parliament in decision making confirmed that indeed MPs do need to use PDAs to support them in decision making processes, data management and enhance information accessibility (Kirondoma *et, a.,,* 2008*).* Such modern ICT provide opportunities to support health service provision or health researches especially in rural or remote areas without basic infrastructure. Telemedicine offers a wide range of benefits which include accessibility to health services, efficient and professional healthcare delivery, quality control of screening programs and reduced health-care costs (Hjelm et.al, 2005). Bynum, Cranford, Irwin and Banken (2006:39), observed that telemedicine can improve the quality of the diagnosis and management of patients in remote areas. Richards, King, Reid, Selvaraj, McNicol, Brebner and Godden (Richards's *et.al*, 2005), are of the view that the use of ICT in health has the potential to improve access to educational opportunities for professionals and access to care in remote areas.

The use of ICT may not deliver the expected health benefits automatically. Before ICT applications in health can become a real success numerous challenges that currently serve as obstacles to their effective utilization need to be resolved (Anderson, Vimarlund & Timpka, and 2002:159). These barriers that limit access to ICT have been defined as internal (first order) and external (second) barriers (Ertmer, Addison, Molly and Woods, 1999:54). Studies by Ertmer.*et al*. (1999:54) and Lim & Khine (2006:99) characterize *internal barriers* as those barriers that are extrinsic to the ICT user and this includes lack of access ICT, insufficient time to plan instruction, and inadequate technical and administrative support. All of the above can inhibit ICT access in health institutions. On the other hand, *external barriers* are those barriers that are intrinsic to the ICT user, and are more concerned with the unwillingness to change, or user's attitude and preferences about ICT use. These barriers are referred as "fear factors" (Yamuah, 2005:2; Ertmer *et al*.1999: 54).

Health stakeholders can be unwilling to use certain ICT due to certain beliefs or they can be resistant to change due to unfamiliar ICT (e.g.

telephones, computers). Resistance to change can therefore hinder ICT use in health institutions for example if a HSP is used to record patient data in manual files, they might be resistant to using a computer for the first time if they have not been given proper training or administration support.

Hjelm (2005), identified four major constraints to ICT-based HSD and these include (i) breakdown in the relationship between health professional and patient, (ii) break-down in relationships between (and among) health professionals, (iii) potential threat of quality deterioration of health information and (iv) organizational and bureaucratic constraints. According to Yamuah (2005:2), the challenges that hinder ICT use in developing countries are (i) lack of electronic means to capture data, (ii) low literacy rates among health providers, (iii) infrastructure constraints such as low distribution of reliable telecommunications and grid power in community health units, (iv) lack of technical support and (v) high establishment costs for ICT projects given limited budget for health services. Sargean (2005:304), identified challenges for ICT use in health services as technological, educational, and social environment. These challenges hinder the widespread use of ICT by patients and staff members in health institutions. Furthermore, Huggins and Izushi (2002:114) added that the delivery of ICT learning in rural communities often has to start with quite a low level of ICT awareness and knowledge among target groups, the target groups being different stakeholders in the health sector. Overall, the barriers in using ICT to enhance HSD relate to the attitude and preference of users, access to certain ICT, and loss of social capital among some professional health workers. Hence, practical solutions to overcome these ICT challenges and enhance effective access to ICT and use are required.

Developing countries are lagging behind in new developments in ICT applications for health service delivery to patients. Despite the aforementioned challenges, telemedicine which is one of the fastest growing areas of ICT applications in the health sector offers numerous opportunities for expanding both urban and rural patient outreach (Baldwin *et.al,* 2002). Telemedicine which started back in the 1920s has been evolving ever since, and its use in developing countries is rising (Richards's *et.al*, 2005). Not only does the use of ICT in developing countries offer tremendous opportunities to enhance HSD, but it also offers new opportunities for poverty alleviation by improving life expectancy.

In Namibia, initiatives have been implemented in the education sector to encourage ICT use. The ICT policy for education is cited as one of the most successful endeavors by the GRN's in its continued effort to spread the use of ICT among its population. 21st century (Tech/na. 2007). The effectiveness, relevance, and potential to address national educational goals aligned to the MDGs goals could be duplicated by MOHSS in its vision to deploy ICT broadly in HSD in Namibia. In other countries such as Egypt, the Ministries of Health have established e-Health programs for purposes of rendering better health services to their society. The Ministry of Communication and Information Technology in Egypt has initiated the incorporation of ICT in health services. The services range from clinical consultation and administration to the provision of medical education to isolated areas. This initiative is made possible by different projects that are underway in Egypt. These include the telemedicine project, the health record system, the emergency medical service call center ambulance project, and the information system and national network for citizen health treatments by the Government (Egypt, 2005). Other African countries can follow the example of Egypt in introducing initiatives to improve ICT use for health services in the context of their countries.

METHODOLOGY

The chapter describes ICT use in the health service delivery in Namibia. The study describes how HSP and patients use ICT to deliver and access health services respectively. The chapter presents HSP and patient views about ICT uses in health service delivery (HSD) and discusses ICT-related health service delivery policy issues. The results are based on a primary survey of 21 health service providers (HSP) and 134 patients in the private and public health sector in Namibia conducted in 2005. The questionnaires covered three main sections; 1) existing ICT and how it is used to deliver health services to patients 2) the constraints in delivering health services, and 3) patient and HSP perceptions about ICT uses for health service delivery in Namibia, particularly in the Khomas and Oshana regions. The sample size was 144 patients and 21 health service providers. The data for the study was collected from the Khomas and Oshana region.

Khomas is representative of a typical urban area in Namibia while Oshana region is situated in the northern part of the country which is primarily a rural setting. The two regions were chosen in order to identify infrastructural and socio-economic deference's in ICT usage that could be attributed to geographic disparities. Khomas region is situated in the central part of Namibia and it is 37,007 square km², and this is where the capital city Windhoek, is situated. The region consists of various health facilities of which, one is a national referral hospital, one intermediate hospital, two health centers, seven clinics, three private hospitals, private clinics and thirty-three outreach points. The region has the highest population which stands at 264,616 compared to other regions in the country, and the population per hospital is 121,278 (Namibia, 2006). Access to ICT in the Khomas region might be higher than Oshana, as the community tends to have better access to resources especially infrastructure endowment. Oshana region is the smallest region (5,290 km²) with a population of 167,797, hence it is densely populated (Namibia, 2004a:1). The Oshana region is the second largest population concentration in Namibia after Windhoek, but it lacks basic infrastructure and most of the services and facilities normally found in urban areas of this size (Anon, 2007a).

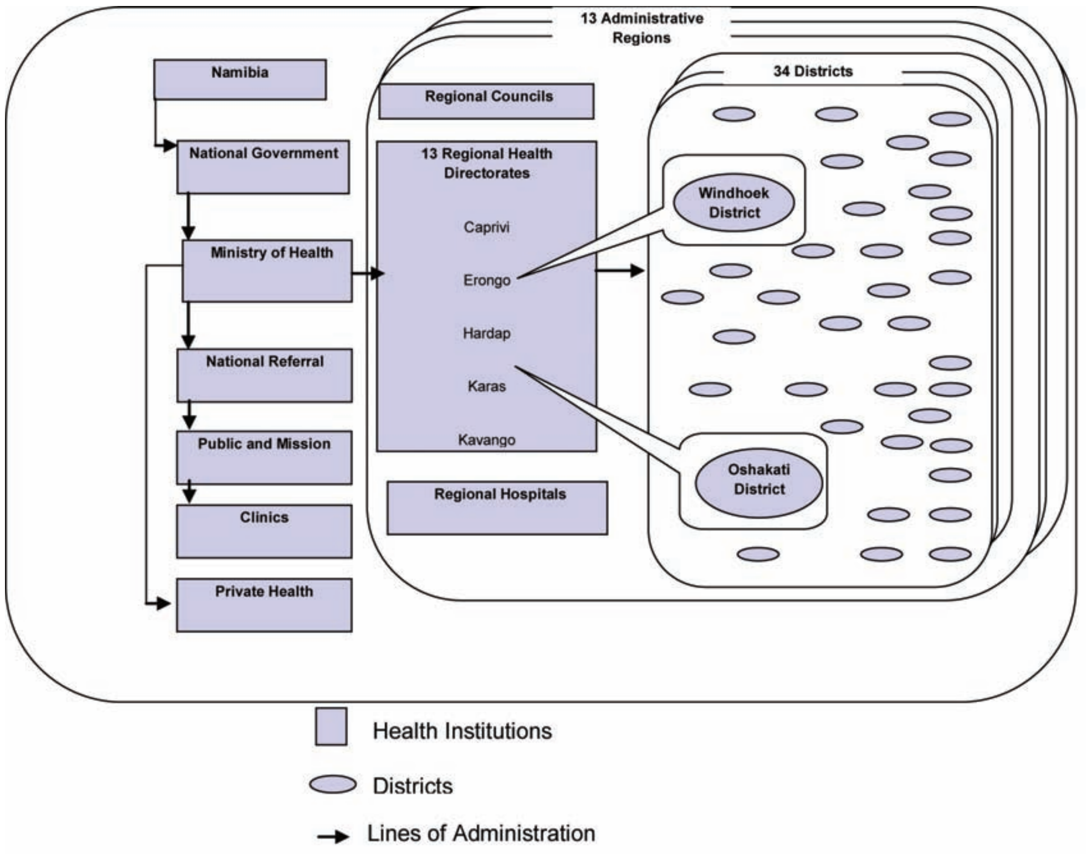
Secondary data sources that were utilized included publications such as journals, white papers and health policies some of which were still under construction. Government policies were examined to determine the enabling environment for ICT applications in HSD. In cases where the necessary documents were not easily accessible, GRN officials from the Policy and Planning Directorate were interviewed to provide additional insights on the potential of ICT deployment in Namibia's health sector.

The study is limited to the use of ICT in the health service delivery and it excludes use in other areas of the health sector such as pharmacies. The study explored ICT use by HSPs in the health facilities such as mission, private and public hospitals. The data collection was limited to the Oshana and Khomas regions, where a sample of stakeholders from each region was interviewed on ICT use in their health facilities and did not cover all the regions of Namibia.

The Namibian Health Services Delivery Landscape

The Oshana health directorate is divided into fifteen health facilities, one Intermediate Hospital (regional), four health centers and twelve clinics. The district also has twenty-eight outreach points. The intermediate hospital is the ultimate referral point in the Oshana region and it is responsible for providing essential back up services and support for clinics and health centers in the region. Health centers are smaller than intermediate hospitals and they are found in two types, namely, day care health centers and rural health centers (i.e., the latter is common to Oshana region). The population per hospital in the Khomas region is 169,147 (Namibia, 2006). The idea of a landscape development was first researched by Korpela et,al. 2004a. In their study, they explained that a

Figure 1. The health service delivery landscape in Namibia, 2007. Source: Survey data, 2006



health landscape is used to depict health service provision to patients in different health sectors and that the landscapes would differ from one country to the next. The 'generic' health service delivery landscape for the Namibia was the first step taken in developing a health landscape model for other regions and a 'generic' model for the whole country. A number of documents were specifically reviewed during the landscape development and these include national health accounts and other government publications. The Namibian generic landscape is depicted in Figure 1 and it illustrates the various stakeholders in the health sector and how they provide ICT related services to patients. The landscape further depicts inter-relations among key stakeholders.

The Ministry of Health and Social Services (MOHSS) is responsible for providing health and social services to the citizens of the country. There are 13 regional directorates, namely; Caprivi, Erongo, Hardap, Karas, Kavango, Khomas, Kunene, Ohangwena, Omaheke, Omusati, Oshikoto, and Otjozondjupa. These directorates are under the management of the MOHSS and within these directorates are 34 districts. The Khomas region has one directorate namely Windhoek. There is one national referral hospital country wide and it is located in the Windhoek district. The national referral hospital is under the management of the MOHSS which is at the national level. It is important to note that the description of NHSDL excludes other stakeholders in healthcare such as, pharmacies and medical aid companies because the study's purpose will primarily focus on use of ICT in the health service delivery for hospitals and health facilities (mission, public and private) in the

Table 1. Summary of ICT use patterns and user perceptions in the Khomas region, 2007

	Personal computer	**Email**	**Internet**	**Mobile phone**	**Radio**	**Television**	**Telephone**	**Fax machine**
	%	**%**	**%**	**%**	**%**	**%**	**%**	**%**
ICT Access								
Current use	44	36	32	94	97	85	90	43
Previous use	72	47	47	97	99	99	97	67
Ownership	24	11	10	92	96	83	64	6
ICT Perceptions								
Expensive	6	n/a	7	0	0	0	0	4
Advanced/do not know how to use ICT.	18	n/a	32	1	0	0	0	14
Time consuming	4	n/a	3	0	0	0	0	0
Not user friendly	0	n/a	0	1	0	0	0	0
Unnecessary	4	n/a	4	0	0	0	0	8
Other	17	n/a	15	2	10	0	0	0
ICT Literacy								
YES	74	n/a	50	99	100	97	99	64
NO	25	n/a	49	1	0	1	1	32
ICT Importance								
Work	40	n/a	21	38	28	13	39	36
Leisure	43	n/a	33	93	94	92	83	38
Health	8	n/a	21	44	83	74	56	17
Education	47	n/a	32	53	76	69	51	19
Other	32	n/a	6	26	0	0	4	0

Source: Survey Data, 2006

Khomas and Oshana region. The entire NHSDL should encompass ICT utilization by both formal and informal health service institutions including traditional care providers.

RESULTS AND DISCUSSIONS

The ability to access affordable health services plays an important role in the effective delivery of health service especially to the poor communities. The use of ICT depends entirely on whether HSP or patients have access to affordable ICT. In addition to the cost factor, effective use of ICT also depends on positive perceptions about deploying these modern technologies to deliver and access health services. The data on patients' ICT use patterns and perceptions is shown in tables 1 and 2 for the Khomas and the Oshana regions respectively.

ICT awareness in the Khomas region (Table 1) is relatively high as patients indicated they have access to most of the technologies. Most (99%) patients showed that they have used a radio and television before, even though for some patients they do not own these ICT at home. In case of television, some patients who did not own a television set at home indicated that they

Table 2. Summary of ICT use patterns and perceptions in the Oshana region, 2007

	Personal computer	Email	Internet	Mobile/ Cell phone	Radio	Television	Telephone	Fax machine
	%	%	%	%	%	%	%	
ICT access								
Current use	31	13	19	95	100	84	77	31
Previous use	40	15	21	98	100	100	97	63
Ownership	7	0	2	94	98	61	47	3
ICT perception								
Expensive	18	n/a	18	0	0	0	0	5
Advanced/do not know how to use	27	n/a	36	3	0	0	0	7
Time consuming	7	n/a	7	0	0	0	0	5
Not user friendly	2	n/a	2	0	0	0	0	0
Unnecessary	2	n/a	3	0	0	0	0	15
Other	32	n/a	44	3	0	0	0	32
ICT Literacy								
YES	39	n/a	21	97	100	97	36	22
NO	61	n/a	77	3	0	3	63	39
ICT Importance								
Work	23	n/a	10	39	24	18	42	31
Leisure	18	n/a	18	98	100	86	81	44
Health	7	n/a	13	39	92	79	45	7
Education	29	n/a	16	55	95	63	37	13
Other	11	n/a	2	12	0	0	0	3

Source: Survey Data, 2006

had access either in their neighborhood, or when they visit health facilities where they watch video cassettes on health education. Awareness of ICT also proves to be strong in mobile phone use, as 92 percent of patients that took part in the survey indicated that they own a mobile phone. Those that did not own them explained that they had at least one person in their household who owned a mobile phone. The high penetration of mobile phone use provides new avenues for the delivery of mobile health services.

There were various perceptions displayed by patients on ICT use. Some patients expressed the view that they cannot operate some of the ICT (e.g. computer, Internet). Most of the patients that expressed the view that they did not know how to use a computer or Internet either felt that the technology was too advanced (i.e. functional illiteracy) or either they had no access to working computer at all. ICT literacy implies the ability for users to operate diverse ICT tools. The surveyed patients indicated a high ICT literacy rate in terms of their capability to operate the radio (100%), mobile phone, and a landline telephone (99%). The ability to use different ICT was also high for PC (74%) and average for Internet (50%).

Large proportions of patients indicated that they use mostly radio (83%) and television (74%) for health related services e.g. listening to health programs or watching health education programs on TV. Telephone (56%) trailed by mobile phone (44%) were the common ICT used for health-related purposes. The traditional ICT such as radio (76%) and TV (69%) are mainly used as mediums for educational purposes. Radio ranked high (i.e. 100%) as the ICT that all the patients in Khomas region could operate, and which could easily be adapted for health education purposes. This is consistent with the results of Kenny's study where he reported that radio was highly used (71%) by rural people in Nepal as their source of information (Kenny, 2002:150). The Internet is slowly being used for health-related services as only (21%) of patients use it for this purpose. The study did not ask respondents on whether or not they used email to obtain for health services.

On the other hand in the Oshana region (see Table 2), a lot of patients indicated relatively low access to ICT such as computers (31%) and the Internet (19%). The main reasons provided for not having access to these ICT were (i) lack of knowledge and (ii) absence of necessary infrastructure to enable access to specific ICT. Despite the low access to ICT, all the patients surveyed stated that they use radio (100%) for entertainment and for listening to health services and that (98%) owned radios in their household. Mobile phones (95%) are also highly used in the Oshana region. Patients in the Oshana region demonstrated a relatively high functional literacy, as most of them could operate radio (100%), telephone (99%) and mobile phone (97%). A summary of ICT use patterns and perceptions in Oshana are shown in Table 2. In the Oshana region, radio (92%) and television (79%), were the two leading ICT that are mostly used for health-related purposes while telephone (45%) and mobile phone (39%) came third and fourth respectively as being used for health-related services. ICT such as mobile phone (55%), radio (95%), television (63%), are currently being used for educational purposes in the study zone of Namibia. In the case of television, HSP mentioned that they provide health education to patients by playing videos with films that inform patients about dangers of spreading diseases such as HIV and AIDS etc and how to combat the disease outbreak.

During the survey, patients were questioned on their willingness to improve their ICT skills. Patients displayed a strong interest in learning how to improving their ICT skills which shows a positive perception towards ICT. On the other hand HSP had different opinions on how existing ICT in their institutions has helped them to enhance the services provided to patients. It is remarkable to note that there was complete consensus among HSP on the view that ICT helps them to access new health information. It was observed that use of computers helps to improve efficiency and effectiveness of health management information. This mostly applied to departments such as admissions, where patient data needed to be captured and stored accurately.

Ninety-one percent of HSP viewed ICT as helping them to interact with other HSP and other health institutions and higher levels of authority. Eighty-one percent of HSP strongly agreed that ICT does provide ways to improve health services even though there are costs involved in the introduction, maintenance and utilization of ICT. More training of staff on ICT use is required to achieve more effectiveness. Ninety-five percent of HSP strongly agreed that the GRN needs to play a more prominent role in the provision of ICT for HSD, as they felt that the public sector is lagging behind in ICT use as compared to the private sector. HSP felt that the public sector should learn from the private sector how ICT is used in the process of service provision to the patients. Results of specific uses of different ICT in HSD are presented in table 3 and discussed in the following section.

The results indicate that ICT are deployed across different functional areas in health service provision in Namibia. The functional areas where ICI is currently deployed are admissions, consultation and clinical support, maternity, family planning, and emergency purposes. Overall,

Table 3. Major ICT applications in Namibia's health institutions, 2007

	Admission	**Consulting/ Clinical Support**	**Maternity**	**Family planning**	**Emergency services**	**Purpose of use**
Type of ICT used						
PC	√					-Patient record's keeping Administrative duties
Internet		√				-Search new health information Office duties
Email		√				-Communication with higher levels (e.g. District)
Mobile phone	√					-Used in cases where landline is not functional.
					√	-Contact emergency vehicles (ambulance) -Communication with other HSP (e.g. Polio campaigns)
Radio	√					-Used for personal reasons
TV		√	√			-Display videos on health education on diseases such HIV and AIDS, TB etc.
Telephone	√		√			-Making appointments
		√				-Consultations -Ordering medication for pharmacies -Commutation with district office
				√		-To call ambulance -To call doctors in emergency cases -Communication with district office, in cases of urgent documents
					√	-For referral cases to big hospitals
Fax Machine		√				-For administrative duties e.g. sending fax to higher levels such as district
					√	For referral cases
Pagers		√				To page doctors on call
					√	To page doctors on call
Electronic patient record		√				Used to keep track of medication (ARVs) intake for HIV and AIDS patients.

Source: Survey data, 2006

Table 4. ICT use constraints in the Khomas and the Oshana regions, 2007

Constraints	Description
Budgetary constraints	Finances are not enough to buy all the necessary ICT to assist in the process of service provision to patients.
Lack of basic infrastructure to support health service delivery	Some health facilities especially those in the rural areas lacked basic infrastructure such as electricity and this was a constraint in using ICT such as personal computers.
Lack of basic technological skills	Some HSP providers do not have skills in operation ICT related tools such as Personal Computers

Source: Survey data, 2007

telephone was the most commonly used ICT across all the various health departments. It is interesting to note that HSPs mentioned that TV was a common form of communication channel for health education as this corresponds with the patient's responses that they use TV as their main source of health information. Mobile phones usage was reported in admission and for emergency services especially when the cheaper landlines are not functioning. Pagers were commonly used in clinical support and emergency services. The personal computers and Internet were used in administrative support in admissions and clinical support respectively. The electronic patient record was used in clinical support to keep track of medications (ARVs) for HIV and AIDs patients. These results demonstrate the extent to which ICT have been deployed in different functional areas in Namibia. Despite making some tangible progress in ICT deployment for HSD, Namibia still confronted with some major challenges which are described in Table 4 above. These challenges were grouped into three main areas, (i) budgetary constraints, (ii) poor ICT infrastructure, and (iii) lack of basic ICT skills among health workers and patients. Budgetary constraints imply the shortage of sufficient public and private) funds required to acquire the necessary modern ICT in order to upgrade HSD systems in Namibia. Related to the problem of funding, is the weak back-borne infrastructure for ICT service delivery. The shortage of electricity hinders the effective utilization of ICT especially in remote rural areas. Without electricity, or alternative energy sources such as solar panels, the use of

computers and Internet will remain limited in geographically remote locations of the country. Even if the country were to allocate adequate funds for the purchase of needed ICT equipment and machinery, and rural electricity generation were to be expanded further, shortage of a critical mass of well trained ICT cadres will remain a major handicap for ICT use for HSD in Namibia. With new ICT constantly coming on stream annually, the development of human capital skills required to support and manage ICT-based health service delivery is central to its effective utilization and sustainability of such services. Although Namibia faces a number of constraints in delivering health services to patients, the foregoing results show a relatively high level of ICT use in both Khomas and Oshana region. This confirms that ICT use in Namibia has been growing and there is scope for further expansion and progress (Schware, 2003:3).

POLICY IMPLICATIONS AND FUTURE DIRECTIONS

In order to sustain the initial progress in ICT use in Namibia, the development of sound effective ICT policies is pivotal. The development of ICT policies plays a vital role in terms of providing timely interventions to stimulate ICT deployment and uptake. Namibia's health sector provides ample opportunities to create a huge market for ICT-based health services that will benefit both HSP and patients alike. According to Galloway and Mochrie (2005:41) policies interventions are needed to support rural ICT development and promote economic sustainability. Such policies should be developed with clear objectives and specific goals in mind, regarding expected achievements of the health institutions. Policies help determine the rate and direction of ICT uses for health purposes and benefits of policy development spills over artificial borders that exists between jurisdictions (Scott, 2004). In addition, key lessons can be drawn from policies, administrative and institutional arrangements, and ideas that work in a given setting. According to the United Nations (2007) public policies are often best designed and implemented in close dialogue with various stakeholders. The UN report specifically mentioned examples of South Korea and India that close cooperation between public and private sectors was crucial to the success of their ICT Industry. Further, in those countries, private industry associations participated in ICT-related policy formulation. Sub-Saharan countries should draw some key lessons from the development of ICT related policies on HSD that have been successfully implemented elsewhere (UN, 2007).

In the East Africa, there is ICT policy coordination at the regional level. The approach aims to increase levels of regional cooperation and development. The ICT policy framework in East Africa is designed to foster sustainable development in various areas and this includes the health sector (UN, 2003:2). McFarlane, Murphy and Clerkin (2006:245) discussed a number of health information policies in Ireland as they relate to telemedicine services. They concluded that using ICT in telemedicine is a challenge that need to be tackled by taking cognizance of the complexities involved, and actively fostering levers to implementation and sustainability through policy, practice and research initiatives. With reference to Asia, Quibria, Ahmed,Tschang and Reyes-Macasaquit (2003:819) state that policies to promote ICT involve investment in education, infrastructure, creation of favorable institutions, fostering new institutional innovations and international cooperation.

Governments and health institutions in Sub-Saharan Africa should have clear policies and specific strategies on how certain ICT should be implemented (Schware, 2003:3). Maumbe and Owei (2007:1) argue that ICT policy in Africa is lagging behind other regions. In order to achieve long term success in e-government policy development and implementation, institutions should examine the socio-economic context, key constraints and formulate appropriate policies that address those challenges. However, governments cannot merely set up their own policies but they must adhere to the international standards. Namibia (2002:33) has adopted the position that government policies, standards, and procedures must be internationally benchmarked for best practices. Furthermore, policies and standards should also facilitate interoperability within an international, voluntary and consensus-based environment for standards setting. The international standards bodies such as International Telecommunication Union guide Namibian policies and standards formulations. According to (Maumbe and Owei, 2007:1) the area of ICT policy development has received less attention in Sub-Saharan Africa, and South Africa is not an exception despite making great strides in e-government development. A study conducted by Joseph and Andrew (2006), recommends that policies must be developed in such a way that they support and stimulate ICT use by rural people. Furthermore, policies should be crafted in such a way that it improves ICT access at low cost especially through public service. E-health policy response of countries has been classified as “none”, “reactive” or “proactive” (Scott, 2004). While none is self-explanatory, reactive suggests policies that are crafted in response to some major internal shock or external pressure. Proactive, which what African countries should strive for, deals with policy development in advance of immediate need and guided by a context specific development strategy that is unique to given country and its socio-economic circumstances or resource endowments.

At the time of our study, Namibia's MOHSS did not have an ICT policy for HSD to patients as it was still in a development stage. But there is a national ICT policy that the MOHSS adheres to. According to the interview with the Directorate of Policy and Planning, the MOHSS adheres to policies established by the public service committees. With the recent establishment of a Ministry of Information and Communication Technology, Namibia is in a much better position to design a sustainable ICT policy for HSD. In addition, successful ICT policy initiatives in education and lessons drawn from other African countries could provide further insights into critical issues for consideration when crafting such a policy.

As already alluded, Namibia's Ministry of ICT is still in its infancy stage (Namibia, 2008). The new Ministry of ICT aims to establish future mechanisms for the collection of relevant information from operators and to conduct comprehensive research to identify relevant context specific issues, trends and other matters that may affect the sector. Further, the Ministry plans to establish a formal process for the periodic reviews of ICT policy documents with a comprehensive feedback mechanism from key stakeholders. Therefore, our chapter contribution to the book on e-government is expected to benefit the Namibian government and several other African governments involved in the design and implementation of sustainable ICT policies in the twenty first century.

CONCLUSION

This chapter examined the use of ICT in HSD in the Namibian context. The chapter described the NHSDL which shows the key health service facilities in the country and the existing and potential arteries for ICT utilizations. The results from the primary survey conducted with patients and also interviews held with HSP in Khomas and Oshana regions highlight the existing patterns of ICT use among patients and the health service departments or functional areas that have deployed ICT. The chapter outlines some of the major constraints in delivering ICT-based health services in Namibia namely, funding shortages, poor infrastructure and low ICT literacy. The high penetration rates for traditional ICT such as televisions and radios coupled with a growing use of mobile phones presents alternative relatively under-explored opportunities for HSD to patients. The increased use of mobile phones and mobile computer lat tops could help overcome geographic and infrastructural challenges associated with ICT use for HSD in Namibia.

The chapter highlights the need for the Government of the Republic of Namibia (GRN) to actively pursue the opportunities presented by ICT such as personal computers and mobile phones to complement traditional ICT-based HSD channels such as radios and televisions. The Namibia Ministry of Information and Communication Technology working in collaboration with the Ministry of Health and Social Services should develop "pro-active" ICT policies that will create an enabling environment for ICT use, and stimulate its uptake by both patients and HSPs. The results indicate a strong momentum for ICT use in HSD that can be further developed, strengthened and natured with the backing of a sound and effective policy development process. Without targeted policy development for ICT use in HSD, the current momentum will fizzle out, and one of the best opportunities to transform HSD in Sub-Saharan Africa (and thereby alleviate poverty) will be sadly missed.

The results in this chapter can be used to provide insights into similar efforts to incorporate ICT in HSD in other African countries. Future studies should examine ICT use in private or public health care focusing on specific patient groups (children, elderly, physically disabled members of society etc), functional areas (e.g. admissions, emergency services, maternity, clinical support, family planning etc), and the treatment of highly contagious disease outbreaks (e.g. HIV and AIDS, SARs, avian flu, swine-flu (HIN1), etc.). An alternative study could assess the willingness to use ICT such as mobile phones, personal digital assistants, and mobile lap-tops, as these are the likely future channels for HSD. Such a study should provide a comprehensive analysis of both the tangible benefits and the negative externalities associated with the use of such applications for HSD in both the short-term and the long-term.

REFERENCES

Anderson, A., Virmarlund, V., & Timpka, T. (2002). Management demands on information and communication technology in process-oriented healthcare organizations: The importance of understanding managers' expectations during early phases of systems design. *Journal of Management in Medicine*, *16*(2/3), 159–169. doi:10.1108/02689230210434907

Baldwin, L. P., Clarke, M., Eldabi, T., & Jones, R. W. (2002). Telemedicine and its role in improving communication in healthcare. *Logistics Information Management*, *15*(4), 309–319. doi:10.1108/09576050210436147

Bynum, A. B., Cranford, C. O., Irwin, C. A., & Banken, J. A. (2006). Effect of telemedicine on patient's diagnosis and treatment. *Journal of Telemedicine and Telecare*, *12*(1), 39. doi:10.1258/135763306775321407

Chandrasekhar, C. P., & Ghosh, J. (2001). Information and communication technologies and health in low income countries: the potential and the constraints. *Bulletin of the World Health Organization*, *79*(9), 850–855.

El Obeid, S., Mendlsohn, J., Lajars, M., Forster, N., & Brule, G. (2001). *Health in Namibia: Progress and Challenges*. Windhoek, Namibia: Raison Research and Information Services of Namibia.

Ertmer, P.A., & Addison, P, L., Molly, R, E. & Woods, D. (1999). Examining teacher's' beliefs about the role of technology in the elementary classroom. [Fall.]. *Journal of Research on Computing in Education*, *32*(1), 54–72.

Hesselmark, O., & Miller, J. (2002). A country ICT survey for Namibia. Retrieved from http://www.cyberzoo.co.za/download/milless/newdocs/Namrep%20v5.pdf

Hjelm, N. M. (2005). Benefits and drawbacks of telemedicine. *Journal of Telemedicine and Telecare*, *11*(2), 60–70. doi:10.1258/1357633053499886

Huggins, R., & Izushi, H. (2002). The Digital Divide and ICT Learning in Rural Communities: Examples of Good Practice Service Delivery. [May.]. *Local Economy*, *17*(2), 111–122. doi:10.1080/02690940210129870

Maumbe, B. M., & Owei, V. T. (2007). E-government Policy Development in South Africa: Current Status, Distributional Issues, and Future Prospects. In *Proceedings of the IST-Africa Conference*, 9th -11th May, Maputo, Mozambique.

Ministry of Information and Communication Technology. (2008). *Information technology Policy for the republic of Namibia 2008*. Windhoek, Namibia: Author.

Namibia. MOHSS (2004b). *The technical efficiency of District Hospitals in Namibia*. Windhoek: Directorate: Policy, Planning and Human Resources Development.

Rao, S. S. (2001). Integrated health care and telemedicine. *Work Study*, *50*(6), 222–229. doi:10.1108/EUM0000000006034

Sargeant, J. M. Medical education for rural areas: Opportunities and challenges for information and communications technologies. *Journal of PostgraduateMedicine, 51*(4), 301-307. Retrieved June 20, 2007 from http://www.jpgmonline.com/text.asp?2005/51/4/301/19244

Scott, R. (2004). Investigating e-health policy-tools for the trade. *Journal of Telemedicine and Telecare*, (10): 246–248. doi:10.1258/1357633041424377

Scott, R. E., Ndumbe, P., & Wootton, R. (2005). An e-health needs assessment of medical residents in Cameroon. *Journal of Telemedicine and Telecare*, 11.

Uldal, S.B., & Amerkhanov, J., Bye, Manankova, S., Mokeev, A., & Norum, J. (2004). A mobile telemedicine unit for emergency and screening purposes: experience from north-west Russia. *Journal of Telemedicine and Telecare*, *10*(1), 11–15. doi:10.1258/135763304322764121

Yamuah, L. K. (2005). ICT in the African health sector; towards healthy nations with ICT wealth. *I4d magazine*. Retrieved June 20, 2006 from http//:www.i4donline.net/may05/africahealth.asp

Zolfo, M. & Lynen (2008). Telemedicine for HIV/AIDS care in Low Resource Settings: Proven Practices. In *Proceedings of the 2008 conference of the IST Africa, Windhoek,* 07-09 May 2008, Ireland, IIMC International Information Management Corporation, Ltd.

This work was previously published in E-Agriculture and E-Government for Global Policy Development: Implications and Future Directions, edited by B.M. Maumbe, pp. 191-206, copyright 2010 by Information Science Reference (an imprint of IGI Global).

Chapter 4.8

Factors Affecting the Adoption of ICT for Health Service Delivery in Namibia:

The Role of Functional Literacy and Policy Implications

Blessing M. Maumbe
Eastern Kentucky University, USA

Meke I. Shivute
Polytechnic of Namibia, Namibia

Vesper T. Owei
Cape Peninsula University of Technology, Republic of South Africa

ABSTRACT

The article examines ICT use in health service provision in Namibia. The patterns of ICT use for health services by patients, public and private health service providers are not yet fully understood. This study describes ICT applications in health service delivery to patients in the Khomas and Oshana regions of Namibia. The study interviewed 134 patients and 21 health service providers. Factor analysis on ICT use identified three main factor groupings namely, 'high technology', 'mobile technology' and 'traditional technology'. Multinomial regression results showed the major factors affecting multiple ICT awareness in the two regions as functional literacy, diverse sources of health information services, age and educational level of the patients. Logistic regression results on individual ICT use identified functional literacy, personal privacy, cost of ICT, age, education, and positive perceptions about ICT applications in improving health services as statistically significant factors influencing adoption by both rural and urban patients in Namibia.

INTRODUCTION

The use of Information and Communication Technologies (ICT) in the provision of health services is growing rapidly throughout Sub-Saharan Africa and the developing world. As ICT are deployed in health service delivery (HSD), there is a need to understand how individuals are using the new devices to access health services. Namibia is one of the few African countries that have demonstrated leadership in ICT utilization (SIDA, 2002; Hesselmark & Miller, 2002:36), and HSD seems to provide growing opportunities for the application of these modern technologies.

For the effective use of ICT for health services to occur, both patients and health service providers (HSP) must be willing and able to use the new devices in health service provision. In addition, the use of ICT for HSD must be socially inclusive; that means both rural and urban-based patients must be exposed to the new ways of health service provision. Moreover, social inclusivity requires that both young and old, rich and poor, able-bodied and physically challenged, and individuals of various backgrounds must have equal access opportunities.

However, the emerging patterns of ICT use for health services by Namibian patients are not fully understood. Similarly, the use of ICT by public and private health service providers remains unknown, yet this may influence how they deliver services to their patients in the future. Given the gap that exists between the understanding of (i) the patterns of ICT use by patients and (ii) the degree or the extent to which ICT are being used for HSD by HSPs in Namibia. It is of paramount importance that knowledge is amplified of how this growing phenomenon is unfolding. Therefore, successful utilization of ICT for HSD requires that digital divide constraints, patient technology demand patterns, service provider access and utilization, and public policy among others are seriously addressed.

Failure to understand the key factors affecting ICT use for health services by patients may lead to gaps in enabling policies, ineffective policy formulation, or a total absence of policy. In turn, this may lead to a general lack of ICT awareness or it might affect the effective use of ICT in HSD in general. Without doubt, HSPs in both private and public health sector play a central role in the provision of ICT-based health services. In order to improve our understanding of the circumstances surrounding ICT use for health services, this particular article seeks to examine; (i) the factors affecting the use of both individual and multiple ICT by Namibian patients (ii) Highlight key constraints that inhibit patient's access to ICT for health services, and (iii) Recommend policy considerations for improving the uptake of ICT for HSD in Namibia. In order to address the above stated issues, this study analyzes the type of ICT being used in HSD to patients in the Khomas and Oshana regions of Namibia, an urban and rural setting respectively.

The rest of the article is structured as follows: In the next section, background information on transformations in HSD in Namibia is presented. Then secondly, the significance and limitations of the study will be described. Thirdly, institutional policies in support of ICT for HSD in Namibia will be examined focusing on government ICT policy and its implications for HSD and this is followed by a presentation on the theoretical framework of the study. Fourthly, the next Section presents the methodology used to collect and analyze data. And finally, the results and discussion of the findings will be presented and this will lead into the concluding remarks and recommendations for future research.

BACKGROUND: TRANSFORMATIONS IN HEALTH SERVICE DELIVERY (HSD) IN NAMIBIA

As in most developing countries, Namibia is at the threshold of expanding its ICT use in HSD to promote sustainable development and the knowledge society (Schware, 2003; Crede□ & Masell, 1998). In today's information society, health professionals need to maximize the potential benefits offered by ICT as a means to improve public access to health care and information (Wallace: 1997:88).

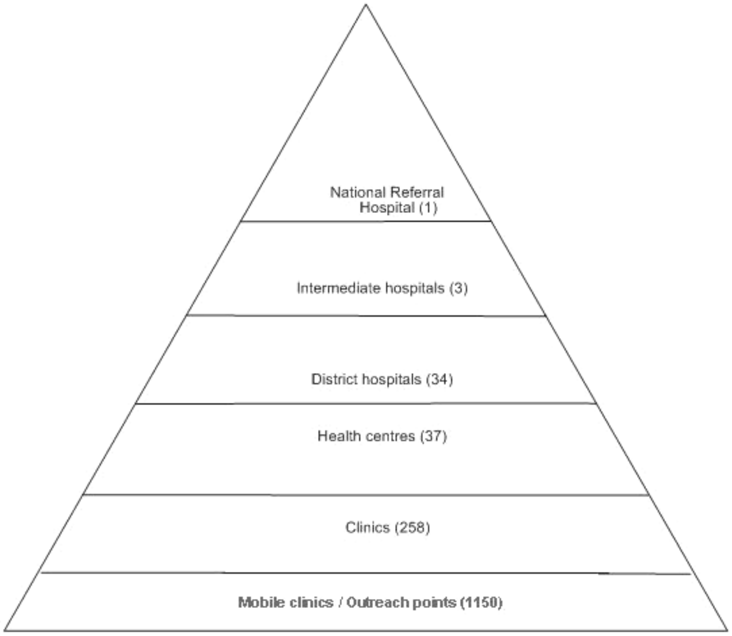
The Government of the Republic of Namibia (GRN) has developed a general ICT policy which was an outcome of several consultative workshops. This policy was aimed at shaping the use of ICT in the country, starting with the education sector. The policy provided the basis for the telecommunications policy and regulatory framework of 1999 (Namibia, 2002:19). In addition, there have been policy reforms in terms of ICT implementation in Namibia (Hesselmark & Miller, 2002:5). According to the Namibian National Information and Communication Infrastructure (2006), the country has been active in ICT policy formulation and in developing the necessary infrastructure for the information society. The country's telecommunications and Internet infrastructure is very advanced by African standards, (United Nations Economic Commission for Africa, 2006). It is important to observe that although a general ICT policy has been developed and implemented, there is still no official policy on ICT use for HSD.

A GRN's national development plan entitled "Namibia Vision 2030" aims to "improve the quality of life of the people of Namibia to the level of their counterparts in the developed world by 2030" (Namibia, 2004c: 7). The 2030 vision pertaining to ICT status in Namibia aims to advance ICT to achieve social and economic transformations in the country. As the cost of ICT continue to fall while the capabilities increase, ICT are bound to be applied throughout all the development sectors of the economy for the benefit of society (Namibia, 2004c: 79). One of the weaknesses of the "Namibia vision 2030" is that it does not describe the current state of ICT for HSD in Namibia, but it simply focuses on what is aimed to be achieved by the year 2030.

The Ministry of Health and Social Services (MOHSS) has adopted a decentralization policy to improve health service provision and management by devolving authority to the thirteen regional directorates of the MOHSS (Namibia, 2003:31). The thirteen regional directorates manage service delivery in all health districts. The provision of health services in Namibia is divided proportionally between the government (i.e., provides 70-80%), missions (i.e., provide 15-20%) and the private sector which provides 5 percent of the health services. Delanyo (2001:2) explains that the non-governmental HSPs in Namibia are mainly in the form of various religious missions, which are subsidized by the government and include hospitals, health centers and clinics, mainly in the rural areas of the northern part of the country. For example, the missions (i.e., Lutheran, Anglican, and Roman Catholic) are non-profit providers, and they are 100 percent subsidized by the MOHSS (Namibia, MOHSS, 2004b:5). The organization of health services in Namibia is depicted in Figure 1.

Given this background on health services provision, what is important to note is the fact that the state of health services is poised for a major improvement with the introduction of ICT in the Namibian health sector. ICT are used to support HSD to all the thirteen regions and thirty four districts. The main aims of using ICT tools such as personal computers is to analyze, document, and distribute the planning, implementation and evaluation of health information, and also to assist with resource allocation and direct changes in policies and strategies. Furthermore, the use of ICT aims to improve the delivery of quality health services and improve the effectiveness of strategies, monitor performance over time and

Figure 1. Organization of health service delivery in Namibia



Source: Namibia, 2003:7.

identify health facilities that need support and supervision (Haoses-Gorases, 2005).

According to Baldwin, Clarke, Eldabi and Jones (2002:312), ICT plays an increasingly crucial role in delivering healthcare nowadays. In Namibia, ICT applications to support HSD are growing, partly because the MOHSS has completely decentralized and computerized the health information system (HIS) to the regional and district level (Namibia, 2004a:26). The foregoing shows that ICT are being used to some extent to support HSD, even though there is need for improvement on the efficiency and effectiveness of the processes at the operational levels.

This study describes and analyzes factors that influence the adoption of ICT for HSD in Namibia with specific reference to the role of functional literacy and policy implications.

MOTIVATION, SIGNIFICANCE AND CONTRIBUTION OF STUDY

Given the growing importance of ICT use for socio-economic development in Africa, it is crucial to study the use of ICT in improving HSD in Namibia. It is crucial so that health services are diffused to communities in remote locations and those faced with health emergencies that require immediate diagnosis and intervention. There are signs of growing ICT related developments in the area of HSD in Namibia. HSD encompasses the provision of information for health care, prevention and treatment. By examining the literature and conducting a survey with both the patients and HSPs, recommendations can be made to policy makers on how to effectively deploy ICT in delivering health services in Namibia. The results of this study can be used to provide lessons for other African countries and draw some insights for policy and further research work.

LIMITATIONS OF THE STUDY

The limitations of this research are threefold; (i) it covers only two regions of Namibia, (ii) targets a specific age group of patients (i.e. those who were 15 years and older at the time of the study), and (iii) the fact that these results are drawn from a cross-sectional survey that are specific to the time of the study. We recognize the fact that ICT uptake is constantly evolving and the value of longitudinal studies should not be underestimated. It is also important to emphasize that this study does not address the use of ICT for the treatment, prevention or caring of patients with a specific disease ailment. Such more specialized studies will help provide valuable contribution to ICT applications in HSD.

LITERATURE REVIEW

Potential Impacts: ICT has the potential to radically change the way health services are delivered to patients and improve the quality of health services by providing easy access to health information. The potential use of ICT as a means to improve the quality of health services is widely acknowledged worldwide, and health institutions are striving to identify ways to deliver their services more efficiently and effectively. ICT can be utilized to minimize geographic isolation for the population in rural areas, and they can facilitate access, dissemination, utilization and exchange of information on combating debilitating diseases such as malaria, tuberculosis and HIV/AIDS (Yamuah, 2005:1). Chandrasekhar (2001:851) adds that ICT has the potential to be used as a mechanism to increase the transparency and efficiency of governance, which in turn would improve the availability and delivery of health services. ICT encourages easy dissemination of disease treatment and disease control and it also helps to reduce costs on patient transfers (Yamuah, 2001:2). Telemedicine is a good example of this, as it simply allows exchange of health information and delivery of health care across distances by using telecommunications (Rao, 2001:223).

Benefits: Numerous benefits in ICT use for health services abound. For instance, ICT use can facilitate the delivery of information in a reliable manner and enhance communication in the health sector. Technologies like the Internet and e-mail have the ability to send information in a fast, efficient and cheap fashion, which can provide remarkable improvements in access to information and care in the health sector (Pradhan, 2003:157). Historically, traditional technologies such as telephones have improved delivery of health services to patients, especially those in remote areas, and they continue to play a major role in this process. Mcwhirter (2003:341) suggested a wide range of ICT options and amongst them a bedside television that has been used as a source of health information for patients in hospitals in England. Radio has also been widely used as a means of communication especially in rural areas to better communicate health information to communities in remote areas. Kenny (2002: 141) reviewed the potential efficacy of radio and telephones and concluded that such ICT are powerful and sustainable tools that meet diverse information needs of the poor and that traditional technologies are less expensive than high technology such as Internet. In Uganda, FM radio transmission and modern graphics transmitted via the TV stations are one-way communication channels that are being utilized to deliver health service information to patients (Kasusse, 2005:148). Similarly, mobile computing or technology which includes laptops, palmtop computers, Personal Digital Assistants (PDAs) etc., are examples of portable ICT that are increasingly being used for health services (Hameed 2003:100) and are making health procedures more accurate and efficient thereby reducing the risk of human error (Chao, Jen, Hung, Li & Chi, 2006:1;Chau and Turner 2006: 307). PDAs have proven useful in African countries such Uganda (Satellife Inc, Uganda Chartered Healthnet and Makerere University in 2003).

Challenges: While there are many benefits offered by using ICT in the health sector, there are a number of challenges which need to be tackled before the benefits are realized. Yamuah (2005:2) states that developing countries are facing a lot of challenges that hinder ICT use. The challenges in the health sector may be summarised as outdated modes of data collection, lack of electronic means to capture data, dependency on manual processes in hospitals for administrative, diagnosis and referral services in Africa and other developing countries, and low literacy rates among health providers that in turn affect ICT utilization, since literacy is critical for ICT use. The literacy problem is actually spreading from computers to new ICT, such as PDAs, 3G mobile phones, etc. Infrastructure constraints such as low distribution of reliable telecommunications and grid power in community health units, and lack of technical support have been identified as a hindrance in ICT use and the high establishment costs for ICT projects given limited budget for health services. The barriers in using ICT to enhance health services relate both to the specific use and access to certain ICT.

Computer use in HSD: Over the past decades, the use of computers in HSD has increased. Computers are being used particularly in large public hospitals and also in different applications such as Health Information Systems (HIS), computer-based psychological testing applications and individual patient monitoring in the intensive care units (Egan & Liu, 1995:357). Rao (2001:222) states that computers have become indispensable to the healthcare industry. The Internet has been widely used in health care industry and it has brought remarkable changes in the way services are delivered. It has been used especially in developed countries to supply health related information, such as diseases symptoms, research in the medical fields, etc. The Internet plays a vital role in the health sector and it has improved the process of delivering services to patients. According to Seror (2001:2), the Internet provides rapid access to medical information and expert consultation, and this will help in the process of delivering services in developing countries. Tele-health is one of the key ICT uses which include health services, education and research supported by the Internet, and it affects the way health services are provided (Seror, 2001:2).

INSTITUTIONAL POLICIES IN SUPPORT OF ICT FOR HEALTH SERVICE DELIVERY

Policies play a vital role in the use of ICT in any sector. According to Galloway and Mochrie (2005:41) policies have been developed for a number of ICT related issues. Galloway and Mochrie (2005:41) stated that policies may best intervene to support rural ICT development for economic sustainability or advantage. Policies should be developed with clear objectives and specific goals in mind, regarding expected achievements of the health institutions. In East Africa, ICT policies are being coordinated at the regional level with the aim to increase socio-economic development. The ICT policy framework in Eastern Africa is designed to foster sustainable development in various areas including the health sector (UN, 2003:2). In Asia, Quibria, Ahmed, Tschang and Reyes-Macasaquit (2003:819) state that policies to promote ICT involve key investments in education, infrastructure, creation of favorable institutions, fostering new institutional innovations and international cooperation. Schware (2003:3) argues that governments and health institutions should have policies and strategies on ICT implementation. Maumbe and Owei (2007:1) are of the opinion that in order to achieve long term success in e-service delivery and e-government policy development, it is critical to examine the socio-economic context and identify key constraints that inhibit the formulation and implementation of appropriate policies.

However, governments cannot merely set up their own policies but they must adhere to the international standards. Namibia (2002:33) has adopted a position that local government policy standards and related processes should be internationally benchmarked and must also facilitate interoperability within an international, voluntary and consensus-based environment for standards setting. The international standards bodies such as International Telecommunication Union guide Namibian policies and standard formulations. According to Maumbe and Owei (2007:1), the area of e-government and ICT policy development and implementation has received less attention in Africa, and South Africa is not an exception despite making great strides in e-government development.

At the time of the study, the Namibian MOHSS did not have an ICT policy developed specifically for the delivery of health services to patients. But there is a national ICT policy that the MOHSS adheres to. According to the interview with the directorate of policy and planning in the MOHSS the ministry adheres to policies set up by the public service management committees. However, it was established that the policy for HSD was in draft form at the time of the study and was still to be implemented. Even though, there is no ICT policy specifically for HSD in Namibia, there have been initiatives in other sectors such e-education. The ICT policy for education has been implemented with the aim of articulating the relevance, responsibility, and effectiveness of integrating ICT in education with a view to meeting the challenges of the 21st century (Tech/na, 2007:1). In this regard, Namibia is deemed to benefit from a similar focused ICT policy for HSD.

THEORETICAL FRAMEWORK FOR TECHNOLOGY ADOPTION IN HEALTH SERVICE DELIVERY

The use of ICT such as PDAs, PC, mobile devices etc. in the health sector has grown and both patients and health service providers need to be aware of these changes. According to Schaper & Pervan (2004), applications such as electronic patient records, telemedicine, clinical information systems will become common place in the health industry. However, the key question should be if such applications are implemented, will the stakeholders adopt or use the applications or ICT provided to them? Understanding the adoption factors and diffusion of ICT is paramount.

Damanpour (1991) study on adoption of health innovations reports that managerial attitudes towards change have positive influence on innovation adoption. Ma and Liu (2004) used the Technology Acceptance Model (TAM) to explain the usage of information technology. Johnson (2005) argues that TAM explains perceived ease of use and perceived usefulness predicts attitude toward use of technology. Further, the author adds that "attitude toward use predicts the behavioral intention to use". Davis (1989), defined perceived usefulness as the extent to which a person believes that using technology would enhance job performance and perceived ease of use refers to the extent to which a person believes that using the technology would be free of mental effort. According to Gagnon et, al, (2005) successful implementation of telehealth will ultimately depend on both human factors and organizational (and managerial or operational) factors.

A number of studies have used TAM as a basis for discovering the effect of external variables on the internal beliefs, attitudes, and intentions of users. A study by Lu, yu , Yiu and Yao (2003) developed a TAM for wireless Internet via mobile devices. Their study focuses on explanatory factors for use of wireless Internet and mobile devices. Lu, yu , Yiu and Yao (2006), conducted a comparison study whereby they compared various theories on technology adoption.

In contrast, the Theory of Planned Behavior (TPB) is believed to provide more specific information that can better guide development (Mathieson, 1991). TPB speculates that individual behavior is determined by behavioral intentions where behavioral intentions are a function of an individual's attitude toward the behavior, the subjective norms surrounding the performance of the behavior, and the individual's perception of the ease with which the behavior can be performed (behavioral control) (Ajzen,1991). The TPB theory was later extended and integrated with TAM by Taylor and Todd (1995). The integrated model further incorporated additional factors that were not present in TAM.

The Unified Theory of Acceptance and use of Technology (UTAUT) explains end user intentions to apply an information system (IS) and subsequent usage behavior. According to Venkatesh et. al.,(2003), the theory consists of four key constructs namely, performance expectancy, effort expectancy, social influence, and facilitating conditions that are direct determinants of usage intention and behavior (dependent factors). Independent factors such gender, age, experience, and voluntariness of use are hypothesized to mediate the impact of the four key constructs on usage intention and behavior (Venkatesh et. al., 2003).

Not much research has been done to understand factors affecting multiple technology adoption in health service provision to patients. This particular study uses a different approach based on (i) the multiple nature of the ICT being adopted for health services. Secondly, the study setting is unique in that it compares the circumstances affecting ICT use for HSD among both rural and urban patients in a developing country context. The selection of variables affecting adoption draws upon common categories of independent variables that were used in previous studies namely, attitudinal, demographic, facilitative, managerial/operational, geographical, and performance related variables. A selection of previous studies and models used on technology adoption are summarized in Table 1.

Since this study focuses on the adoption of several ICT for HSD, it will employ multinomial and logistic regressions to determine significant factors that influence the aggregate use of these modern technologies and to draw policy implications. Those two models help us to understand factors affecting multiple as well as individual ICT adoption respectively. The empirical model uses key factors such as functional literacy, sources of health information services and demographic variables (e.g. age, gender, and level of education) to explain ICT use for HSD to patients. Table 2 summarizes the different categories of independent variables used in the empirical models. Based on the fore-going information; the next section will therefore describe the methodology used to collect and analyze data from respondents.

METHODOLOGY

The study examined ICT use in HSD in Namibia's rural and urban areas. The main focus of our study was on how patients and HSP use ICT in HSD. The study also examined patient views, constraints they face in using ICT to access health services, as well as government ICT policy and its implications for HSD.

Location of the Study

The study was conducted in the Khomas and Oshana regions of Namibia. The rationale for choosing these regions is that Khomas is representative of a typical urban area while Oshana region is situated in the northern part of the country which is primarily a rural setting. By conducting the survey in two different geographical areas, the researchers sought to make comparisons of any geographical and socio-economic differences and or similarities in ICT use for HSD.

Table 1. Selected technology adoption studies

Author	Model description	Data Collection (Sample Size)	Factors	Remarks
Davis (1989)	Technology acceptance model (TAM)	Cluster analysis used to determine the structure of the substrata.	-Near-term usefulness -Long-term usefulness -Ease of use -Behavioral intention to use	Developed the TAM to validate perceived usefulness & ease of technology use.
Lu, et.al., (2003)	Technology Acceptance Model (TAM) for wireless Internet via mobile devices	Empirical study used to examine the entire TAM for wireless Internet model.	Behavioral intention -Usage behavior -Performance expectation -Effort expectancy -Social influence -Facilitating conditions-age, gender, experience, willingness to use.	TAM for wireless Internet proposes a framework for understanding, explaining and predicting factors that influence individual acceptance of wireless Internet and mobile devices.
Chau and Hu (2001)	Comparison of TAM, Theory of Planned Behavior (TPB) and decomposed TPB models.	An empirical survey was used to get responses on telemedicine technology acceptance from more than 400 physicians in public tertiary hospitals in Hong Kong.	-Behavioral intention, attitude -Subjective norms -Perceived behavioral control -Perceived usefulness -Perceived ease of use compatibility	The model was limited to explaining technology acceptance by individual physicians.
(Venkatesh et. al., 2003).	Unified theory of acceptance and use of technology (AUT).	Longitudinal field studies conducted among individuals being introduced to a new technology in four different organizations.	-Individual differences, -Technology complexity, -Facilitating conditions -Social influences - Wireless trust environment - Near-term usefulness -Long-term usefulness -Nature of use-voluntary versus mandatory -Ease of use	The Unified Theory of Acceptance and Use of Technology (AUT) explains 70 percent of the variance in intention to use technology.
Gagnon et. al., (2005)	Contingency Analyses	Telephone interviews to 32 hospitals participating in Extended Telehealth Network of Quebec.	Identification of organizational factors affecting telehealth adoption.	Adoption affected by larger geographical, economic, and socio-political environment.

Table 2. Description of variables

Variable	Variable Description	Measurement/Scale
Dependent variable		
ICTAWARE	ICT awareness	[1] = Traditional technology, [2]= Mobile technology, [3]= High technology
Demographics/Patient Characteristics		
AGE	Age	Years
GENDER	Gender	[1]=Female, [0]=Male
EDUCATION	Level of education	Count/scale 1= Primary 2= Secondary 3=College 4 =University
RACE	Race	[1]=Black, [2[=Colored [3]=White
INCOME	Household income range	N$
LOCATION	Region	[1]=Khomas,[0]= Oshana
Operational/Management Variables		
INFOSCOUNT	Number of health information sources	Count variable
LITCOUNT	Number of ICT a patient can operate	Count variable
PRIVACY	Number of ICT contacts one is willing to share	Count variable
Perception variables		
STC	Skills and training capability	[1]= yes , [0] = no
STPERCEPT	Service convenience	[1]= yes , [0] = no
AFFORDP	Perception on affordability	[1]= yes , [0] = no
PEPINFRA	Perception on infrastructure	[1]= positive perception on infrastructure [0]= otherwise
PEPTRNW	Perception on training	[1]= positive perception on training [0]= otherwise

Source: Survey data, 2006

Khomas region is located in the central part of Namibia and it is 37,007 square km², and this is where the capital city Windhoek, is situated. The region consists of various health facilities that include a national referral hospital, an intermediate hospital, two health centers, seven clinics, three private hospitals, private clinics and thirty-three outreach points. The region has the highest population which stands at 264,616 compared to other regions in the country, and the population per hospital is 121,278 (Namibia, 2006). Access to ICT in the Khomas region is expected to be higher than Oshana, as the community tends to have better access to infrastructural resources. However, access to infrastructure cannot be taken to imply actual use, because it is possible that the community might have access to various ICT but may not necessarily utilize them. Nonetheless, Khomas region tends to have better health facilities as it is more developed than the Oshana region.

On the other hand, Oshana region is the smallest region (5,290 km²) with a population of 167,797, hence it is densely populated (Namibia, 2004a:1). The Oshana region forms the second largest population concentration in Namibia after Windhoek, but it lacks basic infrastructure and most of the services and facilities normally found in urban areas (Anon, 2007). The Oshana health directorate is divided into fifteen health facilities, one Intermediate Hospital (regional), four health centers and twelve clinics. The district also has twenty-eight outreach points. The Intermediate hospital is the ultimate referral point in the Oshana region and it is responsible for providing essential back up services and support for clinics and health centers in the region. Health centers are smaller than Intermediate hospitals and they are found in two types, namely, day care health centers and rural health centers (Namibia, 1998:16). The latter is common to Oshana region. The population per hospital in the Khomas region is 169,147 (Namibia, 2006).

DATA COLLECTION

Primary Data

Two separate surveys on patients and HSPs were conducted. The surveys were carried out in private and public health facilities in the Khomas and Oshana regions to explore ICT use by both patients and HSPs. The surveys were conducted during the period from July 2006 to August 2006. Given the privacy and confidentiality associated with health studies, permission to conduct the research study was first obtained from the Permanent Secretary of the MOHSS before data could be collected. Respondents were given the opportunity to not participate on the survey and were informed that their answers will be kept anonymous and their personal information will not be disclosed publicly. In addition, prior to the implementation of the actual survey, the structured questionnaires were pre-tested to improve the logical flow and rephrase vague questions that both patients and HSPs had some difficulty understanding. In that regard, pre-testing the questionnaires helped to evaluate the clarity of the instructions on the questionnaires and exclude sensitive health questions.

A total of 21 HSP were interviewed to determine factors that influence their use of ICT in delivering health services and specifically how ICT was being used to serve patients. The questionnaire for patients sought to establish kinds of ICT used when seeking health services, and obtain their views on ICT related services rendered by HSPs. The researcher made sure that all the patients who participated in the study were screened based on (i) if they had visited a health facility in the past three months and, (ii) if they were at least 15 years of age. Data was collected from a total of 134 patients in both the Khomas and Oshana regions. Table 3 shows the number of responses from questionnaires in different health facilities.

Table 3. Number of questionnaires administered in the Khomas and Oshana health facilities

Type of health facility	Number of questionnaires administered with patients	Number of Health service providers interviewed
Khomas region	72	10
Oshana region	62	11
Total	134	21

Source: Survey data, 2006

Secondary Data

Firstly, secondary data was sought *from various government publications such as white papers and public health policy documents. The research examined Namibia's ICT policy development and specifically its implications for the health sector. Secondly,* GRN officials from the P*olicy and Planning Directorate in the MOHSS were interviewed to further investigate* policies that engender ICT use in HSD. Secondary data obtained from the review of public policy documents and personal communications with government officials from the Policy and Planning Directorate provided useful insights on Namibia's readiness for ICT use in HSD.

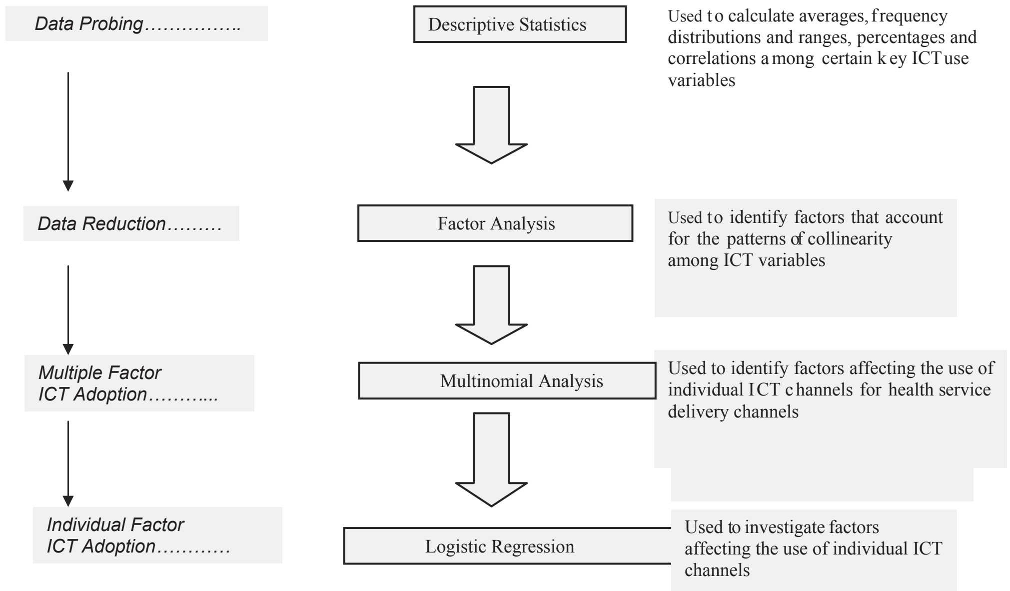
Sampling Procedure

The first step involved the identification of the target population to be studied. The target population in terms of a geographical area studied was the HSPs and patients in health institutions in the Khomas and Oshana regions. The sampling procedure was therefore designed to produce a representative sample of patients from various public and private health facilities in the two regions. The selection procedure of the population sample was based on two sampling methods, namely multi-stage stratified sampling and purposive random sampling. Multi-stage stratified sampling sought to capture different regional health facilities and purposive random sampling sought to include only those patients who met a specific qualifying criteria as already highlighted above.

TECHNIQUES OF ANALYSIS

The analysis was conducted in a series involving four steps. The steps that were used in the analysis are (i) descriptive statistics, (ii) factor analysis, (iii) multi-nominal regression and (iv) binary logistic regression. A summary of the steps or techniques used for data analysis are depicted in Figure 2.

Figure 2. Summary of steps in data analysis procedure



Used to calculate averages, frequency distributions and ranges, percentages and correlations among certain key ICT use variables

Used to identify factors that account for the patterns of collinearity among ICT variables

Used to identify factors affecting the use of individual ICT channels for health service delivery channels

Used to investigate factors affecting the use of individual ICT channels

Source: Survey data, 2006

Descriptive Analysis

This was used to calculate averages, frequency distributions, ranges, percentages and correlations among certain key ICT use variables as well as between ICT use and patient demographics.

Factor Analysis

Factor analysis was conducted *on eight ICT based HSD channels used in the study areas namely, PC, email, Internet, fax, mobile, radio, telephone and television. The aim was to find out if they could load on a common component in the component matrix. Kaiser- Meyer-Olkin and Bartlett's test was conducted to test if the variables were suitable for factor analysis. Bartlett's test was found to be statistically significant for the combined data set*

Multinomial Analysis

Multinomial regression was used to identify factors affecting the use of multiple ICT channels for HSD. The ICT awareness variable was developed using results obtained from the factor analysis which generated three categories which were labeled, 'high technology', 'mobile technology' and 'traditional technology'. A chi-square test was conducted to identify important variables affecting ICT awareness.

Results from the chi-square test were then used to identify variables that were used in the multinomial model. Since there were multiple responses for ICT use, multinomial regression analysis was carried out to determine factors influencing the use of multiple ICT in HSD in Khomas and Oshana region. The dependent variable (ICTAWARE) was determined based on the patient's usage and ownership of ICT.

Logistic Regression Analysis

The data was analyzed further using a logistic regression model to investigate factors affecting the use of individual ICT channels. *Logistic regression analysis was conducted on pre-selected "high technology" and "mobile technology" channels to determine the specific factors driving individual ICT use. Booysen (2006: 46) explains that logistic regression analyzes the relationship between one dependent variable and a number of independent variables. The selected ICT based channels used as dependent variables in the two separate Logistic regression models were (i) PC and (ii) mobile phones respectively.*

RESULTS AND DISCUSSION

The analysis of the results from the Khomas and Oshana regions was carried out to identify patterns of ICT use for health services in the two regions.

Descriptive statistics were conducted on data obtained from patients. Initially, the data sets from the urban and rural health institutions were analyzed separately to describe the ICT use patterns by region. Exploratory factor analysis was conducted to identify factors that explain patterns of collinearity among the eight ICT-based communication channels. Results of factor analysis identified three main factor groupings namely, '*high technology*', '*mobile technology'* and '*traditional technology'*. These factors were then used in the multinomial regression analysis to investigate factors affecting awareness of multiple ICT use by the patients. *Logistic regressions were used to reinforce the results from the multinomial regression analysis by identifying specific factors that influence individual ICT use by patients.*

Table 4. Namibian patient demographics by region, 2007

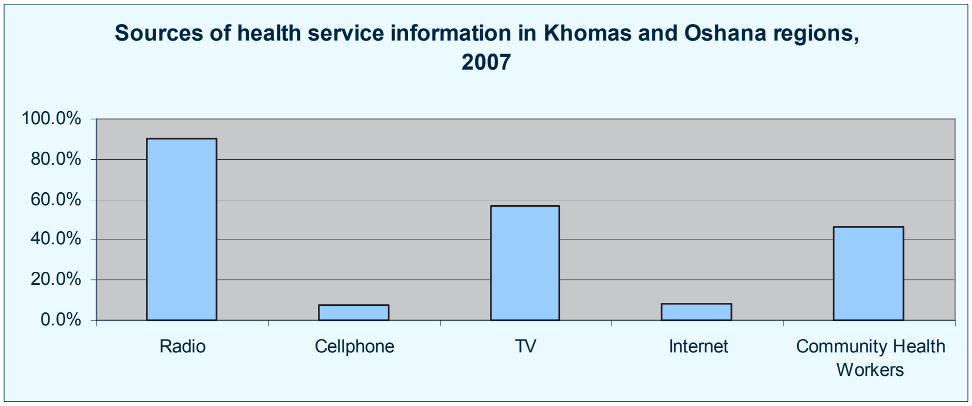
	Khomas region		**Oshana region**		***Both regions***	
Demographics	**Total N=72**	**%**	**Total N=62**	**%**	***Total N=134***	%
Gender						
Female	54	71	44	69	98	73
Male	18	24	18	28	36	27
Age Distribution						
Under 21	11	15	8	13	19	14
21-30	30	40	33	52	63	47
31-40	16	21	11	17	27	20
41-50	9	12	6	9	15	11
51-60	5	7	2	3	7	5
61 and older	0	0	2	3	2	1
Education						
Primary [grade 1- 7]	4	5	7	14	11	8
Secondary [grade 8- 12]	46	61	34	65	80	60
Tertiary College	10	13	10	19	20	15
University	9	12	1	2	10	7
Other	n/a	n/a	n/a	n/a	13	10
Race						
Black	59	82	61	98	120	90
White	3	4	0	0	3	2
Colored	10	14	1	2	11	8
Household Income						
Less than N$ 5,000	43	57	38	59	82	61
N$5001-10000	24	32	14	22	37	27
N$11000-15000	3	4	5	8	5	4
N$16000 and more	none	none	2	3	5	4
Not disclosed	n/a	n/a	n/a	n/a	5	4

Source: Survey data, 2006

Results of Patient Demographics

Patient's demographic characteristics by region are presented in Table 4. Out of a total of 134 respondents from both Khomas and Oshana regions, 71 percent of the respondents were female. The largest group of patients (47%) was in the 21 to 30 years age group from both regions. The majority of patients (89%) were black and (60%) have at least completed secondary education and 15% had finished college. The majority (61%) of the patients surveyed reported a household income of less than N$5000.

Figure 3. Distribution of information sources used by patients in the Khomas and Oshana regions



Source: Survey data, 2006

Comparison of the Khomas and Oshana Regions

The study compared the patterns of ICT use in the two regions. These comparisons covered mainly ICT health information sources, ICT-based communication channels, and their use in HSD.

Figure 3 shows the distribution of sources of information used by patients in the two regions. The two main ICT channels that were being used by patients as their sources of health information are radio and television (TV). Patients in the Khomas region tend to have more access to TV which was expected due to the fact that Khomas is in an urban area. Similarly, Internet use as a source of health information is higher in the Khomas (13%) than in the Oshana region (8.2%).

However, community health services rendered by health workers are higher in the Oshana (55%) than Khomas region (39%). The majority of patients indicated that they depend on multiple sources of health information. In addition, patients from both regions indicated that they also obtain their health information from other sources such as, newspaper, pamphlets from health facilities, health education offered by nurses at health facilities, local or national campaigns and also through telephone enquiries to a health facility.

From the foregoing results, it is evident that ICT use is comparatively higher in the Khomas than in the Oshana region. Khomas being an urban region where most relatively high income people live this could be partly the reasons why access to, and use of ICT is higher than in the Oshana region. Combined data analysis results (i.e. Figure 3) clearly show that radio (90%) was the leading source for health information followed by national TV (58%), community health workers (48%), Internet (13%) and mobile phone (12%). It is interesting to note that mobile phone usage for HSD is still evolving despite more than 90 percent penetration rate recorded during the survey demonstrating a high mobile phone usage in general.

Factor Analysis Results on ICT Use for Health Service Delivery

The study revealed that eight ICT-based channels were used for HSD by patients in Khomas and Oshana regions of Namibia. These ICT-based channels are namely, (i) personal computer, (ii) e-mail, (iii) Internet, (iv) mobile phone, (v) television, (vi) telephone, (vii) fax and (viii) radio. Exploratory factor analysis was conducted to identify common factor loadings that explain collinearity

Table 5. Principal component analysis showing eigenvalues for components and percent of variation explained by each component, 2007

Component/ Variable	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.602	32.524	32.524	2.602	32.524	32.524
2	1.737	21.713	54.236	1.737	21.713	54.236
3	1.012	12.649	66.886	1.012	12.649	66.886
4	.949	11.867	78.753			
5	.623	7.793	86.546			
6	.439	5.485	92.031			
7	.366	4.577	96.608			
8	.271	3.392	100.000			

Extraction Method: Principal Component Analysis.Source: Survey data, 2006

Table 6. Factor loadings on the component matrix for ICT use in the health service delivery system in Namibia, 2007

	Component		
	1	2	3
USEPC	.789	.098	.005
USEMAIL	.839	.009	.021
USEINT	.797	-.186	.023
USEMOB	.133	.908	-.002
USERADI	.051	.922	-.005
USETV	.163	-.040	.821
USETEL	.287	-.072	-.580
USEFAX	.716	-.106	-.009

Source: Survey data, 2006

among the eight ICT variables. A correlation matrix was computed to test variables and confirm whether factor analysis was appropriate for the data. Bartlett's and Kaiser-Meyer-Olkin (KMO) tests were conducted to test for factorability of the data. The Bartlett's test result for sphericity was 276.720 and it was statistically significant at 1 percent level. The result of Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy for this data was 0.677. Both tests indicated appropriateness of using factor analysis in this study.

It is considered that all factors that achieved eigenvalues greater than 0.5 were significant and conversely, those that were less than one were excluded. The number of components and the respective eigenvalues are shown in Table 5.

Principal component analysis (PCA) was the method used for factor analysis. This method aims to minimize the large number of variables to a small set of uncorrelated variables (Hair, Anderson, Tatham & Black: 1995). The PCA produced 8 components of which three were retained, and they had eigenvalues greater than or equal to one. The factor loading cut off point was 0.5. Table 6 shows the structure matrix and the loadings of the specific technologies on different components. The technologies that were grouped under component one are; personal computer, e-mail, Internet and fax. This group comprised of relatively modern technologies and was thus labeled '*high technology'*.

Table 6 shows that the technologies that loaded on component 2 were mobile phone and radio. One of the major characteristics for these technologies is the mobility aspect; and as a result this group was labeled '*mobile technology'*. Telephone and television loaded on component 3, and these technologies comprised traditional media channels and were therefore labeled '*traditional technology'*. According to Hopkinson and Pujari (1999: 282), factor loadings indicate the correlation between the variables and the factors such that variables with large loadings on the factors are grouped together. In this study, a factor loading of the value 0.50 and above is considered good and significant.

The study also examined ICT related constraints in delivering health services to patients. To uncover the constraints, an analysis of the factors that influence ICT use was conducted. However, since the study examined multiple ICT use in HSD, understanding factors affecting such use required a determination of awareness levels of the different technologies.

As already highlighted, the ICT awareness variable was determined using the results of the factor analysis. The awareness variable was based on the use of the three technology groups identified above. For instance, level one referred to the use of *'traditional technology'*, level two *'mobile technology'* and level three *'high technology'* in that particular order. Therefore, the index for ICT awareness comprised four different levels namely; high technology, mobile technology, traditional technology, and no awareness. However, the results show that respondents fell into the first two categories. No respondent showed complete lack of ICT awareness on "traditional" technologies as stated above.

All the variables except one have communality values above the cut off value of 0.5. This suggests that all the variables were adequately represented by the 3 components identified. A multinomial model regression was conducted to investigate factors affecting awareness of multiple ICT channel use for HSD.

Multinomial Logistic Regression Results

The independent variables that were included in the model are, demographics (e.g. age, gender, education etc), sources of health service information, functional literacy, attitude towards privacy and confidentiality, ICT use in HSD, and perception variables on ICT training appreciation and ICT infrastructure. Multinomial logistic regression predicts categorical outcomes with a potential of more than two categories (Statistical Package for the Social Sciences, 2007).

The model fit results of the multinomial regression are presented in Table 7. The model was found to be statistically significant at 1 percent level of significance. Salkind (2004:144) defines statistical significance as the degree of risk one is willing to take that one will reject a null hypothesis when it is actually true. He further explains that significance level is the "risk that is associated with not being 100 percent confident that what one has observed in an experiment is due to the treatment or what was being tested" (Salkind, 2004:144).

The results of chi-squared goodness of fit are reported in Table 8. The Pearson chi-square and a deviance (likelihood ratio) chi-square indicated a 1.000 significance level and this shows a good prediction of the ICT awareness (ICTAWARE) variable. The result (1.000) is not significant; therefore the model fits the data adequately. Lee, Kwon and Schumann (2005:429) explain that values that are greater than 0.05 in deviance statistics indicate a good fit with the data, and this makes the model acceptable. Garson (1998: 1) also

Table 7. Model fitting information for multinomial regression, 2007

Model	Model Fitting Criteria	Likelihood Ratio Tests		
	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	122.750			
Final	12.857	109.892	26	.000

Source: Survey data, 2006

Table 8. Chi-squared goodness-of-fit

	Chi-Square	df	Sig.
Pearson	10.691	81	1.000
Deviance	11.235	81	1.000

Source: Survey data, 2006

Table 9. Multinomial logistic regression results for the Khomas and Oshana regions, 2007

Effect	Model Fitting Criteria	Likelihood Ratio Tests		
Variables	-2 Log Likelihood of Reduced Model	Chi-Square	df	Sig.
Intercept	12.857	.000	0	.
Age	34.162	21.305	5	.001 ***
Race	17.503	4.646	2	.098 *
Education [EDUC]	21.513	8.656	3	.034 **
Functional Literacy [LITCOUNT]	77.352	64.495	5	.000 ***
Sources of health information (INFSCOUN]	31.473	18.615	5	.002 ***
Privacy [INFCOUNT]	19.141	6.284	3	.099 *
Use of ICT for health services [ICTHEALT]	13.733	.876	1	.349 ns
Willingness to develop ICT skills [DEVICTSK]	15.876	3.019	1	.082 *
Perceptions on health services [PEPSERV]	19.273	6.415	1	.011 **

Source: Survey data, 2006

Notes:

****Significance at 1 percent level*

*** Significance at 5 percent level,*

** Significance at 10 percent level*

Ns = Not significant

states that the chi-square statistic test is desired to have an outcome of non-significance, as this indicates that the model has adequate fit for the data. The chi-square goodness of fit intends to find out how well a set of data "fits" an existing set (the observed data set), (Salkind, 2004: 266). Discrepancies between the model and data are also measured in the goodness of fit test. Li, Tan and Xie (2003:299) refers to the goodness of fit as the degree to which the structural equation model fits the sample data. The results of the Cox and Snell and McFadden R-square were 0.603 and 0.880 respectively, and this indicates that the model is highly robust.

Table 9 present the significant variables from the multinomial regression results. The results show that there are three key variables that were statistically significant at 1 percent level, and these are functional literacy (LITCOUNT), age, and sources of health information services (INFOSCOUNT). This finding suggests that functional literacy, access to diverse information sources for health services and age particularly influence multiple uses of ICT channels. Education (EDUC) and a positive perception on health services (PEPSERV) were statistically significant at 5 percent level. Perceptions on health services entail views from patients on whether or not they perceived private and or public ICT services positively or negatively. These results clearly show that patient's ability to effectively utilize the ICT channel (i.e. functional literacy); access to diverse sources of health services information, better educational attainment and age are the most important factors that influenced multiple ICT channel use in HSD in Namibia, particularly in Khomas and Oshana regions. Logistic regression was conducted to further confirm key factors that affect the adoption of individual ICT channels. The results are presented in the next section.

Table 10. Binary logistic regression results for personal computer use in the Khomas and Oshana regions, 2007

	PC			
Variable	B	S.E	Sig.	Exp (B)
Age	-.815	.368	.027**	.443
Education [EDUC]	.467	.241	.052*	1.595
Functional Literacy [LITCOUNT]	3.258	.753	.000***	26.004
Privacy for health information [IMPORTP]	2.965	1.291	.022**	19.386
ICT Improves health services [ICTIMPR]	-3.230	1.898	.089*	.040
Perception on infrastructure [PEPINFRA]	1.773	.945	.061*	5.887

Source: Survey data, 2006

Notes:

****Significance at 1 percent level*

*** Significance at 5 percent level,*

** Significance at 10 percent level*

Ns = Not significant

Results of Binary Logistic Regression on Individual ICT Channel Use

According to Agresti (2002: 175), the logistic regression model compares the observed counts and fitted values by using either likelihood ratio (G^2) or Pearson X^2 statistic. The logistic regression analysis was conducted to ascertain factors that influence individual ICT channel use for health services. In order to identify key factors affecting individual ICT channel adoption, a likelihood ratio chi-square X^2 test of independence was initially conducted to establish associations between the eight ICT based communication channels and the independent variables.

A backward-wald selection method was used to identify the most significant variables influencing ICT adoption leading to the selection of a final model. In this method, variables specified for the model are entered into the model together and they are removed from the model based on their significance of Wald statistic. The pre-selected ICT channels were personal computer and mobile phone. The aim was to select at least one ICT from the "high technology" and "mobile technology" groups and identify major factors affecting its use by Namibian patients.

PC Adoption Results

Table 10 presents the logistic regression results for PC which represents the "high technology" ICT group. Results for PC show seven significant variables namely, functional literacy, age, education, perception on importance of personal privacy in health information, perception that ICT improves health services and perception on infrastructure support. Functional literacy was highly statistically significant at 1 percent level and has a positive effect on the likelihood of PC use. Functional literacy represents the ability for one to operate various ICT communication channels. Results showed that unitary increase in functional literacy (LITCOUNT) increases the odds of using PC by 26 times. This variable had the greatest effect on PC adoption in both Oshana and Khomas regions of Namibia. This result is consistent with the findings of the Multinomial

Table 11. Binary logistic regression results for mobile phone

	Mobile phone			
Variable	B	S.E	Sig.	Exp (B)
Functional Literacy [LITCOUNT]	2.747	.699	.000***	15.592
Privacy [INFCOUNT]	2.569	.899	.004***	13.048
Contact details willing to share [SHAREC]	-6.620	3.589	.058*	.001
Willingness to develop ICT skills [DEVICTSK]	21.125	11209.486	.998	1E+009
Perception on infrastructure [PEPINFRA]	3.212	1.595	.044**	24.835
Perception on ICT cost [ICTCOST]	-2.246	1.091	.040**	.106

Source: Survey data, 2006

Notes:

****Significance at 1 percent level*

*** Significance at 5 percent level,*

** Significance at 10 percent level*

Ns = Not significant

regression model. Perception on the importance of privacy of health information for patients (IMPORTP) was statistically significant at 5 percent level and it had a positive (19.386) effect on the likelihood of PC use. This implies that an increase in positive perception on the importance of privacy of health information increases the likelihood of PC use by 19 times. This means that patients that had a positive perception on the importance of privacy of their health information were more likely to adopt PC as they are confident that it secures their private health information. Age was also statistically significant at 5 percent level, but had a marginal positive effect on PC adoption. Education (EDUC), perception on ICT infrastructure and perception that ICT improves health services (ICTIMPR) had a positive effect on the likelihood of PC use at 10 percent level of statistical significance.

Mobile Technology Adoption Results

Logistic regression results on mobile phone are shown in Table 11. Functional literacy (LITCOUNT) and privacy (INFCOUNT), meaning the number of ICT channels with personal contact details that the patient is willing to share were statistically significant at the 1 percent level of significance. It is important to note that functional literacy was highly significant in both the PC and mobile phone logistic regression results. This implies that functional literacy measured by the patient's ability to operate the modern ICT is critical for their adoption.

Furthermore, a unitary change in functional literacy increases the odds of using mobile phone by 15 times. The result of privacy (INFCOUNT) indicate that a unit increase in the number of ICT related contact details that a patient is willing to share increases the likelihood of mobile phone use by up to 13 times.

A positive perception on infrastructure and the cost of ICT were statistically significant at 5 percent level. A unit increase on the perceptions on infrastructure increases the likelihood of mobile phone usage by approximately 25 times. In addition, a positive perception on the cost of purchasing a mobile phone had a positive effect on the likelihood of mobile phone usage, although the magnitude was marginal. Furthermore, the willingness to share personal contact details specifically with HSP was statistically significant at 10 percent level. This means that individuals who are predisposed to sharing their ICT contact details with HSP are more likely to use mobile phone, although the effect is marginal in this case as well.

Policy Implications of Findings

In finding answers to the research questions posed, literature was reviewed to get a better understanding of the status of ICT in Namibia and other developing countries. From the literature it has been established that:

1. There was no ICT policy specifically for HSD in Namibia at the time of study, but it was only in draft form. However, a general national lCT policy for the Republic of Namibia and a general Information Technology for the public service are in existence and these were further used to comprehend current ICT policies.
2. The ICT policy for education has been implemented with the aim of articulating the relevance, responsibility, and effectiveness of integrating ICT in education with a view to meeting the challenges of the 21st century (Tech/na, 2007:1). A similar policy is needed in the health sector to promote the adoption of ICT for HSD. Key considerations should be given to enhance the use of ICT in the HSD in Namibia. These will be presented in the next section.

CONCLUSION

This study investigated the use of ICT for HSD in Namibia. The results showed that there was widespread ICT use for health services by Namibian patients. The study identified eight different ICT-based channels that were being used in one way or the other for health services. These were television, radio, telephone, mobile phones, personal computers, Internet, email and fax.

Television and radio stood out as the leading sources of ICT-channels for HSD, although there was clear evidence of widespread use of mobile phones and also personal computers to an extent. Results for multinomial regression and binary logistic regressions showed that the key factors affecting ICT use for HSD were functional literacy, sources of health services information, age, level of education, and a positive predisposition towards ICT use for health services among others. From a public policy standpoint, the study suggests the need for the Government of the Republic of Namibia to actively pursue the opportunities presented by ICT such as personal computer and mobile phones to complement traditional ICT-based HSD channels such as radio and television.

It is also recommended that a comprehensive ICT-based HSD policy be drafted to guide strategies and procedures for HSD in the Namibian health sector. Results of the study demonstrate the presence of a relatively high potential to use ICT to transform HSD in Namibia.

Furthermore, the results of this study can be used to provide insights into ICT use in HSD in other African countries. Future studies should probe ICT use in private or public health care focusing on a specific patient group or functional area, e.g. HIV and AIDS, maternity, emergency services etc. Alternatively, a similar study could assess the willingness to use modern technologies such as mobile phones, as there are likely future platforms for HSD; and some risks and benefits associated with such applications.

REFERENCES

Agresti.A. (2002). Categorical Data Analysis. 2nd ed. Canada: John Wiley & Sons.

Anon. (2007). Khomas region. Wikipedia. http://en.wikipedia.org/wiki/Khomas [date accessed: 28 May 2007].

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes*, 50(2), 179-211.

Baldwin, L.P., Clarke, M., Eldabi, T & Jones, R.W. (2002).Telemedicine and its role in improving communication in healthcare. *Logistics Information Management*, 15 (4): 309-319, October.

Booysen, C. (2006). The application of discriminant analysis and logistical regression as methods of compilation in the research function in youth rugby, University of Pretoria: Pretoria.

Chandrasekhar, C.P., & Ghosh, J. (2001). Information and communication technologies and health in low income countries: the potential and the constraints. *Bulletin of the world health organization*, 79(9):850-855.

Chao, C.C., Jen, W.Y., Hung, M.C., Li, Y.C. & Y.P. Chi. (2006). An innovative mobile approach for patient safety services: The case of a Taiwan health care provider.

Technovation (2007), doi:10.1016/j.technovation.2006.12.008.

Chau, P.Y.K. and Hu, P.J.H.(2001). Information technology acceptance by individual professional: a model comparison approach, *Decision Sciences*, 32(4):699-719.

Chau, S., & Turner, P. (2006). Utilization of mobile handheld devices for care management at an Australian aged care facility. *Electronic Commerce Research and Applications*, 5(4):305-312, Winter.

Crede, A & Masell, R.(1998). Knowledge societies…in a nutshell: Information technology for sustainable Development. Canada: IDRC Books.

Davis, F.D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology, *MIS Quarterly*, 13(3): 319-340.

Delanyo, D. (2001). Namibia country briefing paper. Department for international Development Health systems resource centre for the UK DFID. http://www.dfidhealthrc.org/shared/publications/Country_health/Namibia.pdf [date accessed: 10 March 2006].

Equity Network for Southern Africa (EQUINET). (2005). Equity in health Care in Namibia Towards needs-based allocation formula. MOHSS World Health Organization. EQUINET policy paper number 26, Windhoek, Namibia. http://www.healthnet.org.na [date accessed: 12 May 2006].

Egan, G.F., & Liu Z. (1995). Computers and networks in medical and Healthcare systems. *Computers in Biology and Medicine*, 25(3):355-365, May.

Gagnon M., Lamothe,L., Fortin, J., Cloutier, A., Godin, G., Gagne, C and D. Reinharz. (2005). Teleadoption in hospitals: an organizational perspective. In Journal of Health Organization and management, 19(1):32-56.

Galloway, L. and Mochrie, R. (2005). The use of ICT in rural firms: a policy-oriented literature review, *Info*, Vol. 7 No. 3, pp. 33-46.

Garson, G.D. (1998). Statnotes: Logistic regression. Raleigh, North Carolina: Carolina State University. http://www2.chass.ncsu.edu/garson/pa765/logistic.htm) [date accessed: 2 April 2006].

Geldenhuys, E., Herbst, D., Dixon, B.J. Schnetler, J. (ed) & Stoker, D., J. (1989). Survey methods and practice. Revised Ed. Pretoria: Opinion Survey Centre. HSRC.

Greenfield, T. (eds). (2002). Research methods for postgraduates.2nd edition. London: Arnold.

Groves, R.M., Fowler, F.J., Couper, M.P., Lepkowski, J.M., Singer, E. & Tourangeau, R. (eds) (2004). Survey Methodology. New Jersey: John Wiley & Sons.

Hair, J.F., Anderson, R.E., Tatham, R.L. and Black, W.C. (1995), Multivariate Data Analysis with Readings, 4th ed., Prentice-Hall International Edition, London.

Hameed K. (2003). The application of mobile computing and technology to health care services. *Telematics and Informatics*, 20(2): 99-106, May.

Haoses-Gorases, L. (2005). Utilization of Health Information System (HIS) in Namibia: Challenges and opportunities faced by the health care delivery system. Paper presented at the international workshop on Strategies for Permanent Access to Scientific Information in Southern Africa: Focus on Health and Environmental Information for Sustainable Development, Pretoria, 5-7. September 2005.

Hesselmark, O., & Miller, J. (2002). A country ICT survey for Namibia. http://www.cyberzoo.co.za/download/milless/newdocs/Namrep%20v5.pdf [Date accessed: 10 March 2006].

Hopkinson, G.C., & Pujari, D. (1999). A factor analytic study in hedonic consumption. *European journal of Marketing, 33*(3/4): 273-290, April.

Johnson, A.M. (2005). The technology acceptance model and the decision to invest in Information security. Southern Association of Information systems conference. Savannah, Georgia, USA, 25-26, 2005.

Kenny. C. (2002). Information and communication technologies for direct poverty alleviation: costs and benefits. Development Policy, 20 (2): 141-157.

Laurence.G.G. & Paul.R.Y. (eds). (2000). Reading and Understanding more multivariate statistics. American Psychological Association.

Lee, E., Kwon, J. & Schumann, D. W. (2005). Segmenting the non-adopter category in the diffusion of Internet banking. International Journal of Bank Marketing, 23(5):414-437.

Lu, J., Yu.C , Liu.C and Yao. J.E. (2003).Technology acceptance model for wireless Internet. *Electronic Networking Applications and Policy*, 1(3):206-222.

Ma, Q and Liu, L. (2004). The technology acceptance model: a meta-analysis of empirical finings. *Journal of Organizational and End user Computing*, 16 (1), 59-74.

Mathieson, K.(1991). Predicting user intention: comparing the technology acceptance model with the theory of planned behavior, Information Systems Research, 2(3):173-191.

Maumbe. B.M & Owei V. (2007). e-Government policy development in South Africa: distributional issues and implementation hurdles. *Proceedings of the 2007 conference of the IST Africa*, Maputo, 9-11 May 2007: Ireland**,** IIMC International Information Management Corporation Ltd**.**

Mcwhirter, G. (2003). The potential for using hospital bedside TV services in England to provide patients with access to information. *Aslib proceedings*, 55(5/6):339-345, December.

Munukka.K. (2005). Bridging the digital divide? Development of information society in Namibia-Conceptions of the local actors. University of Tempere.

Namibia. Ministry of Foreign Affairs, Information and Broadcasting. (2002a). Information and communication technology policy for the Republic of Namibia. http://www.uneca.org/aisi/nici/Documents/ICT%20Policy%20Document%20Ver%208.2.pdf [date accessed: 8 March 2006].

Namibia. Ministry of Health and Social Services.2006.Health Facilities. http://www.healthnet.com.na [date accessed: 20 April 2006].

Namibia. Ministry of Health and Social Services. (2005). Follow-up to the declaration of commitment on HIV/AIDS (UNGASS): Namibia Country Report. Windhoek: Directorate: Special Programmes (HIV/AIDS, TB & Malaria).

Namibia. MOHSS. (2004a). Annual Report of Oshana region: 2003-2004.Windhoek: Ministry of Health and Social Services.

Namibia. MOHSS. (2004b). The technical efficiency of District Hospitals in Namibia. Windhoek: Directorate: Policy, Planning and Human Resources Development.

Mcwhirter, G. (2003). The potential for using hospital bedside TV services in England to provide patients with access to information. *Aslib proceedings*, 55(5/6):339-345, December.

Namibia. (2004)c. Namibia Vision 2030: Policy Framework for Long-Term National Development. Windhoek: National Planning Commission Secretariat.

Namibia. MOHSS. (2003). Namibia National Health Accounts November 2003.Windhoek: Directorate: Policy, Planning and Human Resources Development.

Namibia.MOHSS.(1998).The referral system. Performance audit report of the Auditor General. Windhoek.

Pradhan, MR.(2003). ICTs application for better health in Nepal. *Kathmandu University Medical Journal, 2*(6):157-163, April-June.

Quibria, M. G., Tschang, T. & Reyes-Macasaquit, M. (2002). New information and communication technologies and poverty. *Journal of the Asia Pacific Economy, 7*: 11-825.

Quibria, M. G., Ahmed, S.N., Tschang, T. & Reyes-Macasaquit, M. (2003). Digital divide: determinants and policies with special reference to Asia. *Journal of the Asian Economics, 13(3)*: 285–309, October.

Rao, S.S. (2001). Integrated health care and telemedicine. *Work study***,** 50 (6):222-229, June.

Salkind, N, J. (2004). Statistics for people who (think they) hate statistics. 2nd ed. London: Sage.

Seror, A. (2001). The Internet, Global Healthcare Management Systems, and Sustainable Development: Future Scenarios. *The Electronic Journal on Information Systems in Developing Countries*, 5(1):1-18, August.

Schaper, L.and Pervan .G. (2004). A model for information and communication technology acceptance and utilization by occupational therapists. http://s-cah-vishnu.infotech.monash.edu.au/dss2004/proceedings/pdf/72_Schaper_Pervan.pdf, [date accessed: 5 June, 2008].

Schware, R. (2003). Information and communications technology (ICT) agencies: functions, structures, and best operational practices. *Information***,** 5(3):3-7, June.

Statistical Package for the Social Sciences (SPSS)**.** (2007). *SPSS regression models*. http:/www.spss.com/regression [date accessed: 9 April 2007].

Stevens, J.P. (2002). Applied multivariate statistics for the social sciences. 4th edition. London: Lawrence Erlbaum Associates.

Taylor, S. and Todd,P.A.(1995). Understanding information technology usage: a test of competing models, information systems Research, 6(2): 144:174.

Schware, R. (2003). Information and communications technology (ICT) agencies: functions, structures, and best operational practices. *Information***,** 5(3):3-7, June.

Statistical Package for the Social Sciences (SPSS)**.** (2007). *SPSS regression models*. http:/www.spss.com/regression [date accessed: 9 April 2007].

Tech/na. (2007). ICT Integration for Equity and Excellence in Education. http://www.tech.na/download/ICTPolicy2005_15March2005.pdf [date accessed: 30th May, 2007].

Venkatesh,V., Morris, M.G., Davis,G.B. and Davis.F.D.(2003).User acceptance of information technology: Toward a unified view", *MIS Quarterly*, 27(3):425-478.

United Nations Economic Commission for Africa (UNECA). (2006). National Information and Communication Infrastructure (NICI) Policies and Plans (e-strategies), Namibia. http://www.uneca.org/aisi/nici/Namibia/namibia.htm [date accessed: 1 November 2006].

Wallace, S. (1997). Health information in the new millennium and beyond: the role of computers and the Internet. *Health Education, 97*(3):88-95, May.

Yamuah, L.K. (2005). ICT in the African health sector: towards healthy nations with ICT Wealth. i4d magazine: May 2005. http//:www.i4donline.net/may05/africanhealth.asp (date accessed: 20 June 2006).

This work was previously published in International Journal of Healthcare Delivery Reform Initiatives, Vol. 1, Issue 1, edited by M. Guah, pp. 63-87, copyright 2009 by IGI Publishing (an imprint of IGI Global).

Chapter 4.9

Decentralisation and Health Systems Performance in Developing Countries:

Impact of "Decision Space" on Primary Health Care Delivery in Nigeria

Adebusoye A. Anifalaje
London School of Economics and Political Science, UK

ABSTRACT

This article attempts to elucidate the intricacies of primary health care delivery in Nigeria. Among myriad complexities, the central proposition made herein is that the absence of an effective regulatory and enforcement framework in developing countries results in a prominent informal decision space. The findings show that the prominence of an informal decision space compromises the objectives of an information-based public health system. The article concludes that decentralisation in developing countries must have a coordinated top-down and bottom-up development component for it to be effective in improving the performance of primary health systems. One of the implications of the study is that researching decentralised healthcare delivery requires analytical models which are able to illuminate the complexities of local accountability in developing countries. The study also reveals the need to further research the dynamics of democratic decentralisation in developing countries as this goes beyond administrative structures but involve socio-cultural institutions.

INTRODUCTION

Health systems simply defined, are the foundational (i.e. institutional, political, legal, economic, technical and socio-cultural) arrangements through which health services are delivered to the population (Berman and Bossert 2000). There is a complex chain of interdependent factors which influence the performance of health systems. In developing countries where there are high mortality and morbidity rates, a multiplicity of stakeholders (i.e. rich nations, international donors, non-governmental organisations (NGOs), bilateral and multilateral agencies) employ different strategies to try and improve specific aspects of the health system (Okuonzi and Macrae 1995). These diverse and often uncoordinated interventions usually have a fragmentary effect on these systems (Buse and Watt 1996). In essence, the imperatives of international health policies and donor-aid practices have a tendency to weaken the capacity of national governments to independently formulate and implement policies which address the health needs of the population (Smith *et al*. 2008).

This article highlights the implications of decentralisation on the performance of health systems in Nigeria. By conceptualising decentralisation as a strategy for delivering health services through a primary health care system, the study is able to focus on the micro-level processes of the health system. The performance of a health system can therefore be investigated through the effectiveness of primary health care delivery. To study this phenomenon, decision space is adopted as an analytical tool (Bossert 1998). This framework conceptualises the multi-level dynamics of primary health decisions made by local government agents. Decision space illuminates the choices of local government actors and how these impact health system performance. It also frames the role of information in monitoring and evaluating the performance of health systems. There are three main reasons for adopting a local perspective of the decision space approach: firstly, primary health care services are the building blocks of general public health systems therefore we would expect a strong association between local and general public health systems performance; secondly, information systems are implemented with a view to aid planning and decision making at the local level. Consequently this focus provides an opportunity to go back one step to evaluate the intricacies of information practices (in a general sense) without reference to a particular health information systems project; lastly, local agents make health decisions out of a quagmire of often conflicting motivations and opposing evidence: this study will provide some insight into the possible factors that actually influence choices made regarding primary care delivery.

With decentralised health sectors, central governments through the Ministry of Health have a complex task of designing the framework through which local government agents can provide adequate health services (WHO 2000). Their challenges include developing the socio-economic, political, legal, administrative and institutional arrangements that will support the efficiency and effectiveness of primary care systems. The formal (and informal) authority afforded local government agents by the central government, combined with the discretions they exercise (both within and outside formal authority) make up their "decision space". The relationship between central and local government actors contributes formally and informally to the decisions made at the local level with consequences for the performance of primary health care systems.

The Decision space framework conceives the relational dynamics between the local and the central government through a principal-agent theory (Griffith 1966 and Rhodes 1986 in Bossert 1998) the central (or State) government as the principal and local governments as agents. It analyses the capacity of the principal to influence decisions made by local government agents in order to align them to the principal's objectives e.g. better performing health system. This being the case, the primary role of the Federal Ministry of Health for instance, would be to make adjustments to local agents' decision space in a way that would align their interests with national public health objectives. The central government can accomplish this by adopting a scheme of rewards and sanctions.

The framework tries to balance this top-down bias by suggesting the mutual influences of central and local government agents. The influence of local government agents is framed in terms of having direct and primary access to contextual knowledge and information which is required by central government agents. Information plays a crucial role in the study and analysis of health systems performance. Within the decision-space framework, local agents use information to evaluate the technical effectiveness of current primary care units and formulate appropriate operational intervention strategies. On the other hand, central government agents also employ this information to build a general public health picture as well as monitor the performance of local agents from a managerial perspective. However, the main thrust of the framework is geared towards the role of central government in aligning the interests of local government actors.

The main observation made in this study is that the decentralisation of health systems in developing countries operates predominantly through an informal decision space. This article therefore shows the consequences of this phenomenon on primary health care delivery. It further argues that this political dimension to analysing health systems performance is fundamental to understanding the challenges of health information system initiatives in developing countries. For these reasons it is important to conceptually explore and empirically investigate the impact of decision space on the delivery of primary health care. Consequently, the overall objective of this research project is to gain a better understanding of the implications of a decentralised health sector on the performance of the health system. To delimit the research focus and scope three questions are framed:

1. How does the decision space of local government actors impact primary health care?
2. In practice, what are the factors that shape, influence and determine the decision space?
3. To what extent does information drive health care decisions?

The empirical fieldwork for these questions was conducted in Nigeria. While agency-centred studies analyse the dynamics of the situated local contexts, they do not provide adequate tools to investigate the influence of the structures within which the agents exist and operate (some IS literature have tried to address this see Alvarez 2003). For instance, instead of studying the implementation or use of a specific information system, this study locates the problem domain within the socio-political dimension of health care delivery in Nigeria, providing a more robust platform for understanding the challenges of health information systems projects. This is because decision space approach serves as a multi-level contextual platform which incorporates the mutual influences of the macro and micro-level environment.

The main contribution of this article therefore is to illuminate the socio-political arrangements which affect the delivery of primary health care in Nigeria. Although focussing on the characteristics of local government agents, this study is able to reveal how the capacity of the State and Central governments impact on local agents' effectiveness in delivery primary health care. The study extends these findings to analyse the role information plays in local health systems and extrapolate to discuss the potential implications for the implementation and use of health information systems.

The rest of the article is presented in two broad sections. The first section is conceptual in nature including the literature review, conceptual framework and methodology. The second section details the empirical content of the study including the analysis and discussion and the research conclusions. A brief outline of implications for future research is also provided.

LITERATURE REVIEW

Health Care Delivery Strategies in Developing Countries

This section will provide the historical context of health delivery strategies in developing countries. Focussing on the challenges and complexities of primary health care, the literature shows the influences of global economic and political ideologies on national and local health care delivery policies.

Primary Health Care System

In the late 1970s, the international health community—comprising of World Health Organisation (WHO) member countries— turned its attention to the failing health systems of many developing countries. The central concern at the time was that majority of the population in poor countries lacked access to basic health care services and therefore suffered high rates of mortality and morbidity (Magnussen *et al.* 2004). An effort to address these failing systems was articulated in the WHO Alma Ata declaration (WHO 1978). The declaration conceived of health as a basic human right and sought to initiate programmes that will build sustainable health systems, with indiscriminate access for all, in developing countries. It proposed the primary health care (PHC) system as the principal means of achieving equitable health service delivery within and between countries (Starfield *et al.* 2005). By focussing on the community-level, health services are more accessible and interventions are likely to be more responsive to local needs as there is increased opportunity for effective local participation (Tarimo and Fowkes 1989). The argument is that there is increased accountability and improved health care service when policies and intervention strategies are formulated with the "users" in a way that aligns with their particular needs (Cornwall *et al.* 2000). With this system, greater emphasis is placed on health promotion and preventative strategies (Atkinson *et al.* 2005) rather than technologically sophisticated and curative bio-medical interventions (Bossert 1979). Cueto (2004) also suggested that PHC was introduced based on the implicit assumption that diseases in developing countries were contingent on socio-economic arrangements and therefore interventions required political will. As a result, the most important task was to mobilise the support of the international community to support the bottom-up approach of improving the performance of health systems. Under this arrangement therefore, the performance of health systems is dependent on the effectiveness and coordination of community-based health units.

By the mid 1980s, the vision of global health suffered several significant setbacks. Firstly, the objective to raise the minimum level of health in all poor countries of the world, was deemed too idealistic (Magnussen *et al.* 2004). Secondly, the proposed PHC system received little support because of the deeply institutionalised tertiary model and a reluctance of "experts and politicians in developed countries to accept the principle that communities should plan and implement their own healthcare services" (Hall and Taylor 2003: 17). Furthermore, with the decline of communism in the former Soviet Union, marketisation was gaining more ground as the appropriate economic ideology for modern society. Economic support for health projects was conditional on recipient countries adopting liberalisation policies. Hall and Taylor (2003) discuss the "failure" of PHC in light of these changes.

As an alternative approach, selective primary health care (SPHC) was adopted (Cueto 2004). In contrast to PHC, SPHC assumes that diseases in developing countries are a natural phenomenon which can be curtailed through economically-viable and technical interventions (Cueto 2004). This approach attempts to tackle major diseases especially those responsible for childhood mortality (Cueto 2004). The "success" of SPHC was attributed to three main factors: 1) its bias towards a market rationality; 2) specific goal of child health and 3) appeal to "rational" and technical interventions (Cueto 2004). While PHC is oriented towards improving general population health, SPHC is a vertical programme addressing specific diseases. The performance of SPHC is judged according to specific project objectives such as immunization coverage, disease control or eradication etc.

Decentralisation

Still driven by a techno-economic rationality, the 1990s was accentuated by a sustained interest in health sector reform. According to the Harvard School of Public Health, health reform is defined as:

sustained, purposeful and fundamental change" – "sustained" in the sense that it is not a "one shot" temporary effort that will not have enduring impacts; "purposeful" in the sense of emerging from a rational, planned and evidence-based process; and "fundamental" in the sense of addressing significant, strategic dimensions of health systems (Berman 1995).

With experiences of the 1980s showing that general health systems had been significantly weakened (Chatora and Tumusime 2004), organisational change, innovative sourcing of funds, increased market rationality, and customer-focussed health services were strategies (e.g. *The World Development Report 1993: Investing in Health*) (World Bank 1993) advocated as a means to achieving sustainable health reforms (Blaauw *et al.* 2003). Nonetheless, decentralisation emerges as a distinctive feature of these reforms albeit employed in shades and degrees (Jeppsson and Okuonzi 2000). Jeppsson & Okuonzi (2000) note for instance that Ugandan health decentralisation model shows power devolved to district levels as part of a wider political decentralisation agenda. On the other hand, they acknowledge that only the health service structure is decentralised in Zambia. Maintaining that useful lessons can be learnt from both approaches, they note that neither approach has been able to produce better health service delivery or improve poverty conditions.

There are often mistaken inferences made about decentralisation of public health service (which is a feature of primary health care) as a form of rolling back the state (Collins and Green 1994). So, based on this rationale, donor agencies fund specific health projects usually without much collaboration with national governments or consideration for the defined health priorities of recipient countries (Loewenson 1993, Okuonzi and Macrae 1995). The perception that developing countries lack requisite capacity e.g. in terms of adequate analytical skills for health policy formulation, is represented as a major obstacle to the effective collaboration necessary for health reform (Filmer *et al.* 1998, Jamison and Mosley 1991). The resultant coordination failure amongst diverse stakeholders (Buse and Watt 1996) precipitated a call for donors to invest in building aid recipients' capacity to develop appropriate health systems (Lee 1998). Besides, the sustainability of health systems in developing countries demand that governments take active responsibility in deciding the direction of public health intervention strategies. Initiatives like Sector-Wide Approaches (SWAp) were responses to the urgent call for the coordination of donor-funded projects and better collaboration with national governments (Peters and Chao 1998). The logic behind these programmes is that projects are based around commonalities of goals and strengthening of national capacity to fulfil its development objectives in terms of effective institutional arrangements and economic policies. There is an expectation that the outworking of a coordinated approach will also stimulate local participation, increase active engagement and provide stability necessary for long-term planning (Chilundo & Aanestad, 2003). However, effective collaboration between donors and recipient countries is made more difficult because it is contingent on trust and confidence in the capacity of recipient countries to manage their health systems. The perception that developing countries lack requisite capacity e.g. in terms of adequate analytical skills for health policy formulation constitutes a significant setback for SWAp (Filmer *et al.* 1998, Jamison and Mosley 1991). Tarimo and Fowkes (1989) identify four main challenges of compartmentalized approach to health reform in developing countries: 1) short-term mindedness in goal setting; 2) insufficient financial aid; 3) lack of appreciation of differences in local contexts; 4) implementation of vertical programmes as a matter of convenience as opposed to needs.

Economic Growth Approach

By the turn of the 21st century, it is widely stated that the problems of poverty and disease are neither technological nor a consequence of knowledge deficiency. However, from the mandate of the Millennium Development Goals, the challenge is perceived in terms of mustering enough political will and finance for a vision of global health. From an economic standpoint, the World Health Organisation (WHO) commission on *Macroeconomics and Health: Investing in health for economic development* report argues that investment in health is of paramount importance (WHO 2001). The main concern is to break the poverty cycle—which reinforces poor health—by boosting economic growth through significant "public investment" (Sachs *et al.* 2004: 122). Economic growth in turn has the capacity to increase productivity and consequently lower poverty (Sachs *et al.* 2004). The foundation of this strategy built on globalisation and depends to a very large extent on the provision of foreign aid. Although the effect of globalisation—in addition to effective institutional arrangements and adequate infrastructures—has been largely beneficial to health conditions, this link is drawn from an economic growth, trickle-down effect. As a result, there are required domestic conditions that must be present in order to reap the benefits. Therefore, foreign aid in itself is unlikely to produce the desired result if there are no frameworks established to guarantee that the finance will be used effectively towards development. However, for most developing countries, deregulation and liberalisation policies have not yielded growth or better health conditions (Cornia 2001).

While there is some agreement with the central proposition of the WHO r*eport on Macroeconomics and Health* that disease is a major player in engendering poverty and therefore investment in health is a key proponent in achieving economic development, there is a major contention regarding its approach. The main criticism of the report is the "reform for finance" approach which betrays a disposition towards the familiar structural adjustment programme (Waitzkin 2003). In this sense, it is argued that developing countries will be worse off while developed countries are able to exploit the opportunities created by these policies (Garrett 2007). The weakness of the WHO report can be linked to paying lip service to health as an end in its own right while actively pursuing an economic growth agenda (Waitzkin 2003).

In contrast to macro-level, top-down growth strategies, others argue that health crises in the developing countries have necessitated a change of strategy in delivering public health services by increasing community involvement and participation (Cornwall *et al.* 2000). The argument is that the bottom-up approach to development is related closely to the "health for all" policy while "new public management" health models detract from this goal (Gwatkin 2000). The realisation that there is increased accountability and improved health care system when policies and intervention strategies are formulated with the "users" (Cornwall 2000), constitutes a new wave of efforts that have started building which gives attention to the health of the poor as well as health inequalities (Gwatkin 2000).

There are observable evidence to suggest that much has to be understood about the complexity of this field because "[d]espite the emphasis placed during the last two decades on public delivery of comprehensive and equitable primary care to developing country populations, coverage remains far from universal and the quality often poor" (Mills *et al.* 2004). It is therefore still contended that PHC is "the only way to reach the poor and the vulnerable groups" (Masaiganah 2004).

Paradoxical Insight

While the decentralisation of the health sector is often implemented through a top-down process, its goal is to develop a bottom-up approach to improving health system performance (Atkinson 1995). As a consequence, health systems research has paid little attention to the socio-political arrangements of decentralisation at the local level (Atkinson et al. 2000, Smith 1997). There are two analytical insights which can be gained by examining this paradox from the local perspective. First, we can empirically investigate how this paradox impacts the extent to which local governments can effectively exercise authority in matters of health service delivery (Adeyemo 2005). Secondly, we can also critically analyse whether the real objective of the top-down process is to actually facilitate increased local decision making.

However, we are not just interested in the extent to which health systems are driven by the transfer of decision-making authority to the local level, but also the factors that affect the nature (or quality) of these decisions. There is a body of literature which attempts to tackle this issue and is based around themes such as rational health planning, evidence-based public health, information-centred health policy etc. The literature advocates a strong modernisation ethos through these concepts, providing equal impetus for technology-based health systems as necessary instruments for collecting, storing, analysing and disseminating health information (some examples of the debates: Dobrow *et al.* 2004, McMichael *et al.* 2005, Murray and Frenk 2001, Niessen *et al.* 2000).

Information and Health Systems in Developing Countries

There is a resonant consensus that effective health planning and interventions depend on accurate data (Green 1999). It is also accepted that relevant and reliable information forms the bedrock of any effective public health system (Stansfield 2005). The effective control or prevention of disease from an epidemiological perspective for instance, is dependent on accurate information regarding its prevalence and geographical distribution. The underperformance of health systems in developing countries have been attributed to the paucity of health information and lack of an information culture. As a result, there is underlying demand for a systematic process of collecting, storing, analysing and disseminating health data and it is to this end that arguments are made in favour of health information systems (HIS) (AbouZahr and Boerma 2005). Despite the relatively strong rationale for these systems, their implementation in developing countries has been shrouded in partial or complete "failure" (Heeks 2006, Littlejohns *et al.* 2003). To illuminate the challenges of information practices in developing countries, we can assess three dimensions of health information systems diffusion for improving health systems performance: 1) dataset consensus; 2) HIS integration; 3) HIS sustainability.

Dataset Consensus

It is argued that although the problem with health information systems in developing countries is the absence of complete and quality data, planning ahead on how data will be used and by whom, and under what circumstances and constraints have implications for future accessibility of data from health systems (McGrail and Black 2005). Accordingly, one of the key features of an information system at the primary health care level is an *essential data set, which may be defined as a set of the most important data elements, selected from all primary health care vertical programmes, that should be reported by health service providers on a routine basis, with the aim of being able to generate indicators that monitor the provision of health services in an integrated manner* (Shaw 2005: 632)

From the above definition, the striking advantage presented by establishing an essential data set is the relevance of the data for local level use. It is also clear that establishing an essential (or minimum) data set for health information would most likely be fraught with a lot of challenges. Some of the difficult questions to resolve would include how to determine the "most important data elements", according to what criteria, and primarily serving what (or whose) purpose (Bowker and Star 1999). We can infer from the fragmented nature of the health system in developing countries that achieving any consensus would be even more difficult because of the multiple stakeholders and interests represented. The alternative is for health workers to collect numerous data for different overlapping projects without regard to the duplication of efforts and wastage of already scarce resource. This alternative is increasingly unacceptable and ways are being sought to address the issue. Without belittling the complexity of this process Shaw (2005) provides a framework for developing this essential data set using the experience of an HIS project in South Africa as an illustration. There are roughly two sides to the framework.

Firstly, data collection is stratified according to information needs along a hierarchical structure. This process is organised such that each level (e.g. national, state and local government) collects data relevant to their needs but only returns relevant data to the upper levels. Secondly, this progresses as a bottom-up approach but a minimum national dataset is negotiated and directed from a top-down process (Shaw, 2005).

Integrating HIS

As previously mentioned, a major obstacle for primary health care is the proliferation of uncoordinated vertical programmes. This has a direct spill over effect on information systems projects. In developing countries, health information systems are largely designed as silos of compartmentalised systems (Braa 2000). Employing the concepts of "historicity and heterogeneity," Aanestad *et al.* (2005) provide an extensive analysis of the challenges inherent in integrating health information systems in developing countries. The problem of historicity relates to the influence of institutionalised systems (e.g. legacy systems), established approaches and dominant values which contend with the introduction of novel health information systems (for theoretical discussion, see Ciborra 2002 , Ciborra and Associates 2000 on standards and information infrastructures). Heterogeneity on the other hand, reflects the impact of multiple donor agencies funding stand-alone vertical systems without consideration for the interdependencies that exist across health programmes (Chilundo and Aanestad 2004). Consequently, the integration of HIS goes beyond establishing standards like "minimum data sets" (Shaw 2005) or integrating different technological artefacts but by necessity includes the alignment of divergent actor orientations, goals and rationalities (Smith *et al.* 2008). Given the scale of the challenge, "coping" with some level of HIS fragmentation is arguably inevitable (Aanestad et al 2005).

HIS Sustainability

Embedded in the general idea of sustainability are the notions of self-sustenance and sufficiency but HIS sustainability focuses more on the capacity of "user organisations to identify and manage risks that threaten the long-term viability of the HIS, following the withdrawal of external support" (Kimaro and Nhampossa 2005: 276). Kimaro and Nhampossa (2005: 276-277) further propose factors that militate against the sustainability of HIS: "inadequate infrastructure and human resource capacity; inappropriate policies and strategies to manage the sustainability problem and fragmented donor policy." To mitigate these factors, they propose that HIS must become a part of the operational day-to-day fabric of the "institutions" using them i.e. they must become "institutionalised". Their central arguments are summed up as follows: 1) sustainable HIS, in addition to being institutionalised, must be designed and developed in a way that is easily adaptable to changing user needs and requirements; 2) the implementation of a new HIS embodies values that would demand the "cultivation and institutionalisation of a new kind of culture"; 3) "donors influence the processes of institutionalisation, and thus the sustainability of systems significantly."

An important perspective to HIS sustainability is the idea of scalability. This concept argues that health information systems must be dynamic and flexibly designed. Otherwise, rigidity to a specific level of the health care will limit its impact on general health systems, greatly diminish its acceptability and face oppositions to its institutionalisation. Therefore HIS must be have the capacity to be either scaled up (to national) or down (to local) according to the health information hierarchy of needs (for more discussion, see: Bergqvist *et al.* 2006, Braa *et al.* 2004, Mengiste and Nielsen 2006, Sahay and Walsham 2006)

A Case of Alignment

The HIS literature illuminate the rationale underpinning an information-based health system. The challenges to achieving consensus on data, integrating and sustaining HIS implementation initiatives can be understood from a different dimension by exploring the entrenchment of health systems in the political intrigue highlighted in the literature on health care delivery strategies in developing countries. The literature first shows a muddle of top-down versus bottom-up approach to health systems development. Therefore HIS implementation strategies although seeking to develop locally relevant systems, must navigate the politically-charged terrain of macro-level initiatives which have direct influence on the information gathered at the local level, how it is analysed, interpreted, used and disseminated. In the same breadth that the historicity of information systems resemble an infrastructure which has a direct influence on the introduction of new technologies, so does the history of primary health care delivery in developing countries impact innovative systems which may attempt to change the course of history. This is in the sense that central and local government agents in developing countries have developed motivations and capacities over the years. These represent their distinctive characteristics. Therefore any initiative to improve primary health care delivery through better information systems or any other tool will require an alignment of sorts which first and foremost appreciates the current and historical reality and culture and in collaborative dialogue allow a more effective system to evolve. There is an expectation that the outworking of these integrations will also stimulate local participation, increase active engagement and provide stability necessary for long-term planning *(Chilundo and Aanestad 2003).*

The motivation of this research project is therefore driven by the question: "How can we understand the characteristics of the local context in order to appreciate the challenges of primary care delivery in developing countries?" This is discussed in the next section.

Research Question

This article proposes that HIS analyses although contextual, can be better illuminated through the framework of political dynamics intrinsic to health systems performance. Similarly, Smith *et al.* (2008) also argue that HIS implementation solely founded on "managerialist grounds would tend to be subverted by the reality of long-standing political structures" (Smith, *et al.* 2008). The political dimensions of primary care delivery are thus essential in the domain of health systems performance. Therefore the question of this study is, "*What are the implications of a decentralised health sector on the performance of the health system?*" As a broad question, it is delimited and made more concrete by asking three distinct but interrelated sub-questions:

1. How does the decision space of local government actors impact primary health care?

This question attempts to deploy the decision space approach in understanding the implications of decentralisation on primary health care delivery. By critically adopting this approach, the study conceptually investigates the factors underpinning health systems performance at the primary care level. The question is important in framing how the decentralised health sector operates and the perceived influence of the principal on the decision space of local agents. Theoretically, this approach states that the principal (e.g. Central or State government) is able to align the activities of the agent (e.g. local government officials) to its objective through a scheme of rewards and sanctions. On the other hand, it also observes that agents wield considerable influence because they produce contextual information required by the principal. This question therefore illuminates how this tension impacts the primary health care system.

2. In practice, what are the factors that shape, influence and determine the decision space?

This is a more contextual question aimed at finding out the diverse instruments, belief systems and ideologies that actually influence decisions at the local level. From an empirical angle, this question will assess and query the primacy of a formal decision space in the context of developing countries where there is significantly reduced capacity of the principal to either reward good performance or punish aberrant activities. This question will therefore attempt to draw out the prominence of an informal decision space.

3. To what extent does information drive health care decisions?

This question problematises the linear conceptualisation linking information, health delivery strategy and outcome. The question is critical because the resultant informal decision space has far-reaching implications for the institutional, political and socio-cultural arrangements which influence decision making and health systems performance. The question therefore provides a more insightful study into the diverse role of information in primary health care delivery and health systems performance.

ANALYTICAL FRAMEWORK

While the conceptual framework is implicit in the research questions it is important to highlight its key features and how it will be used in this study.

Theoretical Context

Bossert (1998) developed the concept of decision space as part of a comprehensive framework to analyse the decentralisation of health systems in developing countries. In developing this analytical framework, it is noted that decentralisation is an instrumental means to achieving "equity, efficiency, quality and financial soundness" (this article refers to these goals generally as the objectives of better performing health systems) (Bossert 1998). The rationale underpinning such analytical tool was based on the claim that there was no adequate means of analysing three constitutive aspects of decentralisation:

(1) the amount of choice that is transferred from central institutions to institutions at the periphery of health systems, (2) what choices local officials make with their increased discretion and (3) what effect these choices have on the performance of the health system (Bossert 1998: 1513).

Bossert suggests that the principal-agent approach is possibly the most illuminating framework with which to analyse decentralisation. At the heart of the principal-agent approach is the conceptualisation of the relationship between the centre and the local. He maintains that there are policy implications for how the centre can influence decisions made at the local level in such a way that will increase the likelihood of better performing health systems.

Conceptual Tool

According to the principal-agent approach, decentralisation is understood from the perspective of the principal who uses various strategies to align the activities of the agent in achieving the principal's objectives. These include rewards, punishments and the monitoring of compliance through information returns. According to Bossert, the weakness of this approach is that it does not provide a way of identifying the "range of choice allowed by decentralisation" (pg. 1517). The decision space approach is essentially a modification of the principal-agent approach such that it incorporates this spectrum of choice devolved from the centre to the local levels.

There are three broadly defining aspects of the decision space approach: 1) *mapping the boundaries of the space;* 2) *conceptualising the consequence of decision space on local choice;* 3) *analysing the performance implications of the space.*

For the purposes of the questions posed in this study, the decision space approach will be adapted as an analytical framework in the following ways:

Mapping the decision space boundary: contents of national policy documents regarding the role and responsibilities of local governments in primary health care delivery will be discussed at a general level in descriptive terms. Emphasis will be placed on empirically investigating the actual (i.e. informal) decision space boundaries of local officials in Nigeria and the relational dynamics between central (analytically including State government) and local government agencies. The nature of this informal decision space will also be analysed to draw implications on the level of contestation that exist between the two levels of government. Data will be collected to illuminate these dynamics and subsequent analysis would be guided by three propositions of the framework. 1) the decision space is created by legislative act; 2) informal decision space exists when there is ineffective enforcement of legislation; 3) decision space may be contested by local officials.

Decision space and local choice: the issue of choice and decision space will be investigated along the lines of the following singular proposition: the impact that the decision space (formal and informal but concentrating more on the latter) has on the kinds of choices made by local officials.

*Decision Space and performance implications: t*he study will look at the implications of the following three propositions of this framework (from the local actors' perspective) on primary care health systems performance in Nigeria: 1) incentives and sanctions used by the principal to align interests according to the characteristics of the agent; 2) health information as a monitoring tool: this proposition will analyse the response and perception of local agents to information as a performance management tool; 3) health information as a reflection of health systems performance: this proposition will investigate the opinions of local agents to information as a vital public health resource with implications for health systems performance.

METHODOLOGY

The methodology adopted by this study is by nature reflexive and located within the tradition of interpretive qualitative research (Walsham 1995, 2006). This approach has two basic characteristics – interpretation and reflection. Interpretation implies that the multiple perceptions provided by participants involved in the field situation are taken to represent 'reality' and that these perceptions are then interpreted by the researcher according to the adopted theories about the domain of study (Geertz 1973). The reflexivity mentioned here is in the spirit of what Scott (2000) defined as "lived methodology". Reflexivity is viewed as an essential part of the research process by stimulating critical reflection on taken-for-granted theories, accounts and interpretations (Walsham 1995, 2006). According to this approach, the empirical material is not bound to fit the framework of theoretical ideas, rather it allows research findings to inform and reshape analytical conceptions. At the same time, this approach allows a certain degree of flexibility in accommodating creative and innovative interpretations of decentralisation in the developing country context without prejudging their relevance to current understanding of health systems performance. While the research will involve studying the policy, institutional, structural and social context within which decentralisation is implemented, the focal unit of analysis will be the primary health care unit.

Research Method

Myers (1997), with specific reference to IS research, critically analyses the use of four possible qualitative research methods e.g. grounded theory, ethnography, action research and case study research. This next section justifies the appropriateness of a case study method for this research project.

Case Study Research

Case study as a research method is used to empirically investigate "a contemporary phenomenon within its real life context, especially when the boundaries between phenomenon and context are not clearly evident" (Yin 2003: 13). This article argues that according to Yin's (2003) criteria and definition, this research topic is best investigated using a case study method. Although in building the context of this study it is necessary to include historical and "processual" analysis (Pettigrew 1997), the principal focus of the investigation will concentrate on contemporary challenges of primary health care provision in Nigeria. From another perspective, case studies can also be employed for building new analytical frameworks (Eisenhardt 1989) for understanding the complexity of primary health care delivery.

This research employs a single-case design which gathers different perspectives within the Nigerian public health system but all these perspectives serve as a representative type of primary health care delivery (for example Shaw *et al.* 2007). These different perspectives are from different levels of the primary health care system. For instance, health information systems national consultant, State public health director, Community physician, Local family physician, general practitioner and Facility health care worker. These perspectives also have a wide geographic span ranging from East, West, North, South and Middle-belt.

The circumstance under which it would be suitable to conduct a single case study is when the case is either "critical," "unique," "typical," "revelatory" or "longitudinal," (Yin 2003:41-42). Accordingly, the choice of a single-case design is justifiable from the viewpoint of the case being representative i.e. "typical". The next section introduces a more concrete discussion of data collection methods including the unit of analysis and how these methodological considerations were translated in the fieldwork research.

Data Collection Methods

Interviews are arguably the most significant means of gathering qualitative data and semi-structured interviews the most widely used in information systems research (Myers and Newman 2007). Accordingly, the primary data collection method for this project was made up of five semi-structured telephone interviews of Nigerian primary care practitioners. This included: former state Director of Public Health, Permanent Secretary and current Head of Department of Community Medicine and Primary Care; Senior Registrar Family Medicine; and three primary care doctors. Information was also gleaned from personal communication with an health information system consultant in Nigeria.. Copious amounts of notes were taken during each interview after which they were word processed immediately. The main criteria for choosing interviewees were the depth of experience in their respective level of primary health care in Nigeria, the breadth of knowledge including levels of health care delivery and geographical location, understanding of the political dimension of delivering primary health care.

The substantive questions asked were related to the complexities of primary health care delivery in Nigeria. These questions were classified along the three sub-questions of the research project. The particular focus was on the experiences of local practitioners and their perspective regarding the influence of local and central government agents on the delivery of primary health care. Anecdotal or illustrative responses were encouraged especially where they provide a rich description of the situation.

To ensure reliability of data, evidence is triangulated from the different data sources to evaluate the congruence of opinions. Where there is a divergence of ideas, this is followed up by seeking clarity from the respondent after presenting the contrary view. In addition feedback was given to all interviewees to give them a chance to clarify the interpretations given by the researcher. Most of the interviewees were conducted over a couple of days which also gave room for reflection by both the respondent and the researcher.

The data is expected to serve as evidence in three main ways. First, the analysis and discussion should serve as a tool in persuading the audience of a more complex dynamic at work in delivering primary health care at the local level. Secondly, the evidence should be contextually rich enough to show that primary care delivery is not only technically challenging both also politically intricate.

Data Analysis and Discussion

In order to produce data that are more reflective of reality, data analysis will be conducted through the identified propositions of the conceptual framework and the researcher's informed intuition (Valsiner 2000). Under each proposition, themes from different data sources are highlighted, detailing the most recurring or significantly pronounced themes for the narrative analysis.

Understanding Decentralisation and Health Systems Performance in Nigeria

This section presents the findings from the field in an analytical way by adopting the framework propositions to discuss the evidence from the field. The analysis captures the main areas of input from all interviewees and represents the chain of recurring themes. Where this is not the case, a clear indication of the data source and the counter views are provided (interestingly, this only occurs in the discussion relating to the perceived quality and role of information in primary health care). An attempt is made to analyse these variations using the analytical framework and the researcher's understanding of the field.

Mapping the Decision Boundary

Decision Space: An Act of Legislation

Under the Nigerian *concurrent legislative list*, the constitution allows the provision of a decentralised health care system within the three tiers of government i.e. Federal, State and Local. General and specialist hospitals are principally assigned to the State and Federal government respectively and primary health care is provided by the local government. Having said this, the State and Federal government still provide technical assistance to the local government for instance on polio immunisation and rollback Malaria programme.

Primary health care is the first level of health care delivery service. It is community based therefore patients are only referred to general hospitals or specialist tertiary hospitals if this transfer is deemed necessary at the primary care level. There are three main delivery strategies: 1) health promotion including health education; 2) prevention of diseases (particularly communicable diseased) and immunisation programmes; and 3) provision of facilities for early diagnosis of diseases.

To deliver these functions, the primary care system comprises of health centres, clinics and posts. The health posts are the most remote, providing the most basic form of health care service. It typically operates as an outpatient facility. Health clinics mainly consist of maternity centres and dispensaries. They provide the treatment of minor diseases like malaria and diarrhoea. In the primary health system, health centres are the closest representation of hospitals. They provide extensive preventive health services including health promotion (e.g. environmental sanitation and education on personal hygiene). They also provide the diagnosis and treatment of diseases.

It is therefore constitutionally recognised that local government agents have the principal authority and responsibility for fulfilling these functions under the primary health care system. However, by legislation, the operations of the local government primary health care are directly supervised by the State Ministry of Health (SMOH) who is then accountable to the Federal Ministry of Health (FMOH). The local government reports to SMOH and these report annually and quarterly to the FMOH. One of the direct consequences of a weak accountability structure is presence of a considerably large informal decision space.

Informal Decision Space

In practice, there is no enforceable accountability structure at the local level. The oversight of the FMOH is across a wide distance therefore logistics are difficult for the FMOH which is based in the Capital, Abuja. There is also the issue of misplaced empathy and priority regarding the development of the health system in Nigeria. The FMOH gives an inordinate amount of attention to building hospitals and to curative medical approaches, even though this is not in concert with the national health policy. In effect, local government officials are not only autonomous but a significant proportion of their activities are carried out through an informal decision space.

In terms of proximity, the State has a better chance of being more effective in supervising PHC delivery because all medical officers from the local government meet monthly at the State level. Notwithstanding, the local health system is rife with general political apathy and instability. In theory, constituents can make complaints to the State regarding local government agents who do not deliver according to their terms of office. The State then calls the Local Government Chairman to account. If they can't defend their position then sanctions may be considered. This is however highly unlikely. The SMOH does not have the capacity to either sanction or reward local government officials. The practical option is usually to appeal to their better judgement and sense of duty when they come together at the monthly meetings. In addition, downward accountability to local constituents does not really exist because of an endemic problem with the democratic process: voting is perceived as dangerous and so most people stay away instead of risking their lives. Therefore, local constituents have limited electoral power to call their public representatives to order because of the immature state of the democratic system.

The activities of local government agents are typified by self interest and excessive corruption. Even though there is a concerted effort by the federal government to curtail behaviours of corruption, the commissions set up to enforce this (i.e. National Anti-Corruption Commission and Economic and Financial Crimes Commission), are themselves perceived to be susceptible to corruption and are therefore ineffective. The ineffective enforcement of the formal decision space mapped out by legislation therefore produces a thriving informal decision space at the local level. Nigeria's primary health care system is perceived to be run by local officials who are not bound either by Federal or State health policy imperatives or legislation. There is therefore a different kind of contestation regarding the decision space afforded these local agents.

Decision Space Contested

Instead of local agents seeking a wider decision space, public health practitioners are seeking to extricate the functional delivery of PHC from the influence of politicians. Among other things, they argue that the bureaucratic bottleneck affects the effectiveness of the service provided. Some examples are that, requisitions are intolerably delayed before being fulfilled and immunisation exercises undertaken are not paid for in time. There is therefore a contention that health care delivery should not be run by government but possibly by health boards. This autonomy will include budget facilities and financial independence for public health practitioners.

Public health practitioners ascribe to the view that primary health care is a vital public health service with particular outreach to the poor. Their contention is not regarding the State provision of this service as a public good but its operational involvement. Therefore they protest that a lot more should be done to encourage initiatives such as the National Health Insurance Scheme because they are run by Health Maintenance Organisations and are therefore more accountable and scrutinised. In this case, Government should cater for the poor through a social security system but the primary health care service would still be provided by a third party.

As a summary, we observe that legislation allows the decentralisation of the health sector in Nigeria. However, the lack of an effective enforcement structure leads to a situation where the informal decision space is more prominent than the formal. Consequently, the exception becomes the rule and conceptually speaking, anomaly reigns. There is also a sense that the lack of enforcement is not primarily due to capability but the informal decision space thrives because the FMOH is not really interested in primary health but tertiary health care. Therefore, primary health care is invariably inefficient and the general health system essentially underperforming.

Decision Space and Local Choice

Local Choice Within an Informal Space

The choices made by local government officials have primarily been not to pay adequate attention to primary health care issues. Most of these officers are there for their own selfish reasons because the remuneration for holding this post has recently become more attractive and therefore people vie for these offices without an interest of the community at heart. This attitude affects the local delivery of health services adversely. Local government choices are based on politics and not need. Even those who would like to make a positive difference are constrained because as politicians the feel obliged to payback their election campaign sponsors who strongly influence the political agenda.

For instance, some of these choices translate into charging for immunisation which is meant to be provided free of charge. Another illustration is that the General Hospital which the State government says should be provided free health services at the point of delivery have become an operational farce. The only service which ends up being free is the initial consultation. The required drugs are invariably out of stock. This is because only a proportion of the allocation makes it to the hospital in the first place, the consignment that makes it most conveniently find its way to the nearest pharmacy where more money will be paid for it. When patients come for drugs, they are directed to the nearest pharmacy.

Some of the more substantive factors that influence local choice include the background of the local government chairman. Where this is a health background, there seems to be a better appreciation of PHC otherwise it is treated as least priority. Highly educated local government agents also contribute to the level of attention PHC receives. Other factors also depend on the agenda of influential personalities who may want to boast about their local government area and therefore lobby politicians for rapid health care development programmes in their area. The effect of these diverse influences can be seen where for instance there is a local government area with a population of five thousand being served by three health care centres while another population of seventy thousand does not have any health care centres.

Decision Space and Performance

In Nigeria, a large proportion of the community is rural (it is estimated that about three quarters of the population live in rural areas). This has serious implication for the health profile of the country. For instance, in spite of how sophisticated health service delivery is in the urban areas, this improvement only represents a significantly small proportion of the total population. Similarly, the lack of vital public infrastructures for health delivery in rural areas combined with the high level of poverty in these areas has resulted in the poor health status of the country as a whole. The primary health care service has a major role in determining the overall performance of the health system. However, PHCs in Nigeria are not efficient and there are significant difference between the extensive policy formulations at the centre and action at the local level. Even thought there are extensive policy directives on providing primary health care it is usually either ignored or not followed.

Incentives and Sanctions

To compound this issue, financial and non-financial incentives or sanctions are not applicable in the Nigerian context. In addition to the absence of an effective enforcement structure, the local government has an independent budget allocation and therefore the FMOH is not responsible for salaries of local PHC officials. The regime of incentives and sanctions are therefore too weak to bring about any substantial change in the local government's primary health care performance.

Nonetheless, the evaluation of health care delivery is conducted through the monitoring of health information.

Health Information as a Monitoring Tool

The local government sends required health information to the SMOH. These are received by career officers who normally should collate, analyse and verify the results but this is rarely done (if at all). Apart from the fact that there are very limited visits from the SMOH to verify data returns, when do visits do happen local governments are notified in advance, defeating the purpose of the exercise.

As an illustration, in one of the supposedly largest State hospitals serving a local government area, there have only been 3 visitations by the State Monitoring Teams and 1 visit by the federal government in the last 6 years. In fact, the purpose of the FG visit was to evaluate the feasibility of the hospital being a centre for AIDS treatment as supposed to monitoring the performance returns of the hospital.

In order to save face and not be found wanting, potentially damaging health data is often manipulated before being reported to the upper levels. For example there has been a programme of polio eradication every two months for the last one year where all children under five are supposed to be immunised however, polio is still widespread but the federal government does not report this. It is often said that anyone who knows anything about the health care system in Nigeria will not trust the health records.

Health Information as Health Systems Performance

The problems with reliable health records are much more nuanced as a component strategy of general public health. Information management is very crucial to primary health care in terms of health planning, disease monitoring and surveillance etc. There is a view from the Director of Public Health that primary health care in Nigeria has a good information management system. The argument is that prior to any intervention programme in a locality, a situational analysis is conducted to identity the main health problems and need. Therefore subsequent action is based on concrete and well studied information. From an operational management level, the State Primary Health Doctor's perception is also that health workers in the rural areas take data recording seriously. In addition, they are said to be meticulous in reporting the information they collect to the extent that some go out of their way to ensure accuracy. However, it is noted that there is another extreme set of workers who are unscrupulous regarding information collection. For example, an independent examiner on the programme for Polio eradication noted the "super-efficiency" with which certain health workers had administered the vaccinations and had logged all the information. On further investigated she realised that the vaccines had been disposed of and the time was spent meticulously cooking the log books.

Some other public health doctors (e.g. in the local government and private sector) however feel that many health workers don't appreciate data collection probably due to their level of education but still collect the data because it is mandatory. They admit that some errors in the data may suggest that health workers may not be as meticulous as community health physicians. Nonetheless, there is a view that it is highly unlikely that health workers would intentionally fabricate data especially since the data reported have to tally with other stakeholder data and reports (e.g. drug consignments).

There are two categories of data collation: the first is on disease surveillance and notification, the second is on monitoring and evaluation. A designated local primary care officer collects weekly disease surveillance data from primary health centres including some private establishments. These data focus on specific epidemic prone diseases like cholera. These data are sent to the SMOH epidemiologist who analyses the figures to see if an epidemic prevalence threshold has been broken. A monitoring and evaluation officer collects data from peripheral facilities monthly. These facilities ideally fill in the National Health Information Management System form everyday. Data collected include drugs dispensed, family planning, deliveries, treatments etc. Health data for the month are verified by the community health physician before being reported to the SMOH.

Generally, the reality of practice is that data reliability is not a priority in the primary health care system. As such there are no field surveys—conducted at either the local or state level—to verify the data reported. Data reliability is a major problem in Nigeria to the extent that there are even problems with the national census.

Assuming that records collected at the primary care level is mostly reliably. The data is rarely analysed and when analysed seldom lead to concrete action plans which will improve performance of the primary health care. There is therefore a substantial gap between information, policy and action. For example, when polio was reported at a local government area there was only one follow-up when there should have been a few.

Closely related to this is the fact that there is no feedback structure for local health practitioners to review the data submitted in light of a set performance target. There is a notion that the absence of feedback is partly due to the lack of appreciation of the effect it can have on performance at the ground level. Apart from the lack of appreciation, it is also suggested that local agents shy away from the additional cost of getting extra resources to fulfil this role.

There is evidence however to suggest that when the occasional feedback is given, it proves highly effective. For example, a feedback workshop on immunisation, which showed the performance level of a particular local government, motivated workers to try and bridge the gap between target and performance. This reaction is usually more accentuated when there is a comparison with other local government areas or states.

Empirical Findings and Framework Critique

Mapping the Decision Boundary

Nigeria has had a long-standing decentralised health system (Gupta *et al.* 2003). The framework helps to insightfully analyse the tensions that exist between the central and local agents in the delivery of primary health care. Furthermore, it gives clear indications regarding the objectives of a decentralised health system i.e. equity, efficiency, quality and financial soundness.

The decision space lens also helped illuminate the circumstances under which an informal decision space might be created e.g. lack of effective enforcement. In the context of the Nigerian health sector, this was clearly an issue which had unquestionable impact on the delivery of primary health care. The framework however, did not provide tools for understanding how to interpret a situation where the informal decision space is the norm rather than the anomaly and how to understand its potential impact on the performance of the health system (this would be discussed further in the conclusion).While there are definite decision boundaries for the delivery of primary health care at the local level, the peculiar nature of the informal decision space somewhat makes the discussion about the range of choice available to local agents irrelevant. The reality on the ground suggests that there are no effective structures to enforce formally defined choices at the local level. Choices made regarding primary health care are therefore practically autonomous. Consequently, the focus of this analytical framework on local agents contesting or negotiating for a wider decision space is not applicable. The contestation is however present in a more classic debate about the role of the State in providing public services (this theme would also be elaborated in the concluding sections).

Decision Space and Local Choice

While the original framework conceives the range of choices available to local agents in concrete terms (i.e. finance, human resource, facilities etc), this study adopts the notion of choice as an empirical object. That is, the effective and actual perception of choices applicable in the field. This is because, the PHC choices made at the local level in Nigeria are analysed through the perspective of an informal decision space. The analysis showed a prevalence of apathy towards health delivery and self-serving motivations. While it is evident that this has been detrimental to the primary care system in Nigeria, the framework highlighted that the particular characteristics of the local government in terms of motivations and capacity affects health systems performance. In the Nigerian context, there seemed to be an association between the local government agents' professional background (including level of education) and the delivery of primary health care. Suggesting that agent's with a medical background and high level of education are usually more motivated and capable of effectively delivering primary health care. The framework was therefore useful albeit through a slight modification of focus being more on the informal decision space.

Decision Space and Performance

The notion of control to achieve better health systems performance was not well developed in this framework. The analytical weight is predominantly skewed towards the principal i.e. central or state. The suggestions of an incentive or sanction strategy were not really useful in understanding health decentralisation and performance in the Nigerian context. This is partly because this section of the analytical tool is built on the assumptions of a formal decision space (which is by and large insignificant in practice). Nevertheless, the framework also indicates that the local agents also wield some influence over the principal because they generate and own contextual information needed by the principal. This provided a little more ammunition in understanding decision space and performance through the dimension of information. The study for instance was able to highlight how the local agents can manipulate data in order to cover up their poor performance. This analysis was also quite superficial because of the instrumental view of information portrayed in the framework.

In the concluding section, this article suggests how some concepts from the development and information systems literature might be able to provide a richer and more robust analytical approach to studying the link between local agent's decision space and performance.

To bring all the component parts of the study together, Table 1 attempts to provide a brief snapshot of the links between the primary questions of this research project and its findings. This is done by operationalizing the research questions through specific analytical propositions and justifying the findings through exemplary evidence from the field.

CONCLUSION

In developing countries the study of decentralisation and health systems performance incorporates the analysis of an intricate web of agencies and institutional structures. This research project approached the problem domain from the perspective of tensions generated between the local level being agents and upper government levels (e.g. State and Federal) being principals. In particular, it investigated how the devolution of decision-making authority to local government agents (i.e. decision space) impact on the primary health care system. The following conclusions of this study navigate the subtle conceptual and empirical nuances of this problem domain.

Weak State, Rogue Agent: Complementary Vices

The findings of the study suggest that where you have a weak principal, agents will operate predominantly through an informal decision space. The formal decision space therefore serves as a platform for breeding unaccountable local agents. However, in developing countries, it is not just the lack of an accountability structure (see Abouzahr *et al.* 2005) that necessarily leads to the poor delivery of primary health care and the failing health system. Rather, the motivation and capacity of local agents also have some influence in determining the quality of primary health care in a particular locality. In the absence of a competent State to enforce the boundaries of a formal decision space, self-seeking local government officials exploit the opportunity to indulge in unscrupulous activities with public finances at the expense of the local health system.

The access of poor people to health care facilities are not only curtailed but their right to influence issues regarding their health is also limited. For public health systems to be effective, people have to take an active part in shaping health care strategies (Macfarlane *et al.* 2000). This necessitates a rethinking for national health policy makers to institute a public health system that collaborates with local actors to reflect the diversity of local needs as indicated by the local communities (see Newell 1989).

Information is an Elusive Reality

Developing countries face a host of challenges at different stages and functions of the primary care information process (Godlee *et al.* 2004). At the technical level, although the process is fairly routinized, the reliability of the data collected rests on the competence and motivation of health workers. A lack of appreciation for data may be due to not understanding how this data actually fits into the bigger picture of health care delivery. However, without a visible feedback and data verification structure, this exercise would only be perceived as theoretical. As supported by this study, the managerial imperative which views information as a monitoring and control instrument (Berg 2001) has been widely criticised as narrowly conceived in the information systems field (Ciborra 2000, Kallinikos 2006) .

In conclusion, this study explores the significant contextual factors which have far-reaching implications for the implementation and use of health information systems for improving health care delivery in developing country context. As far as it is exploratory, the study has not been particularly concrete in investigating a grounded HIS project. The viewpoint of the researcher, which was substantiated through this study, is that most matters in developing countries (and especially in the domain of health care) do not warrant the centrality of technology because a rich understanding can often be obtained by studying the social and political foundations on which previous technological initiatives have been built.

REFERENCES

Aanestad, M.*, et al.* (2005) “Strategies for Development and Integration of Health Information Systems: Coping with Historicity and Heterogeneity “, *Information Systems Group Working Article: University of Oslo,* 5.

AbouZahr, C. and T. Boerma (2005) “Health Information Systems: The Foundations of Public Health”, *Bulletin of the World Health Organization,* 83 (8), pp. 578-583.

Adeyemo, A. (2005) “Local Government and Health Care Delivery in Nigeria: A Case Study”, *J. Hum. Ecol,* 18 (2), pp. 149-160.

Alvarez, A. J. S. (2003) “Towards an Interpretative Integrative Framework to Conceptualise Social Processes in Large Information Systems Implementations”, *Information Technology for Development,* 10 pp. 233-247.

Atkinson, S. (1995) “Restructuring Health Care: Tracking the Decentralization Debate”, *Progress in Human Geography,* 19 (4), pp. 486-503.

Atkinson, S., L. Fernandes, S. Caprara and J. Gideon (2005) “Prevention and Promotion in

Decentralized Rural Health Systems: A Comparative Study from Northeast Brazil", *Health Policy and Planning,* 20 (2), pp. 69-79.

Atkinson, S., R. Medeiros, P. Oliveira and R. Dias de Almeida (2000) "Going Down to the Local: Incorporating Social Organisation and Political Culture into Assessments of Decentralised Health Care", *Social Science and Medicine,* 51 pp. 619-636.

Berg, M. (2001) "Implementing Information Systems in Health Care Organizations: Myths and Challenges", *International Journal of Medical Informatics,* 64 pp. 143-146.

Bergqvist, J., P. Dahlberg and F. Ljungberg (2006) *Scalability through Cultivation. Designing It Support for Co-Ordination Work* Last accessed: 6 February 2007 Last updated: Address: http://citeseer.ist.psu.edu/cache/articles/cs/23947/http:zSzzSzwww.dahlberg.sezSzpubzSzmaster.pdf/scalability-through-cultivation-designing.pdf.

Berman, P. (Ed.) (1995) *Health Sector Reform: Making Health Development Sustainable.,* Harvard University Press, Boston.

Berman, P. and T. Bossert (2000) "Appraising a Decade of Health Sector Reform in Developing Countries" *Havard School of Public Health* Washington, DC.

Bhasker, R. (1998) "Philosophy and Scientific Realism" in *Critical Realism: Essential Readings*, (Archer, M., R. Bhasker, A. Collier, T. Lawson and A. Norrie eds) Routledge, London, pp. 16-48.

Blaauw, D., L. Gilson, L. Penn-Kekana and H. Schneider (2003) "Organisational Relationships and the 'Software' of Health Sector Reform. Background Article Disease Control Priorities Project (Dcpp) Capacity Strengthening and Management Reform" *Centre for Health Policy, School ff Public Health, University of The Witwatersrand*

Bossert, T. (1979) "Health Policies in Africa and Latin America: Adopting the Primary Care Approach", *Social Science and Medicine,* 13 (C), p. 65.

Bossert, T. (1998) "Analyzing the Decentralization of Health Systems in Developing Countries: Decision Space, Innovation and Performance", *Social Science and Medicine* 47 (10), pp. 1513-1527.

Bowker, G. and S. Star (1999) *Sorting Things Out: Classification and Its Consequences,* The MIT Press, Cambridge, MA.

Braa, J. (2000) "Developing District-Based Health Care Information Systems: The South African Experience". in *Proceedings of IRIS 23. Laboratorium for Interaction Technology,* University of Trollhättan Uddevalla,

Braa, J.*, et al.* (2001) "A Study of the Actual and Potential Usage of Information and Communication Technology at District and Provincial Levels in Mozambique with a Focus on the Health Sector", *EJISDC,* 5 (2), pp. 1-29.

Braa, J., E. Monteiro and S. Sahay (2004) "Networks of Action: Sustainable Health Information Systems across Developing Countries", *MIS Quarterly: Management Information Systems,* 28 (3)**,** pp. 337-362.

Buse, K. and G. Watt (1996) "Aid Coordination for Health Sector Reform: A Conceptual Framework for Analysis and Assessment", *Health Policy,* 38 pp. 173-187.

Chatora, R. and P. Tumusime (2004) "Primary Health Care: A Review of Its Implementation in Sub-Saharan Africa", *Primary Health Care Research and Development,* 5 pp. 296-306.

Chilundo, B. and M. Aanestad (2003) "Vertical of Integrated Health Programmes? The Consequence for the Laboratory Information Systems in Mozambique". in *Electronic Proceedings of the IFIP TC8 & TC9 . WG8.2 + 9.4 Working Conference on Information Systems Perspectives and Challenges in the Context of Globalization,* Athens, Greece,

Chilundo, B. and M. Aanestad (2004) "Negotiating Multiple Rationalities in the Process of Integrating the Information Systems of Disease-Specific Health Programmes", *EJISDC,* 20 (2), pp. 1-28.

Ciborra, C. (2002) *The Labyrinths of Information: Challenging the Wisdom of Systems,* Oxford University Press, Oxford.

Ciborra, C. (Ed.) (2000) *From Control to Drift. The Dynamics of Corporate Information Infrastructures,* Oxford University Press, Oxford.

Ciborra, C. and Associates (2000) *From Control to Drift: The Dynamics of Corporate Information Infrastructure,* Oxford University Press, Oxford.

Collins, C. and A. Green (1994) "Decentralization and Primary Health Care: Some Negative Implications in Developing Countries." *Int J Health Serv,* 24 (3), pp. 459-75.

Cornia, G. A. (2001) "Globalization and Health: Results and Options", *Bulletin of the World Health Organization,* 79 pp. 834-841.

Cornwall, A., H. Lucas and K. Pasteur (2000) "Introduction: Accountability through Participation:Developing Workable Partnership Models in the Health Sector", *IDS Bulletin,* 31 (1), pp. 1-13.

Cueto, M. (2004) "The Origins of Primary Health Care and Selective Primary Health Care", *American Journal of Public Health,* 94 (11), pp. 1864-1874.

Deaton, A. (2003) "Health, Inequality, and Economic Development", *Journal of Economic Literature,* XLI pp. 113-158.

Dobrow, M., V. Goel and R. Upshur (2004) "Evidence-Based Health Policy: Context and Utilisation", *Social Science and Medicine,* 58 pp. 207-217.

Eisenhardt, K. (1989) "Building Theories from Case Study Research", *Academy of Management Review,* 14 (4), pp. 532 - 550.

Filmer, D., L Pritchett and J. Hammer. (1998) "Health Policy in Poor Countries: Weak Links in the Chain?" *World Bank, Development Research Group, Poverty and Human Resources* Washington, D.C.

Gallup, J. L. and J. D. Sachs (2001) "The Economic Burden of Malaria", *The American Society of Tropical Medicine and Hygiene,* 64 (1,2), pp. 85-96.

Garrett, L. (2007) *The Challenge of Global Health* Foreign Affairs Last accessed: 1 March 2007 Last updated: Address: http://www.foreignaffairs.org/20070101faessay86103/laurie-garrett/the-challenge-of-global-health.html.

Geertz, C. (1973) *The Interpretation of Cultures,* Basic Books, New York.

Godlee, F.*, et al.* (2004) "Can We Achieve Health Information for All by 2015", *Lancet,* 364 pp. 295-300.

Goodman, N. (1978) *Ways of Worldmaking,* Hackett, Indianapolis.

Green, A. (1999) *An Introduction to Health Planning in Developing Countries, (2nd Ed.)* Oxford University Press, Oxford.

Griffith, J. A. G. (1966) Central Departments and Local Authorities. University of Toronto Press, Toronto, Ont.

Gupta, M., V. Gauri and S. Khemani (2003) "Decentralized Delivery of Primary Health Services in Nigeria. Survey Evidence from the States of Lagos and Kogi" *The world Bank* Africa Region.

Gwatkin, D. (2000) "Critical Reflection: Health Inequalities and the Health of the Poor. What Do We Know? What Can We Do?" *Bulletin of the World Health Organisation,* 78 (1), pp. 3-18.

Hall, J. J. and R. Taylor (2003) "Health for All Beyond 2000: The Demise of the Alma-Ata Declaration and Primary Health Care in Developing Countries", *Medical Journal of Australia,* 178 (1), pp. 17-20.

Heeks, R. (2006) "Health Information Systems: Failure, Success and Improvisation", *International Journal of Medical Informatics,* 75 pp. 125-137.

Jamison, D. and W. Mosley (1991) "Disease Control Priorities in Developing Countries: Health Policy Responses to Epidemiological Change", *American Journal of Public Health,* 81 (1), pp. 15-22.

Jeppsson, A. and S. A. Okuonzi (2000) "Vertical or Holistic Decentralization of the Health Sector? Experiences from Zambia and Uganda", *The International Journal of Health Planning and Management,* 15 (4), pp. 273-289.

Kallinikos, J. (2006) *The Consequences of Infformation. Institutional Implications of Technological Change* Edward Elgar, Cheltenham.

Kimaro, H. and J. Nhampossa (2005) "Analysing the Problem of Unsustainable Health Information Systems in Less-Developed Economies: Case Studies from Tanzania and Mozambique", *Information Technology for Development,* 11 (3), pp. 273-298.

Klein, H. and M. Myers (1999) "A Set of Principles for Conducting and Evaluating Interpretive Field Studies", *MIS Quarterly,* 23 (1), pp. 67-93.

Lee, K. (1998) "Shaping the Future of Global Health Cooperation: Where Can We Go from Here?" *Lancet,* 351 pp. 899–902.

Littlejohns, P., J. C. Wyatt and L. Garvican (2003) "Evaluating Computerised Health Information Systems: Hard Lessons Still to Be Learnt", *BMJ,* 326 pp. 860-863.

Loewenson, R. (1993) "Structural Adjustment and Health Policy in Africa", *Int J Health Serv,* 23 (4), pp. 717-730.

Macfarlane, S., M. Racelis and F. Muli-Musiime (2000) "Public Health in Developing Countries", *The Lancet,* 356 pp. 841-46.

Magnussen, L., J. Ehiri and P. Jolly (2004) "Comprehensive Versus Selective Primary Health Care: Lessons for Global Health Policy", *Health Affairs,* 23 (3), pp. 167 - 176.

Masaiganah, M. S. (2004) "Primary Health Care for the People: Health Policy in Tanzania", *Development,* 47 (2), pp. 136-139.

McGrail, K. and C. Black (2005) "Access to Data in Health Information Systems", *Bulletin of the World Health Organization,* 83 (8), p. 563.

McMichael, C., E. Waters and J. Volmick (2005) "Evidence-Based Public Health: What Does It Offer Developing Countries?" *Journal of Public Health,* 27 (2), pp. 215-221.

McPake, B. and E. Banda (1994) "Contracting out of Health Services in Developing Countries." *Health Policy Plan,* 9 (1), pp. 25-30.

Mengiste, S. and P. Nielsen (2006) *Scaling Health Information Systems in Developing Countries: On the Essence of Being Installed Base Friendly* Last accessed: 6 February 2007 Last updated: Address: http://www.itu.dk/iris29/IRIS29/14-5.pdf.

Mills, A., *et al.* (2004) "The Performance of Different Models of Primary Care Provision in Southern Africa", *Social Science and Medicine,* 59 (5), pp. 931-943.

Murray, C. and J. Frenk (2001) "World Health Report 2000: A Step Towards Evidence-Based Health Policy", *The Lancet,* 357 pp. 1698-700.

Myers, M. (1997) "Qualitative Research in Information Systems", *MISQ Quarterly,* 21 (2), pp. 241-242.

Myers, M. D. and M. Newman (2007) "The Qualitative Interview in Is Research: Examining the Craft", *Information and Organization,* X (x).

Newell, K. (1989) "The Way Ahead for District Health Systems", *World Health Forum,* 10 (1), pp. 80-87.

Niessen, L., E. Grijseels and F. Rutten (2000) "The Evidenced-Based Approach in Health Policy and Health Care Delivery", *Social Science and Medicine,* 51 pp. 859-869.

Okuonzi, S. A. and J. Macrae (1995) "Whose Policy Is It Anyway? International and National Influences on Health Policy Development in Uganda", *Health Policy and Planning,* 10 (2), pp. 122-132.

Paglin, M. (1974) "Public Health and Development: A New Analytical Framework", *Economica, New Series,* 41 (164), pp. 432-441.

Peters, D. and S. Chao (1998) "The Sector-Wide Approach in Health: What Is It? Where Is It Going? " *International Journal for Health Planning and Management,* 13 pp. 177-190.

Pettigrew, A. (1997) "What Is a Processual Analysis?" *Scandinavian Journal of Management,* 13 (4), pp. 337-348.

Rhodes, R. A. W. (1986) The National World of Local Government. Allen and Unwin, London.

Sachs, J., *et al.* (2004) "Ending Africa's Poverty Trap", *Brookings Articles on Economic Activity,* 1 pp. 117-240.

Sahay, S. and G. Walsham (2006) "Scaling Health Information Systems in India: Challenges and Approaches", *Information Technology for Development,* 12 (3), pp. 185-200.

Sayer, A. (2000) *Realism and Social Science,* Sage, London.

Scott, S. (2000) "Lived Methodology: A Situated Discussion of 'Truth and Method' in Interpretive Information Systems Research" *London School of Economics. Department of Information Systems Working Article Series 91*

Shaw, V. (2005) "Health Information System Reform in South Africa: Developing an Essential Data Set", *Bulletin of the World Health Organization,* 83 (8), pp. 632-636.

Smith, B. C. (1997) "The Decentralization of Health Care in Developing Countries: Organisational Option", *Public Administration and Development,* 17 pp. 399-412.

Smith, M., S. Madon, et al. (2008) "Integrated Health Information Systems in Tanzania: Experience and Challenges", EJISDC, 33 (1), pp. 1-21.

Stansfield, S. (2005) "Editorial - Structuring Information and Incentives to Improve Health", *Bulletin of the World Health Organisation,* 83 (8), pp. 562-563.

Starfield, B., L. Shi and J. Macinko (2005) "Contribution of Primary Care to Health Systems and Health", *Milbank Quarterly* 3 pp. 457–502.

Tarimo, E. and F. Fowkes (1989) "Strengthening the Backbone of Primary Health Care", *World Health Forum,* 10 (1), pp. 74-79.

Valsiner, J. (2000) "Data as Representations: Contextualizing Qualitative and Quantitative Research Strategies ", *Social Science Information,* 39 (1), pp. 99-113.

Waitzkin, H. (2003) "Report of the Who Commission on Macroeconomics and Health: A Summary and Critique", *The Lancet,* 361 pp. 523-26.

Walsham, G. (1995) "Interpretive Case Studies in Is Research: Nature and Method", *EJISDC,* 4 (2), pp. 74-81.

Walsham, G. (2006) "Doing Interpretive Research", *EJISDC,* 15 pp. 320-330.

Walt, G. and L. Gilson (1994) "Reforming the Health Sector in Developing Countries: The Central Role of Policy Analysis." *Health Policy Plan,* 9 (4), pp. 353-370.

WHO (1978) "Declaration of Alma-Ata". in *International Conference on Primary Health Care,* Alma-Ata, USSR,6-12 September,

WHO (2000) "The World Health Report 2000" *WHO* Geneva.

WHO (2001) "Commission on Macroeconomics and Health. Macroeconomics and Health: Investing in Health for Economic Development." *WHO* Geneva.

World Bank (1993) "The World Development Report 1993: Investing in Health" *Oxford University Press* New York.

Yin, R. K. (2003) *Case Study Research: Design and Methods,* (Third Edition) Sage. Third Edition, London.

This work was previously published in International Journal of Healthcare Delivery Reform Initiatives, Vol. 1, Issue 1, edited by M. Guah, pp. 25-47, copyright 2009 by IGI Publishing (an imprint of IGI Global).

Chapter 4.10

Assessing Physician and Nurse Satisfaction with an Ambulatory Care EMR:

One Facility's Approach

Karen A. Wager
Medical University of South Carolina, USA

James B. Smith
Medical University of South Carolina, USA

James S. Zoller
Medical University of South Carolina, USA

John L. Waller
Medical University of South Carolina, USA

David E. Soper
Medical University of South Carolina, USA

Frank C. Clark
Medical University of South Carolina, USA

ABSTRACT

Evaluating clinician satisfaction with an electronic medical record (EMR) system is an important dimension to overall acceptance and use, yet project managers often lack the time and resources to formally assess user satisfaction and solicit feedback. This article describes the methods used to assess clinician satisfaction with an EMR and identify opportunities for improving its use at a 300-physician academic practice setting. We administered an online survey to physicians and nurses; 244 (44%) responded. We compared physician and nurse mean ratings across 5 domains, and found physicians' satisfactions scores were statistically lower than nurses in several areas ($p<.001$). Participants identify EMR benefits and limitations, and offered specific recommendations for improving EMR use at this facility. Methods used in this study may be particularly useful to other organizations seeking a practical approach to evaluating EMR satisfaction and use.

INTRODUCTION

The degree of interest and momentum in furthering the widespread adoption and use of electronic medical record (EMR) (or electronic health record systems) is at an all time high in the United States. Healthcare providers, purchasers, payers and suppliers are all looking to the EMR as a tool to help promote quality, enhance patient safety, and reduce costs. Despite this energy, recent estimates indicate EMR adoption rates in ambulatory care remain in the 15-20% range (Hillestad et al., 2005). Cost, lack of uniform interoperability standards, limited evidence showing use improves patient outcomes and clinician acceptance are among the barriers to widespread EMR adoption (Bates, 2005). Those who have overcome these initial hurdles and made the transition from a paper-based medical record system to an EMR often lack the time, resources and expertise to evaluate the system's impact on the organization, including clinician use and satisfaction with the system (Anderson & Aydin, 2005; Wager, Lee, & Glaser, 2005).

Use and satisfaction are two key measures of the success of any information system (DeLone & McLean, 2003), including EMR system success (Anderson & Aydin, 2005). Various researchers have assessed physician use and satisfaction with the EMR (Sittig, Kuperman, & Fiskio, 1999; Gadd & Penrod, 2001; Penrod & Gadd, 2001; Likourezos et al., 2004; Joos, Chen, Jirjis, & Johnson, 2006) and some have found that user group perspectives can differ even within the same institution (Wager, Lee, White, Ward, & Ornstein, 2000; O'Connell, Cho, Shah, Brown, & Shiffman, 2004b; Hier, Rothschild, LeMaistre, & Keeler, 2005). Assessing user reaction to the human-computer interface is also an important dimension (Sittig, Kuperman, & Fiskio, 1999; Despont-Gros, Mueller, & Lovis, 2005) in evaluating EMR satisfaction. Likewise, the timing of the evaluation study is important. Conducting formative evaluation studies during enterprise EMR implementation can be particularly useful in identifying perceived problems and making adjustments to the implementation plan or reallocating resources as needed (Friedman & Wyatt, 1997; Burkle, Ammenwerth, Prokosch, & Dudeck, 2001; Anderson & Aydin, 2005; Brender, 2006).

Our study was designed to assess physician and nurse use and satisfaction with an enterprise-wide ambulatory care EMR. We incorporated into the evaluation a means of assessing physician and nurses' reactions to the human-computer interface and also solicited their input and suggestions on how to improve the system's usefulness to our organization. This article summarizes the methods used, findings, and relevance to other organizations in the throes of implementing and evaluating EMR acceptance.

BACKGROUND

The Medical University of South Carolina (MUSC) in Charleston, South Carolina has implemented an electronic medical record (EMR) system, known as Practice Partner Patient Record® in the majority of its ambulatory clinics over the past few years. Although EMR use is not new to MUSC (family medicine has used the system since the early 1990s and internal medicine since the mid-1990s), it was not until February 2004 that we secured funding to deploy the EMR throughout the ambulatory care enterprise. When the system is fully implemented, paper medical records will have been replaced, and both primary care and specialty providers will share a *single* electronic medical record for their patients. This message was conveyed from the top down, starting with senior leadership and the dean of our medical school.

The EMR product itself has many of the attributes of a typical EMR system, including electronic health data capture, results management, decision-support, and electronic communications. However, MUSC has not yet installed enterprise-wide direct order entry nor activated the preventive care reminder functions. Disease-specific progress note templates are available for facilitating program note entry; however, direct data entry is not a requirement for using the system, and transcribed notes can also be incorporated. The system also includes a prescription writer, which allows prescriptions to be entered and tracked in the patient record while automatically checking for interactions with other medications and documented allergies. Patients receive printed prescriptions at the time of the visit; the prescriptions are not yet sent electronically to the pharmacy.

We provided formal training sessions to physicians, nurses and administrative support; however, nurses and administrative staff received at least four hours of initial training, while most physicians only had 30-45 minutes of training. Nurses and administrative staff were trained in small groups in a classroom setting with computer workstations for each individual. Physicians were offered several options for training, including small group sessions, but the far majority opted for one-on-one training with a clinical analyst. Knowing that physicians' schedules were harried, we decided to provide more intensive training to nurses and administrative staff. We felt if nurses and administrative staff were comfortable with the system, they could assist physicians in their respective departments as needed.

The purpose of the study was to gain insight into user satisfaction and determine if there were differences in user group satisfaction, and solicit formal feedback on how to improve the system's use at our organization. We defined 'user' as any MUSC employee or student who had been issued an EMR login and password. This article describes the methods used to conduct the survey and the results from our attending physician and nurse user community.

METHODS

Survey Instrument

We conducted preliminary interviews with physicians and nurses regarding their views and experiences with the EMR, but were interested in soliciting input from all EMR users at MUSC. Given the size of the user group, we decided to adopt a survey approach. We adapted the *Questionnaire for User Interaction Satisfaction (QUIS)*, developed by researchers at the University of Maryland, for use in this study after reviewing the literature, consulting with medical informatics professionals and soliciting input from EMR physician leaders at MUSC. The QUIS has been tested as a valid and reliable instrument in settings similar to MUSC (Chin, Diehl, & Norman, 1988) and was used recently by researchers affiliated with Brigham and Women's Hospital to assess physician satisfaction with its internally developed outpatient EMR (Sittig, Kuperman, & Fiskio, 1999). The QUIS has also validated for online administration (Slaughter, Harper, and Norman, 1994). The instrument assesses user satisfaction in five major domains, with four to six questions in each: (1) overall user reactions, (2) screen design and layout, (3) terminology and system messages, (4) learning, and (5) system capabilities. Recognizing that participants might respond differently depending upon whether they were assessing how long it takes to open the application or navigate within it, we separated the item "system speed" survey component into two statements—system launch speed and navigation speed. We asked participants to rate each question on a scale from 0 (the lowest) to 9 (the highest) level of satisfaction.

We included several additional items in the survey: (a) demographic data (e.g., position, age, gender), (b) use of the EMR (whether provider dictated notes or directly entered them into EMR), and (c) three open-ended questions, in which participants were asked to identify the three greatest benefits or advantages and three greatest limitations or disadvantages to using the EMR and any recommendations they have for improving the use and effectiveness of the EMR within their clinic or at MUSC. The items and scale from the QUIS were kept intact. A draft survey was sent to a pilot group of physicians, nurses and administrative staff. Suggested changes were incorporated into the final version of the survey. Institutional Review Board approval was obtained prior to conducting the study.

User Population and Survey Administration

We sent an e-mail message from one of the authors (who happened to serve as chair of the Physician Information Council) to all attending physicians and nurses listed in the EMR user database. Our sampling frame included all individuals who had been issued an EMR username and password—for a total population of attending physicians (245) and nurse EMR users (304) of 549. In the e-mail message, participants were asked to click on an embedded hyperlink to complete the online questionnaire. We gave participants the option of printing and faxing the completed survey to us (48 surveys were returned by fax). Two reminder notices were sent—one week and two weeks following the initial mailing. All participants were assured confidentiality of their responses.

Data Analysis

Survey responses were downloaded from the survey provider to an electronic database and then imported into SPSS for analysis (Windows, 2005).

Responses to open-ended questions were grouped and assigned to categories by the primary author, experienced in qualitative research. These were then tabulated within each of the categories and discussed among the participating authors.

Table 1. Reliability of domains (Crohbach's Alpha)

Domain	Alpha
Overall user satisfaction	.911
Screen design and layout	.859
Terms and system information	.891
Learning	.876
System capabilities	.835
Overall	.961

RESULTS

Demographics of Participants and Their Use of EMR system

We received 244 completed surveys from attending physicians and nurses for an overall response rate of 44%. Forty-seven (47%) of physicians and 38% of nurses responded. 32% of participating physicians and 98% nurses are women; 85% are between the ages of 30-60, equally distributed within each decade of life. Nearly 37% of physicians and 19% of nurses reported having prior experience with other EMR systems, and 62% have used the EMR at MUSC for at least one year.

When physician participants were asked how often they dictate patient information that is eventually transcribed into the EMR, 39% reported frequently (defined as more than 50% of the time), 4% sometimes (25-50% of the time) and 58% reported rarely or never (defined as less than 25% of the time) (n=109). Almost 40% of participants reported having paper medical records pulled daily for patient visits, 14% sometimes, and 44% rarely or never (n=108). 70% reported that they access the EMR remotely on at least a weekly or daily basis.

Satisfaction with EMR

We assessed the internal consistency reliability of the five domains of the QUIS part of the survey (Table 1) and examined mean satisfaction scores for attending physicians and nurses for each item within the five domains. Overall Crohbach's alpha was 0.961.

Attending physician and nurse mean scores are shown in Table 2. Items were rated on a scale of 0 to 9, with 0 being the most negative, 9 the most

Table 2. Physician and nurse mean satisfaction scores by domain/item

Domain	Item (0-9 scale)	Physician	Nurse
Overall satisfaction	Terrible……………Wonderful	5.07	5.92*
	Difficult……………Easy	5.17	6.21*
	Frustrating……………Satisfying	4.33	5.09*
	Inadequate Power……………Adequate Power	4.45	5.02
	Dull……………Stimulating	4.65	5.39*
	Rigid……………Flexible	4.42	5.41*
	Overall satisfaction composite score	**4.67**	**5.50***
Screen Design and Layout	Characters on the screen: Hard to read……………Easy to read	6.67	7.16
	Highlighting on the screen simplifies task: Not at all……………Very much	5.49	6.54*
	Organization of information on screen: Confusing……………Very clear	5.45	6.17*
	Sequence of screens: Confusing……………Very clear	5.56	5.81
Terms and System Information	Use of terms throughout system: Inconsistent……………Consistent	6.09	6.58
	Computer terminology is related to the task you are doing: Never……………Always	5.89	6.31
	Position of messages on screen: Inconsistent……………Consistent	6.05	6.48
	Messages on screen which prompt user for input: Confusing……………Very clear	5.42	6.14*
	Computer keeps you informed about what it is doing: Never……………Always	4.90	5.42
	Error messages: Unhelpful……………Helpful	3.22	4.19
Learning	Learning to operate the system: Difficult……………Easy	5.23	5.98*
	Exploring new features by trial and error: Difficult……………Easy	4.73	5.76*
	Remembering names and use of commands: Difficult……………Easy	4.93	5.51
	Tasks can be performed in a straight forward manner: Never……………Always	5.06	5.74*
	Help messages on the screen: Confusing……………Clear	4.14	5.12*
	Supplemental reference materials: Confusing……………Clear	4.10	5.45*
System Capabilities	System speed (to open or launch program): Too Slow……………Fast Enough	2.65	2.85
	System speed (to navigate within EMR, e.g. open a note): Too slow……………Fast enough	4.41	4.13
	System reliability: Unreliable……………Reliable	4.72	5.01
	System tends to be: Noisy……………Quiet	7.23	7.87*
	Correcting your mistakes: Difficult……………Easy	5.12	4.96
	Experienced and inexperienced users' needs are taken into consideration: Never……………Always	4.68	5.31

**significant at the p>.05 level*

positive. Both groups gave low ratings to system launch speed and clarity of error messages. Items rated most positive by both groups included system noise, ease in reading characters, consistency of terms, and the clarity of messages appearing on-screen. We calculated overall satisfaction scores for physicians and nurses using the average of the six items in the overall user reaction domain as a proxy. Overall satisfactions scores were 4.67 and 5.50 (t-test, $p < .001$) for attending physicians and nurses, respectively. We compared attending physician ratings of the other 22 individual items with those of nurses and found that the physicians' mean ratings of the EMR were statistically significantly lower in nine of the 22 items ($p<.05$). Using one-way ANOVA, we found no difference in overall satisfaction between experience groups, less than 6 months, 6-12 months, 1-2 years, and more than 2 years.

We also ran a standard multivariate regression with overall satisfaction score as the dependent variable and the 22 remaining items as independent variables and found two items were significant predictors of overall satisfaction—(1) task can be performed in a straightforward manner ($p<.001$) and (2) clarity of help messages on screen ($p<.01$).

Perceived EMR Benefits, Limitations and Recommendations for Improved Use

Participants were asked three open-ended questions:

- What have you found to be the three greatest benefits or advantages to using the EMR?
- What have you found to be the three greatest limitations or disadvantages to using the EMR?
- What recommendations do you have for improving the use and effectiveness of the EMR within their clinic/area at MUSC?

Benefits/Advantages to the EMR System

Nearly 82% of physicians and 56% of nurses identified availability and accessibility of the patient's record as a major benefit or advantage to using the EMR. See Table 3. Included in this category were comments related to having access to other clinic notes and records and having remote access to the EMR. One physician commented, "*Everyone has access to the entirety of the record across all disciplines.*" Another noted, "*The EMR greatly facilitates communication among primary care providers and specialists by having all patient information in one place.*" Other frequently cited benefits included (a) quality of record/documentation (legibility, data consistency and accuracy, organization of record, coding/compliance); (b) comprehensiveness and completeness of patient record (e.g., medications, results from diagnostic tests); (c) impact on efficiency (e.g., speed, timeliness in completing notes);(d) continuity of care and standards of care (e.g., templates, continuous outpatient record); and (e) avoidance of perils inherent with paper records (e.g., no lost charts, no moving charts).

Limitations/Disadvantages to the EMR System

Limitations or disadvantages identified by at least ten participants are listed in Table 4. The two most-cited limitations or disadvantages of the EMR were speed and cumbersome user interface. Both physicians and nurses described the system as being too slow. Approximately 20 participants mentioned that the start time to open the application was particularly problematic. System downtime, including the moments when the "system crashes", "locks up or freezes" and requires user to "reboot" were described as frustrating by 14% of physicians and 22% of nurses. One physician commented that system crashes are frustrating: "*The program froze three times*

Table 3.Most frequently cited benefits/advantages to using MUSC's EMR system

EMR Benefit	**Physicians** n=114	**Nurses** n=130
Availability and access to patient record	81.6%	56.2%
Quality of record/documentation	36.0%	14.6%
Comprehensiveness and completeness of record	33.3%	25.4%
Positive impact on efficiency	13.2%	10.0%
Continuity of care and standards of care	13.2%	10.8%
Ease of use	12.3%	15.4%
Avoidance of perils of paper	9.6%	20.0%

Table 4. Most frequently cited limitations/disadvantages to using MUSC's EMR system

EMR Limitation	**Physicians** n=114	**Nurses** n=130
Cumbersome user interface	38.6%	24.6%
Speed/too slow	37.3%	32.3%
Having to access multiple clinical systems or poor integration with other systems	17.5%	4.6%
Problems with templates	11.4%	4.6%
Insufficient training and support staff	11.4%	3.8%
Downtime (including system crashes or system locking/freezing up)	14.0%	21.5%
Time-consuming to use	13.2%	14.6%

today while I was editing the same note, losing the edits each time. I spent 30 minutes trying to edit a single note without success." A nurse noted, "*When the system is down, you are put completely on hold*." Several participants also expressed frustration with the amount of typing required and the time-consuming nature of entering data into the system. Understanding error messages and correcting mistakes also emerged as points of frustration. Comments reflecting concerns including statements such as: "*too much trial and error", "if you don't already know how to do something, you'll never figure it out", and "some error messages don't tell you how to solve the problem."*

Suggestions for Improving EMR Use at MUSC

Participants gave numerous written suggestions for improving EMR use at MUSC—73% of the physicians and 49% of nurses wrote comments. Suggestions ran the gamut from *"provide more training", "fix bugs in system", "address speed and reliability of system", to "make it more user friendly."*

Several common themes emerged from the written suggestions. Some of these relate to how the EMR is structured and used at MUSC and others relate more directly to the Practice Partner application itself. General suggestions included (1) address the speed/performance issues, (2) expand training and support personnel/resources, (3) improve the user interface/templates and simplify data entry, and (4) integrate more fully with other MUSC applications (e.g., scheduling, lab, radiology).

DISCUSSION

Nearly 250 physician and nurse EMR users at MUSC participated in this study. Nurses are more satisfied overall with the EMR system than are attending physicians. The greater system acceptance by nurses may be due to the approach MUSC took in implementing the EMR enterprise-wide. Initial efforts were focused on nurses and administrative staff, because these individuals were expected to lead in the effort. We felt if nurses were comfortable with the system, they could assist physicians. The downside of this approach is it has been time-consuming and resource-intensive to roll out the EMR throughout all the ambulatory care areas. Consequently, some physician users have not been fully trained on all of the system capabilities—yet, they have been using the application for two or more years.

Additionally, 58% of participating physicians report that they rarely, if ever dictate. Earlier studies have shown that data entry can negatively impact physicians' perceptions of their time, particularly if physicians are not proficient typists or comfortable entering information in the examination room with the patient (Gadd & Penrod, 2001; Penrod & Gadd, 2001; O'Connell, Cho, Shah, Brown, & Shiffman, 2004a; Hier, Rothschild, LeMaistre, & Keeler, 2005; Scott, Rundall, Vogt, & Hsu, 2005; Linder et al., 2006).

Researchers at Partners HealthCare System conducted a time-motion study and found no differences in primary care physician time utilization before and after EMR implementation, yet the majority of their physicians still perceived that the EMR required more time than paper records to document patient information (Pizziferri et al., 2005). Nurses in an earlier study reported that the EMR enabled them to finish their work much faster than before implementation (Likourezos et al., 2004); although we did not ask this specific question, it may help explain why MUSC nurses generally viewed the system more positively than physicians.

Nurses also tended to value the "avoidance of the perils of paper" more often than the physicians did, yet they did not mention availability as a major benefit as often as physicians did. We categorize these measures of availability/accessibility and avoidance of periods with paper separately, yet they are related. Nurses are responsible for ensuring that the patient's record is available at the time of the visit, thus, they experience the "grief" when the record is not available. Physicians are not the ones searching for the paper record, so they may not describe the benefit in quite the same manner. On the other hand, physicians were more likely to mention the benefits associated with having access to clinic notes from other physicians and more likely to comment on the overall quality of the documentation. Having a more "complete" picture of the patient's care (e.g., other visit notes, ancillary test results) stood out as particularly important to physicians. The EMR benefits identified by MUSC physicians and nurses are consistent with earlier studies (Sittig, Kuperman, & Fiskio, 1999; Gadd & Penrod, 2001; Penrod & Gadd, 2001; Likourezos et al., 2004; Joos, Chen, Jirjis, & Johnson, 2006).

Physicians and nurses had similar concerns when asked about limitations of the system or opportunities for improving its use at MUSC. In fact, speed and performance-related concerns seemed to cast a cloud over the benefits. Physicians and nurses identified speed and the slowness of the system as a *major* concern—launching the system was particularly problematic. Yet, in our multivariate regression analysis, system speed did not show up as a significant predictor of overall satisfaction. Although this finding surprised us, an earlier study at Brigham and Women's also found that system "response time" was not correlated with overall user satisfaction (Sittig, Kuperman, & Fiskio, 1999). Factors associated with physicians' ability to effectively use the system were more likely to be predictors of EMR satisfaction than speed alone.

In addition to their concerns with speed and performance, nearly 40% of the physicians felt the user interface was cumbersome, took too many clicks, and made it difficult to make corrections or changes. A common complaint was the "s*ystem requires too many steps or clicks to perform a simple task.*" Other institutions using different EMR applications have found their clinicians share these same concerns (Sittig, Kuperman, & Fiskio, 1999; Wager, Lee, White, Ward, & Ornstein, 2000; Gadd & Penrod, 2001; Penrod & Gadd, 2001; Miller & Sim, 2004; Scott, Rundall, Vogt, & Hsu, 2005). Some of the difficulty or frustration at MUSC may stem from a lack of sufficient training. For example, we observed from the open-ended comments that participants are frustrated with aspects of the system they may not fully understand how to use (e.g., writing prescriptions, modifying templates). Other frustrations may stem from using an EMR whereby primary care providers and specialists share and record their notes in a *single* patient record. Historically, each set of providers had specialty-specific records that only those in the specific group could view and modify.

Interestingly, the results of this survey are remarkably similar to those reported by researchers at Brigham and Women's in their ambulatory care division, despite this group's use of an in-house-developed EMR system. Using the same QUIS instrument, researchers there discovered that attending physicians scored their EMR lowest in the areas of system speed (although they did not distinguish between launch speed and speed of navigating within the application), helpfulness of error messages, and flexibility of system (Sittig, Kuperman, & Fiskio, 1999). The pattern of responses are quite similar, although MUSC physician reactions were less positive in terms of screen design and layout ($p<.01$), terms and system information ($p<.01$) and learning ($p<.001$). Brigham and Women's may have a more advanced training environment, and because they developed the EMR in-house, they have more flexibility in customizing the screens and layout to accommodate their physicians' preferences. No differences were found among overall user reaction and system capabilities. The physicians participating in the study at Brigham and Women had two or more years EMR experience.

Our study evaluated responses from both relatively new and experienced users. One might assume that due to the learning curve in moving from a paper-based system to an EMR, more experienced EMR users would be more satisfied with the system than less experienced users as Gamm et al. suggest (Gamm, Barsukiewicz, Dansky, & Vasey). We did not find that to be the case in our study. EMR users with less than one year of experience were equally satisfied overall with the system as were those who had used the application for two or more years.

Participants in this study provided a host of important suggestions for improving the EMR's use at MUSC. Other institutions would do well to address these issues and concerns up front to avoid problems later.

Our study has two primary limitations. First, the study is limited to a single healthcare organization and one EMR product. Thus, the results may not be generalizable to other healthcare organizations or those who use a different EMR system. Second, response bias is a concern. We compared the demographics of our physician and nurse participant populations with the general physician and nurse EMR population at MUSC and found no differences, yet response rate remains a limitation.

The real value of this study to other healthcare organizations may not be the results per se found at MUSC, but rather the methods and process used. Using the QUIS instrument, we were able to identify the aspects of our EMR system that stood out as problematic to clinician users—launch speed, navigation speed, and the clarity and helpfulness of error messages. Equally, if not more importantly, we provided all clinicians with the opportunity to offer suggestions on how to improve the system, and since this survey, we have incorporated many of their suggestions into our environment. Our leadership team has taken a number of steps to address the most widespread concerns identified by this survey and validated through other avenues. We believe other institutions will find the methods used in this study helpful in assessing clinician satisfaction and in soliciting suggestions for improvement.

CONCLUSION

Results of this survey suggest that MUSC physicians and nurses recognize and value having access to a single electronic patient record that is shared across the ambulatory care enterprise. However, they view the current system as less than ideal. Speed, performance and the user interface (e.g., need to simplify data entry) are of concern. Likewise, additional training and resources are needed to more effectively support the system and its users. Our leadership team has taken a number of steps to address the most widespread concerns identified by this survey and validated elsewhere. Steps to enhance system speed/performance and reliability are being taken, and multi-modal programs of improved training and user support are being implemented. We expect to observe the results of these initiatives and report outcomes in due course.

Assessing user satisfaction with the EMR is important in providing leadership with additional insight into the issues and concerns. Conducting formal evaluation studies, however, are often not done because of lack of available expertise and resources. We believe that surveys such as this one can prove to be a useful resource not only to our healthcare organization's leadership team, but to those in other healthcare institutions interested in easily assessing EMR satisfaction across the enterprise.

REFERENCES

Anderson, J., & Aydin, C. (Eds.). (2005). *Evaluating the organizational impact of healthcare information systems*, 2nd ed. Springer.

Bates, D. (2005). Physicians and ambulatory electronic health records. *Health Affairs, 24*(5), 1180-1189.

Brender, J. (2006). *Handbook of evaluation methods for health informatics*. Elsevier.

Burkle, T., Ammenwerth, E., Prokosch, H., & Dudeck, J. (2001). Evaluation of clinical information systems. What can be evaluated and what cannot?. *Journal of Evaluation in Clinical Practice, 7*(4), 373-385.

Chin, J., Diehl, V., & Norman, K. (1988). *Development of an instrument measuring user satisfaction of the human-computer interface.* Paper presented at the CHI, New Ork.

DeLone, W., & McLean, E. (2003). The DeLone and McLean model of information systems success: A ten-year update. *Journal of Management Information Systems, 19*(4), 9-30.

Despont-Gros, C., Mueller, H., & Lovis, C. (2005). Evaluating user interactions with clinical information systems: A model based on human-computer interactions models. *Journal of Biomedical Informatics, 38*, 244-255.

Friedman, C., & Wyatt, J. (1997). *Evaluation methods in medical informatics*. New York: Springer.

Gadd, C., & Penrod, L. (2001). Assessing physician attitudes regarding use of an outpatient EMR: A longitudinal, multi-practice study. *Proceedings/ AMIA Annual Symposium*, 194-198.

Gamm, L., Barsukiewicz, C., Dansky, K., & Vasey, J. *Pre- and post-control model research on end-users' satisfaction with an electronic medical record: Preliminary results.* Paper presented at the AMIA.

Hier, D., Rothschild, A., LeMaistre, A., & Keeler, J. (2005). Differing faculty and housestaff acceptance of an electronic health record one-year after implementation. *International Journal of Medical Informatics, 74*, 657-662.

Hillestad, R., Bigelow, J., Bower, A., Girosi, F., Meili, R., Scoville, R., et al. (2005). Can electronic medical record systems transform healthcare? Potential health benefits, savings and costs. *Health Affairs, 24*(5), 1103-1117.

Joos, D., Chen, Q., Jirjis, J., & Johnson, K. (2006). *An electronic medical record in primary care: Impact on satisfaction, work efficiency and clinic processes.* Paper presented at the AMIA, Washington, DC.

Likourezos, A., Chalfin, D., Murphy, D., Sommer, B., Darcy, K., & Davidson, S. (2004). Physician and nurse satisfaction with an electronic medical record system. *Journal of Emergency Medicine, 27*(4), 419-424.

Linder, J., Schnipper, J., Tsurikova, R., Melnikas, A., Volk, L., & Middleton, B. (2006). *Barriers to electronic health record use during patient visits.* Paper presented at the AMIA, Washington, DC.

Miller, R., & Sim, I. (2004). Physicians' use of electronic medical records: Barriers and solutions. *Health Affairs, 23*(2), 116-126.

O'Connell, R., Cho, C., Shah, N., Brown, K., & Shiffman, R. (2004a). Take note: Differential EHR satisfaction with two implementations under one roof. *J Am Med Inform Assoc., 11*(1), 43-49.

O'Connell, R., Cho, C., Shah, N., Brown, K., & Shiffman, R. (2004b). Take note: Differential EHR satisfaction with two implementations under one roof. *J Am Med Inform Assoc., 11*(1), 43-49.

Penrod, L., & Gadd, C. (2001). Attitudes of academic-based and community-based physicians regarding EMR use during outpatient encounters. *Proceedings/AMIA Annual Symposium*, 528-532.

Pizziferri, L., Kittler, A., Volk, L., Honour, M., Gupta, S., Wang, S., et al. (2005). Primary care physician time utilization before and after implementation of an electronic medical record: A time-motion study. *Journal of Biomedical Informatics, 38*, 176-188.

Scott, J., Rundall, T., Vogt, T., & Hsu, J. (2005). Kaiser Permanente's experience of implementing an electronic medical record: A qualitative study. *BMJ, 331*, 1313-1316.

Sittig, D., Kuperman, G., & Fiskio, J. (1999). *Evaluating physician satisfaction regarding user interactions with an electronic medical record system.* Paper presented at the AMIA.

Slaughter, L.A., Harper, B.D., and Norman, K.L. (1994). Assessing the equivalence of the paper and online formats of the QUIS 5.5. In *Proceedings of Mid Atlantic Human Factors Conference,* (pp. 87-91)Washington, DC.

Wager, K., Lee, F., & Glaser, J. (2005). *Managing healthcare information systems: A practical approach for healthcare executives*. San Francisco, CA: Jossey-Bass.

Wager, K., Lee, F., White, A., Ward, D., & Ornstein, S. (2000). Impact of an electronic medical record system on community-based primary care practices. *The Journal of the American Board of Family Practice, 13*(5), 338-348.

Windows, S. (2005). Version 14.0.2005. Chicago: SPSS Inc.

This work was previously published in International Journal of Healthcare Information Systems and Informatics, Vol. 3, Issue 1, edited by J. Tan, pp. 63-74, copyright 2008 by IGI Publishing (an imprint of IGI Global).

Chapter 4.11

Reforming Public Healthcare in the Republic of Ireland with Information Systems:

A Comparative Study with the Private Sector

David Sammon
University College Cork, Ireland

Frederic Adam
University College Cork, Ireland

EXECUTIVE SUMMARY

The need for reforming public healthcare towards greater efficiency and measurable returns on investment has been felt by governments in many countries. In Ireland, this led to the PPARS project, which sought to implement SAP across all public healthcare sites. This project, however, was unsuccessful and led to a parliamentary inquiry. To understand why the PPARS project failed, we carried out an extensive case study of the project and compared our findings to the implementation of JD Edwards in a multinational in the private sector. Our study reveals that despite specific circumstances in the public sector that contributed to the failure of the ERP project, the primary causes of failure result from a lack of understanding of what ERP involves and a failure to prepare adequately, which can be found in any organisation, public or private. This leads to significant lessons for ERP implementations and IS projects involving substantial change

NTRODUCTION

The need to reform the delivery of healthcare services to suit the needs of modern societies has been felt around the world and such reforms have been attempted in many countries, for instance, the USA, the UK, Germany, Canada, France, India, Australia, and The Netherlands. Faced with growing dissatisfaction and concerns regarding healthcare provision in the Republic of Ireland (for example, lengthening waiting lists for many key healthcare services such as major surgery and cancer treatment, and the ever increasing cost of labour and administrative overhead) successive

Irish governments have jumped on the bandwagon of healthcare reforms, in a bid to control and justify the ever increasing operational costs and so-called transformational investments in the delivery of public healthcare services.

At the core of the Irish government's National Health Strategy (2001) was the centralisation of governance of public healthcare under the authority of the Health Service Executive (HSE) which was established in 2005. The key requirement of this centralised agency is to manage the Health Service as a single national entity and provide a monitoring and leadership role so as to increase transparency of the services delivered to the Irish public and make available information pertaining to the use of funding and the responsiveness of services to demands.

In order to develop this information capability in one functional area, the HSE has tried to promote greater integration by deploying a nationwide Enterprise Resource Planning (ERP) application to administer HR and payroll issues in a way that gives more visibility on the hiring and allocation of staff (one of the greatest cost centres in the healthcare sector) within the entire organisation. However, despite years of efforts between 1997 and 2005, the Personnel, Payroll and Related Systems (PPARS) project, established to manage the development and implementation of the ideal—"a fully integrated Human Resource Management system"—has failed to deliver concrete benefits, being suspended by the Irish Government in the late 2005, pending a still on-going Parliamentary investigation.

In this article, we investigate the reasons why the HSE has found it so difficult to implement an ERP application and, using a similar case study of an ERP implementation in the private sector, we attempt to rationally establish whether the causes of failure are specific to the healthcare sector or if they are shared with ERP projects in other environments. The article is structured as follows: a background to ERP is presented and the issue of ERP implementation is highlighted. Following on from this, after a presentation of the context of healthcare in the Republic of Ireland, we present the research protocol we used in the two case studies presented in this article. The article then presents a narrative of the HSE's ERP implementation and, drawing comparison with the case of Banta Global Turnkey (BGT), establishes what is different and what is similar in the public healthcare case and in the private organisation.

Understanding Enterprise Resource Planning (ERP) Systems

ERP systems are positioned as one of the most sought after means of organisational transformation and IT innovation since the mid 1990s and form the cornerstone of IS for an ever increasing percentage of organisations (El Amrani, Rowe, Geffroy-Maronnat, 2006; Holland & Light, 2001; Markus & Tanis, 2000; Sharif, Irani, & Love, 2005; Stefanou, 2000; Swanson & Ramiller, 2004). Such an observation has been made in both the trade press and academic literature, suggesting that ERP systems have sustained their attractiveness to managers, and when their rate of adoption and implementation is examined (over the last decade) it can be observed that these ERP systems were indeed the *de facto* solution to organisational integration problems.

The basic concept of an ERP system is comparatively simple and has evolved over the past 30 years, from the ideal of optimising operations and reducing costs, through to control and standardisation (Sammon & Adam, 2002; Watson & Schneider, 1999). ERP systems also promised to deliver on the informational requirements of an organisation, such was its scope. For example, according to Wood and Caldas (2001, p. 387), ERP was described as "a comprehensive information technology package built on the promise that all critical information should be totally integrated in one single information database." In fact, the origins of ERP can be traced back much further, to the Industrial Revolution and the initial attempts at optimising industrial activities with regard to materials and inventory management (O'Gorman, 2004). Indeed, the issues of materials and inventory control addressed by Material Requirements Planning (MRP) in the 1960s, which evolved into the (Manufacturing Resource Planning (MRP II) systems of the 1970s, are still at the core of present day ERP systems. However, an ERP system differs from MRP/MRPII systems, not only in terms of system requirements, but also in technical requirements. While "MRP II has traditionally focused on the planning and scheduling on internal resources, ERP strives to plan and schedule supplier resources as well, based on the dynamic customer demands and schedules" (Chen, 2001, p. 376). Therefore, ERP systems are positioned as the second phase in the general progression towards the integration of "enterprises" internal and external constituencies (Kalakota & Robinson, 2001). The continued evolution of ERP systems has brought about an increased depth and breadth of "best practice" software functionality, supporting a wider range of industrial sectors.[1] As a result, even in nonmanufacturing industries, ERP systems offer the potential for consolidation of internal operations and an integrated, enterprise-wide view of the organisation.

The Issue of ERP implementation

Notwithstanding the obvious interest motivated by the concept of ERP, the record of organisations having sought to reap the benefits from highly integrated enterprise-wide systems has been rather mixed (Stefanou, 2000). James and Wolf (2000) reported that 80% of the benefit that organisations achieved from their ERP system came from changes, such as inventory optimisation, the benefits of which could have achieved without making the IT investment. Furthermore, Jahnke (2002) reported that over 50% of organisations that attempted an ERP implementation were dissatisfied with the results. In addition, Jahnke (2002, p. 1) commented that "forty percent of the projects failed to achieve their business case within one year of going live, and those companies that did achieve benefits said that achievement took six months longer than expected." This insight proves extremely worrying for organisations investing in ERP packages and calls into question the expectations of organisational decision-makers as to the initial benefit of ERP vs. the actual value-for-money from the changes introduced from the initiation of such an IS/IT investment. However, according to James and Wolf (2000, p. 2), reporting on an instance of an ERP implementation, many of the benefits that we are able to achieve today could not have been predicted at the time that we started work on ERP. In fact, in hindsight it appears that much of the value of these large systems lay in the infrastructure foundation they created for future growth based on Information Technology.

Indeed, Ward and Peppard (2002, p. 432) highlight that "benefits from strategic IS/IT investments are uncertain and depend on future events, making priority setting even more difficult." In fact, Ward and Peppard (2002, p. 434) further comment that, "setting objective priorities on scant evidence is not very reliable."

Swanson and Ramiller (2004, p. 554) noted in their award winning MISQ research article titled "Innovating Mindfully with Information Technology," that by the mid-1990s, ERP was a topic that was being banded about in boardrooms. It wasn't just an information technology (IT) project, but a strategic business imperative… the ERP genie was out of the bottle—every company needed to have an ERP implementation.

Indeed, it can also be argued that reports of this nature has further provided ERP packages with longevity greater than previous IS fads and fashions. However, Swanson and Ramiller (2004, p. 554), borrowing Weick's concept of *mindfulness*, suggest that *adopting organisations entertain scant reasoning for their moves. Especially where the innovation achieves a high public profile, as with ERP, deliberative behaviour can be swamped by an acute urgency to join the stampeding herd, notwithstanding the high cost and apparent risk involved.*

Indeed, this *mindless* behaviour in pursuit of best practice is the rule, with the exception being a *mindful* organisation engaging in such an IT innovation.

To summarise, investing in an ERP package has been characterised as a *transformation investment* (Ross & Beath, 2002), which requires managers to understand the importance of changes to the business in order to achieve the expected benefits from the project (Murphy & Simon, 2002; Ross & Beath, 2002). Paradoxically, while investments in ERP packages are amongst the most significant an organisation will ever have to engage in, the realities of ERP implementation are not fully understood by managers (Olsen & Saetre, 2007) and the benefits expected at the outset of the project are not always a realistic feature of actual project outcomes (Chen, 2001; James & Wolf, 2000; Law & Ngai, 2007; Murphy & Simon, 2002; Shang & Seddon, 2002). All too often organisations fail to prepare appropriately for an ERP project implementation, which has been referred to as *mindlessness* by Swanson and Ramiller (2004), and as a result invest in what is essentially an IT initiative as opposed to a business change project (Murphy & Simon, 2002; Wood & Caldas, 2001; Ross & Beath, 2002). In light of these observations, it can be argued that assessing the level of benefit realisation is a somewhat subjective exercise where operational efficiency could be considered of strategic value to an organisation (long term), and therefore categorised as a strategic benefit (Murray, 2005). This subjective view is based on managerial interpretation of the impact of the implemented enterprise-wide ERP system on organisational activity, used as a means of providing retrospective explanations for the earlier rationales in selecting an ERP package. The fact that so few organisations actually do carry out postimplementation assessments may be an empirical illustration of this point.

Context of Healthcare in the Republic of Ireland

The Irish Department of Health was established in 1947, under the Ministers and Secretaries (Amendment) Act, 1946. Prior to 1947, the public Health Services were the responsibility of the Department of Local Government and Public Health, and continued to be administered by local authorities until 1970. The Health Act (1970) established eight Health Boards (Eastern, Midland, Mid-Western, North Eastern, North Western, South Eastern, Southern, Western) and increased the Department of Health's direct involvement in the execution of health policy. The passing of the Health (Eastern Regional Health Authority) Act (1999) effectively dissolved the Eastern Health Board and replaced it with the Eastern Regional Health Authority (ERHA) and three new Health Boards namely, South West Area Health Board, Northern Area Health Board, and East Coast Area Health Board. Currently, the Department of Health and Children (DOH&C) has overall responsibility for the development of health policy and for the planning of Health Services. The Health Boards established under the Health Act 1970 were the statutory bodies responsible for the provision of health and personal social services in their functional areas. However, in 2005 the Health Service Executive (HSE) was established and was the first ever body to manage the Health Service as a single national entity.[2]

While the structure of the Irish Health Services remained unchanged for over 30 years, a number of health reforms were planned. In 2001, the Irish government launched its National Health Strategy: Quality and Fairness, A Health System for You. The strategy set out key objectives for the health system for the following 7-10 years. These objectives were centred on four national goals:

1. Better Health for Everyone,
2. Fair Access,
3. Appropriate Care in the Appropriate Setting, and
4. High Performance.

In addition, the strategy identified the need for a whole range of system changes to occur in order for these goals to be achieved. These Frameworks for Change were:

1. Primary Care
2. Acute Hospital Services
3. Funding
4. Human Resources
5. Organisational Change
6. Information

Furthermore, in June of 2003, the Government announced the Health Service reform programme initiating an unprecedented change programme for the Irish health system. The programme emerged from the recommendations contained in two reports: the *Report of the Commission on Financial Management and Control Systems in the Health Service*—referred to as the Brennan Report (DOH&C, 2003)—and the *Audit of Structures and Functions in the Health System*—referred to as the Prospectus Report (DOH&C, 2003). Both of these reports highlighted the need for quality information systems and the need to identify the negative consequences of inadequate investment in such systems in the past. A central tenet of the reform proposals was the establishment of a National Shared Services Centre (NSSC), which was intended to coordinate data, typically HR and finance data, previously gathered and processed within the health agencies. The Prospectus Report highlighted the need for a single HR Function to coordinate and lead system-wide activities and for the establishment of shared services in IT. It also placed a high priority on a robust information gathering and analysis capability, and on the national management of resources to integrate service delivery.

The Brennan Report included in its terms of reference the need to enhance the capability of the Health Services regarding: Management Accounting, Costing, and Associated Information Systems. Furthermore, in a section of the report calling for greater investment in IT, the report argued that the on-going PPARS project (which, since its beginning in 1997 and up to that point had been confined to five Health Boards and Saint James Hospital) should be extended to "all major spending agencies." Of its seven IT recommendations, three explicitly focus on the centrality of the PPARS project in a reformed Health Service, while a further three include PPARS implicitly (albeit with a much revised scope). Therefore, these two reports devote key parts of their findings and recommendations to the positive role that PPARS has to play in the Irish Health Services of the future.

Therefore, in June of 2003, the government made key decisions relating to the reform of the Health Service. The key elements of the programme included:

1. A major rationalisation of existing Health Service agencies to reduce fragmentation. This includes the abolition of the existing health board/authority structures.
2. The reorganisation of the Department of Health and Children, to ensure improved policy development and oversight.
3. The establishment of a Health Services Executive which is the first ever body charged with managing the Health Service as a single national entity.
4. The modernisation of supporting processes (Service Planning, Management Reporting, etc.) so that the Health Service is in line with recognised international best practice.

Table 1. Principles of preparedness

Principles of Preparedness	Description
Priority Project	Management has to categorise the ERP project as one of the priority projects of the organisation and an ERP system should be looked upon as the acquisition of an asset, not as an expenditure.
Proactive Approach	An ERP implementation should be undertaken as a proactive measure in addressing organisational symptoms that suggest the pressing business need.
Organisational Goals	The implementation of an ERP system is based on a business engineering blue-print; therefore, organisations must chart their organisational goals and identify the key processes that affect the organisational success.
Communicate and Manage Expectations	The objectives in implementing ERP and the corresponding expectations should be clearly documented. The discipline of conducting work through documentation is a necessary prerequisite.
BPR	Carry out BPR in advance of ERP or alternatively implement an ERP package in its *vanilla* form. Facilitate the opportunity to incorporate best practices from industry into the organisations systems and procedures (a clear policy has to be made for implementation of the ERP in vanilla and its review could be made only after 6 months.
Implementation Methodology	Work on a proven methodology to reduce the actual implementation time and the associated direct and indirect costs and implementation delays with partners and certified consultants who are experts in the area. Overall, the morale of the organisation would be high if the implementation could be completed at quick speed, even if it may not be an optimal implementation.
Education on ERP	Organisational personnel should be apprised as to what ERP would be and what it would not be. An apprisal should cover ERP principles in generic terms and case studies to highlight attitudes and principles that have been successful and issues that have been problematic.
Best Business Personnel	Once it is decided to implement ERP, it is necessary, although difficult, to release the best and committed business personnel to the project on a full-time basis. In fact, those who cannot be spared are the ones who will be required on the project team. An advanced plan and commitment is essential at all levels to release the selected personnel.
Cross–Functional Team	The team should span the entire organisation and a representative from each critical business area to be impacted by the ERP implementation should be a member of the team.
Approach to Training	A training centre with adequate facilities must be planned, as a "make-shift" temporary one could be counter-productive.
Technical Infrastructure	Ensure the availability of adequate network infrastructure pre- and post-implementation. For example, it is absolutely necessary to have adequate network infrastructure, as close to real environment as is possible for training and testing purposes.
Mindset Change and Attitude to Learning	Top managers must be ready to allow a mindset change by accepting that a lot of learning has to be done at all levels, including at top management. This attitude would facilitate the exchange of ideas with people who have already experienced and successfully implemented this change.

As a result, this reform programme was aimed at ensuring that the health system was organised and managed in a way which helped it achieve the four national goals of the health strategy, and, therefore, set out a range of structural, organisational, financial management, and systems reforms.

Research Protocol and Research Methods

Yin (2003) proposed that case studies are most appropriate when the research objective involves studying contemporary events, without the need to control variables or subject behaviour. In fact, Benbasat, Goldstein, and Mead (1987, p. 370) commented that "the case research strategy is well-suited to capturing the knowledge of practitioners and developing theories from it." As a result, the research strategy adopted for this research study is guided by the framework proposed by Eisenhardt (1989). The objective of this research to (1) understand the reasons for the complete failure of the PPARS project and (2) to establish the extent to which these reasons are specific to the health sector or the public sector was operationalised under three research questions as follows:

Research Question 1: Understanding Preparedness and Awareness

For this research question, we defined preparedness as the actions taken by the organisation towards ensuring the smooth execution of the ERP project. Furthermore, we defined awareness as the level of understanding in the organisation, at the beginning of the project, of what an ERP implementation involves as shaped by knowledgeable internal human resources and the discourse of external experts.

A number of researchers (Chen, 2001; Gargeya & Brady, 2005; Kim, Lee, & Gosain, 2005; Markus, Axline, Petrie, & Tanis, 2000; Shehab, Sharp, Supramaniam, & Spedding, 2004; Siriginidi, 2000; Teltumbde, 2000) have commented on the importance of preparedness for embarking on an enterprise-wide ERP project. These researchers propose a number of factors that should be considered prior to implementing an ERP package. In rating organisations for these two criteria, we predefined *Principles of Preparedness*, which we extracted from a review of the existing literature (see Table 1).

Research Question 2: The Nature of Problems during Project Execution

The focus of this question was squarely on understanding and recording what actually went wrong, in the words of the participants, as the project unfolded. Given the reliance on the case study method, and the use of multiple perspectives in collecting data about our cases, we were able to obtain very accurate, confirmed facts about what happened during the projects. Although the process of uncovering the problems that occurred in our case studies was largely emergent, it appeared that standard categories of problems could be found that could be used in general and proved useful in helping us draw comparisons between the cases. The areas we used were: Planning, Fit to Organisation, Staffing, and Change Management.

Research Question 3: Benchmarking the HSE Case against a Private Sector Organisation

This question involved drawing a systematic comparison between the case of the HSE and the case of a private sector organisation having gone through a similar project, in a similar time frame and in a contemporary fashion. This required a replication of the protocol followed for the case of the HSE (under research questions 1 and 2 above) and trying to establish whether the events reported by informants and the problems encountered could lead us to specific conclusions with regard to the specificities of the HSE case vs. the similarity with the project in the private organisation. Whilst this is not an absolute method for comparing the health sector to other sectors, it allowed us to verify that, in fact, the stories told in both cases are much more similar then dissimilar, as the findings sections indicate.

We applied the first two research questions to the PPARS project, which was the *intrinsic* case

Table 2. Initial perceptions of cases selected for the research study

Characteristic	BGT	HSE
Sector	Private	Public
ERP Package	JDE World	SAP R/3
ERP Footprint	Core Operations (Supply Chain Manufacturing and Finance)	HR / Payroll
ERP System Type	Value Chain Operations	Support Operations
Project Type	IT	IT
Enterprise-Wide View	No	No
Project Initiation	1996	1997
Project Outcome	Near Failure	Failure (project suspended)
Point-of-Contact Comment	"I could tell you all the things not to do. We have not done well with our implementation"	"This project is not going well. It will face huge issues in use the way it is being rolled-out nationally"[3]

Table 3. Breakdown of interviews by case

Organisation	Interviewee	Duration of Study
HSE	National Assistant Director of the PPARS Project Agency Implementation Manager HSE Area Payroll Manager HSE Area Applications Manager HSE Area Change Manager HSE Area * Implementation Manager HSE Area * IT Project Manager HSE Area Business Analyst National Project Team *	2 years
BGT	Former Vice President of IS * Vice President of IS Software Development Director IS Project Manager Director of Finance Global Director of Supply Chain Management * Global Director of Supply Chain Management General Manager of BGT site Corporate Selection Team Member	1 ½ years

study we had elected to carry out (in the words of Stake, 2000). We also looked for a second organisation in the private sector for the purpose of comparison. In the context of this study, for an organisation to be considered suitable for selection, it had to have undertaken an enterprise-wide ERP project, and at the time of first contact with the organisation, be in the post-implementation phase for all or part of the project, depending on the implementation approach followed by the organisation. This somewhat *opportunistic* (Patton, 1990) approach to purposeful sampling led to the selection of Banta Global Turnkey (BGT) due to its similarities with the PPARS project in terms of duration, problems encountered and outcome (see Table 2).

The principal method of data collection we relied upon was the interview of key participants in both organisations. Table 3 presents a breakdown of the personnel interviewed within the two organisations and identifies their positions of responsibility within their respective organisations. Furthermore, the personnel interviewed were most of the remaining key decision-makers and most knowledgeable persons, in relation to the decisions made at the outset of the enterprise-

Table 4. Documentation reviewed within each case

Organisation	Documentation Reviewed
HSE	PPARS Project Web Site (www.ppars.ie) Hay Report (*Quality Assurance Review of PPARS,* 2002) Irish Medical Times Report (www.imt.ie) (various reports throughout 2005 and 2006) Annual Report (2005) Various HSE Web Sites (Web Sites of the HSE Areas) Various National Newspapers Television Programmes (Prime Time, RTE News Reports) Oireachtas Reports (www.oireachtas.ie) Masters Dissertation completed by the Implementation Manager at the Western Area HSE Comptroller and Auditor General Report on Value for Money Examination (Development of HRM system for the Health Service – PPARS) (2005)
BGT	Enterprise Ireland E-Business Report (BGT) Annual Report (2003-2005) BGT Web Site (www.bgt.com) Masters Dissertation completed by the VP for IS at Banta

wide ERP project.

To further allow for triangulation of the opinions expressed and facts reported to us by our informants, we also made extensive use of written and published documents whenever this was useful and possible. For each case, the documentation provided specific details to corroborate, and in some instances clarify, factual evidence collected through interviews. Table 4 presents a list of the documentation collected and examined for each organisation.

The PPARS and BGT Cases

This section presents a case narrative for the Irish Health Service PPARS and BGT ERP projects. These constructed case narratives afford the researcher an opportunity to understand the uniqueness of the approach that each organisation adopted in undertaking the enterprise-wide ERP project within their specific organisational context. This helps to explain that, although the two organisations pursued their project for a variety of different reasons, their experiences in arriving at the outcomes from the project initiative, based on their levels of awareness and preparedness, are somewhat similar.

The PPARS (Personnel, Payroll, and Related Systems) Narrative

In 1997, 6 years before the Health Service reform programme was formalised, five Health Boards (ERHA - Eastern Regional Health Authority, Midlands Health Board, Mid-Western Health Board, North-Eastern Health Board, North-Western Health Board), but not all of them nationally, along with Saint James Hospital were interested in a replacement HR/Payroll solution. At that time, HR systems were extremely primitive and largely paper-based throughout the Irish health sector and, in whatever electronic mode they existed, they would have been rather simplistic and certainly stand-alone. Payroll solutions would have been more sophisticated but would not have necessarily been able to provide the DOH&C with the whole array of information that was required. In fact, even the total number of personnel employed by the Health Service nationally, employee absenteeism rates, and cost efficiency of services by area, and so forth, were not available. Furthermore, existing systems were no longer appropriate to support the delivery of a world-class Health Service, where limited interfaces existed between Payroll, Personnel, and

Finance functions resulting in large volumes of paper transactions. As a result, the PPARS project was established when the five Health Agencies and Saint James Hospital secured funding in the mid-1990s. This heralded what is referred to as Phase 1 of the PPARS project.

The ERP software selection process undertaken by the Irish Health Services in 1996 as part of the PPARS project is somewhat of an unknown. While a procurement process was conducted, the transparency of this process has indeed been called into question. In fact, on suspension of the PPARS project in 2005, government investigations commenced into the procurement process followed, from which SAP was selected as the package to meet the requirements of the Irish Health Services. It is difficult to establish whether the decision to select SAP was made following a review of a number of shortlisted competing ERP packages. However, it has been suggested that alternatives to a single, integrated, standardised, national system of the nature of SAP were never fully considered at the outset of the project. In any case, the selection of the SAP package can be seen as an extreme choice for the original project goals, given the extreme complexity of this ERP application. The lack of information makes it difficult to reach definitive conclusions, but some informants speculated that the Health Services software selection process had been a politically motivated decision making process, which would make it characteristic of a *mindless* approach (Swanson & Ramiller, 2004).

Thus, in 1997, the five Health Boards and Saint James Hospital commenced PPARS Phase 1, with the implementation of a revised Organisational Structure (Organisation Management module) and Personnel Administration (gathering of core personnel data: Personnel Administration module). Furthermore, as part of Phase 1, the SAP Basic Pay module and a number of HR modules such as qualifications, and training/events management were also implemented. As a result of the Phase 1 deployment, some of the Health Boards involved also implemented interfaces to their existing payroll systems as they continued to use their existing payroll systems.

Following the Western Health Board "going live" with Phase 1 in July 2001, the DOH&C decided to do a "stock-take" of the PPARS project. They hired Hay Management Consultants to do a Quality Assurance Review of PPARS, including a brief fact finding review of the benefits that had been realised from Phase 1 and those expected from Phase 2, an identification of the key issues and concerns regarding the project to-date and expected in Phase 2, and general experiences to-date in PPARS (Phase 1) from the point of view of a National Health Service project across all participating Health Service entities. In January of 2002, the Consultants made a number of recommendations towards ensuring that the project delivered "value-for-money" in the national context. As a result, Phase 2 of the PPARS project kicked-off (2002), and the DOH&C sanctioned the additional funding to continue and complete the PPARS project accordingly. The deployment of the SAP functionality within the PPARS project remained on a phased basis (Phase 1 and Phase 2) for the original sites and became an amalgamation of Phase 1 and 2 for the remaining Health Boards joining the project in mid-stream (see Table 5). Deloitte Consulting was chosen as the implementation partner for Phase 2 of PPARS.

Phase 2 commenced with the development of an agreed blueprint for the relevant business processes in each Health Board. All of the Health Boards were included and, as a result, PPARS became a two-speed project, with six sites engaged in Phase 2 and the rest playing catch-up.

The PPARS SAP HR/Payroll ERP project was never completed on a national scale and the "post-implementation phase" was not reached by the time the project was terminated. The PPARS project is estimated to have cost the Irish state anything between €150 and €500 million, where original estimates of costs were set at €8.8 million. Furthermore, the project was due to have a

3 year implementation schedule, but 8 years later, it was still not fully implemented. Saint James Hospital was the first Irish Health Service entity to "go-live" in November of 2003. The North-Western Health Board went live in July of 2004; the Midlands Health Board went live in September of 2004; the Mid-Western Health Board went live in November of 2004; while the Western Health Board, North-Eastern Health Board, Eastern Regional Heath Authority, South-Eastern Health Board, and Southern Health Board, who were due to "go-live" in 2005, were never completed. The reasons behind the suspension of the project are highlighted in Research Question 2.

The BGT Narrative

The Banta Global Turnkey (BGT) Group is a $400 mllion division of Banta Corporation, founded in 1995 following the takeover of an Irish company called BG Turnkey Services. BGT serves as a global outsourcing partner to leading companies in the technology, pharmaceutical and medical device sectors and has established a network of global manufacturing and distribution facilities located in key markets of the Americas, Europe, the Middle East, and Asia, having 11 sites in total worldwide, and employing 2,200 staff. In 1995, at the time of the takeover, BG Turnkey had 5 European sites and 1 North American operation. Banta Corporation also had a few Turnkey sites (three in North America) conducting similar business to BG Turnkey. At that stage, Banta Corporation did not have JD Edwards, but a small ERP system called Acuman (provided by a Dublin-based software firm) was operational in BG Turnkey.

Initially, the nine Turnkey sites merged into one group and then, Banta Corporation, in the U.S., decided to leave the European operation function on its own. So while the European sites were still referred to as Turnkey, they essentially had a separate management group and had very little involvement with the North American Turnkey sites. As a result, there was effectively a two-group structure: a North American group and European Turnkey group. However, when they commenced the ERP package evaluation process in 1996, in an effort to select an ERP system for the Turnkey business, the two groups proceeded together. The joint project was led from the U.S. and a steering committee was formed, consisting predominately of managers from the U.S. and members of a small U.S.-based consultancy group. Following a series of site visits a full set of requirements for BGT were established and documented.

A large number of prospective ERP vendors were selected and a mix of business and IT personnel were involved in a "show-and-tell."[4] The business and IT personnel developed a series of scripts, which were provided to vendors so that they could demonstrate that the product did what BGT wanted it to do. This led to a short-list of vendors, namely: Oracle, SAP, and JD Edwards. SAP was never a real contender as it was perceived

Table 5. Outline and project phase detail

Phase	Focus of Phase
Phase 1	• Personnel Administration (PA) • Organisation Management (OM) • Personnel Development (PD) (qualifications) • Training and Events (T&E) • Absence Recording
Phase 2	• Time Management (TM) • Payroll (PY) • Compensation Management (CM) • Mass Pay Increases only • Enhancements to existing modules through further integration

as far too complex for BGT. Furthermore, Oracle, although short-listed, did not seem to be able to demonstrate the capability that BGT needed in support of the business. As a result of this attrition, the JD Edwards World ERP package was selected. Despite having spent a considerable portion of their budget (about half a million dollars) on the selection process, BGT decided not to go ahead with the implementation of the JD Edwards World package, because they simply could not cost justify the investment at that time. However, in 1997 the Year 2000 (Y2K) problem was becoming an issue for both groups. The European operation had a Y2K problem with their Acuman system, but the vendor had a ready made Y2K upgrade. However, the U.S. operation discovered that their systems were not Y2K compliant and decided to proceed with the implementation of JD Edwards.

In 1998, the U.S. sites rolled-out JD Edwards World and the European group upgraded their Acuman system. The scope of the ERP project was to cover the financial requirements and the Supply Chain Manufacturing requirements in the SCM part of the business across the entire US operation. Then, in May of 1999, BGT won a large contract with Compaq, and it was decided to reform a single Global Turnkey group worldwide and implement a global ERP system. Thus, on the back of winning that contract, it was decided to implement JD Edwards World in Europe by rolling it out in a number of the European sites (e.g., Cork in late 1999) and a number of "green-field" sites (e.g., Singapore in early 2000—specifically setup for the Compaq business).

Faced with a heightened level of frustration regarding their experiences and struggles with the JD Edwards World ERP package, mostly due to the reactive approach adopted to roll-out within the European operation, BGT took a decision in 2003 to finish out all of the European sites properly. An additional $5 million expenditure was allocated. As part of this, BGT decided to roll-out the ERP in Scotland in 2004. However, BGT won business in Scotland, at the start of 2004, and had to roll it out in 10 weeks, in a similar approach to the previous rollouts in the other European sites. Thus, BGT found themselves in a situation where the Scottish site was being finished up, Cork and Holland, respectively, had to be finished, and Limerick would be completed in 2005. In fact, even as of late 2005, not all of the sites in the BGT group had JD Edwards fully implemented as *the* ERP system, for example, the Cork site still had a combination of Acuman and JD Edwards World supporting their operations and in 2006 the Limerick site still did not have the JD Edwards World system in place.

The true accumulated cost of selecting, implementing, supporting and modifying JD Edwards over 10 year period covered by the project is unknown. The ERP project had not been completed on a global scale at the time of this research and, as a result, BGT had not reached a post-implementation phase with its ERP. In this 10 year period, BGT has also undertaken a number of other project initiatives. For example, in 2001, a number of Business Process Improvement (BPI) initiatives were undertaken in the areas of Finance and SCM within BGT. These BPI initiatives focused explicitly on the business and adding value through standardising internal business processes and tightening integration with customers and suppliers, in an effort to drive out costs by removing surplus activities across the entire BGT global organisation. Therefore, these initiatives have directly impacted on the JD Edwards system at the site level, where the focus and objective has been to address the need for a global organisational architecture and business process infrastructure, that is, to rectify the disastrous experiences of BGT due to the absence of a coherent approach to implementation from the outset of the JD Edwards World ERP project as evidenced by the analysis presented in the next section.

ANALYSIS AND DISCUSSION

Prima facie, it is interesting to note that despite the very different situations and organisational contexts of the two organisations studied, the narratives presented feature very striking similarities in terms of the extensive project timeframe nearing 10 years in total and the failure to complete the project in a strict sense, despite some results being achieved. The following sections analyse these similarities in greater detail.

Research Question 1: Analysing the Preparedness of the Organisations

The goal of research question 1 was to use the principles of preparedness which we had extracted from current literature on ERP to judge the extent to which the organisations we studied had the requisite level of awareness when they undertook their ERP project and whether they then took requisite actions in order to attain a level of understanding and direction that would serve them well toward successfully implementing their new applications. Table 6 shows how the HSE rates against the principles of preparedness. It indicates that the PPARS project began its life firmly understood as an IT project, with virtually no support from key business areas. This lack of high prioritisation was combined with a very weak understanding of just what an ERP project involved in terms of impact on the organisation and required change to business practices. Against this backdrop, the project lacked focus and specific business goals from the beginning and, even when there were simple objectives that could be pursued, such as the integration of payroll systems nationally, the pre-requisite steps of practice harmonisation and process standardisation were never even attempted. This sealed the fate of the project in that, 10 years later, newspapers reported satisfyingly that the HSE was still not able to tell how many staff they had and how much they were being paid.[5] Faced with this reality, the Irish government was pushed into a knee-jerk reaction and terminated the PPARS project.

In parallel, the organisation of the project was poor and never achieved the requisite level of professionalism and leadership. This was highlighted several times during the life time of the project (notably by consultants' reports) but was never addressed. A failure to allocate knowledgeable staff to the project, a chronic lack of training, and excessive turnover of participants all conspired to ensure that the key problems in the deployment of the ERP application were never adequately communicated to the national directorate of the project and therefore never tackled at the appropriate level.

By contrast, Table 7 shows how BGT rates against the principles of preparedness. The BGT case is characterised by the observation that although the enterprise-wide ERP project commenced in 1995, over a decade later the project had not reached completion. Fundamentally, this was due to the failure to articulate a global business need for the project and to poor management of the project throughout its life-cycle. The implementation of an enterprise-wide ERP system could not be cost-justified in BGT in 1996, due to the lack of a real strategic need for the project, and so it was undertaken as an IT project, in the context of Y2K compliance in the U.S. operation. This compliance objective was indeed met but key elements, such as an enterprise-wide organisational architecture, a global process infrastructure, and embracing a standardised BGT group-way of doing things, did not exist. As a result, no real long-term business value-added was realised from the project and the overall outcome of the project has been judged to be less than successful within BGT. In particular, there was a chronic failure to realise that the nature of the activity was changing and that the days of the one site one customer organisation were numbered.

Going forward, BGT needed to be able to serve all customers from many sites and this required an integrated ERP which could not be delivered out of the mosaic of ERP instances running in the different sites, especially in Europe. Thus, standardisation was neither pursued nor achieved until the project was relaunched in the shape of the BPIs. There were also latent causes of failures in terms of the management of the project, which lacked direction and never focused on acquiring the best resources for the project on a full-time basis from any of the key functional areas. Training was also largely ignored, which, coupled with the lack of serious support for the user population post go-live, led to much frustration and dissatisfaction with the application in-use.

Research question 1 leads us to conclude that some organisations (either public or private sector) are ill-prepared for ERP projects and that they compound their lack of awareness with poor project management which sets the scene for largely negative outcomes being reported for their ERP projects.

Both cases show the failure to provide clear directions for the project at the start by not stating objectives clearly, making the project a number one priority, and allocating the best staff in the key positions to the project team. They also show the failure to comprehend the difficulty of what is being undertaken and the lack of vision in terms of forecasting where problems will arise or even monitoring when and where they do arise. Specifically, in the HSE, the lack of leadership and political will to drive required changes in local practices and pre-empt the implementation of the ERP application with a specific programme of harmonisation of procedures and reduction of local idiosyncrasies led to the project unfolding without any realistic hope of achieving its primary aims, a fact which was known to many actors well before the project was terminated. Thus, it was hoped that, somehow, the technical solution (the piece of software) could solve all the problems of visibility in this complex organisation without having to go through the pains of reforming *the beast* through a comprehensive change management programme.

Research Question 2: Categorising the Problems Encountered

Research question 2 was about scanning the case data to report in a great detail, the consequences of the lack of preparedness in terms of what problems actually arose in the organisations we studied. As already discussed, we used standard categories for reporting problems in both cases, namely: Planning, Fit to Organisation, Staffing, and Change Management, which greatly facilitated the comparison between the two organisations. An interesting follow up from the presentation of the problems involved trying to understand whether the organisations had been able to identify that they were faced with these problems early enough so that they could find ways to cope with them. It is interesting to see that in both cases, the key problems, that is, the lack of a standard approach, was identified, but managers failed to address the problems that arose from this initial failure until later in the project lifecycle. In the case of the HSE, it was actually simply too late to rescue PPARS and turn public perception around.

Table 8 presents the problems faced by the HSE in their PPARS project. In the Health Service, the real drivers of the project are unknown, although its origins did address the replacement of various agency-specific HR/Payroll solutions. However, the vision and primary goal of the PPARS project was never clearly articulated, communicated, understood, and agreed nationally. Where the primary goal of PPARS may have been to transform HRM in the Health Service, it was simply perceived as the computerisation of employee records and the replacement of existing Payroll systems. Furthermore, at the outset, involvement in the PPARS project was not compulsory across the Health Service, while those entities involved were given total autonomy in how they approached the project. Therefore, no real strategic business need existed for the project and the Health Service failed to identify and prioritise the crucial business processes that needed to be represented on the ERP system.

Thus, it was a defining characteristic of the Health Service case that:

1. The vision and primary goal of the project (which was a business transformation project) was never clearly articulated, communicated, understood, and agreed nationally. Where the primary goal of PPARS may have been to transform HRM in the Health Service, it was simply seen as the computerisation of employee records and the replacement of existing payroll systems.
2. There was very little executive sponsorship and organisational buy-in to PPARS throughout the Health Service.
3. The allocation of key business personnel onto the project (best resources and full-time participation) was not a feature of the PPARS project on a national level. While some areas had representative groups on the project, some areas had little or no representation on the project.
4. No project governance existed for the lifetime of the PPARS project. The PPARS project was characterised by the fact that there were no clearly defined lines of authority, responsibility, and accountability.
5. Preparations around the governance of the project were lacking. In fact, in 2002 the Hay Management Group recommended that the issue of governance be addressed if the project was to continue. However, the commencement of Phase 2 of the project did not bring a re-examination of the approach to the project from that of Phase 1. Furthermore, a change in scope from Phase 1 to Phase 2 did not sufficiently highlight the needs that were being addressed over-and-above those of Phase 1, and it appeared as if Phase 2 of the project was not given adequate consideration and planning. As a result of this lack of preparation, considerable cost and time overruns characterised the PPARS project.

Table 9 presents the problems identified within BGT in relation to their ERP project. Traditionally, BGT would have rolled out the JD Edwards World ERP system very quickly across sites, on the back of winning business and in support of the customer service model requirements, but without an appreciation of the possibilities to standardise the internal business processes. As a result of this approach, BGT would then have to return to those same sites (post-implementation) to rectify the problems inherent in their initial approach. In fact, the former Vice President of IS commented that if it was not for the fact that BGT embraced other initiatives that were being undertaken (Finance and SCM BPI),

BGT would have to report an ERP disaster. However, as the BGT organisation has proceeded with implementations, they have got better and have become more familiar with the JD Edwards World package. BPI is the key to getting value out of our ERP.

The BPI initiatives focused on what existed within BGT in terms of the JD Edwards World infrastructure, introduced proper training for personnel, automated processes, standardised processes to provide a global process infrastructure, and coded data in a standardised way in order to facilitate global reporting. These BPI projects were not IT projects (unlike the initial JD Edwards project) and they were understood to be business projects that were IT-enabled. According to the former Vice President of IS "what we are doing in the BPI projects will give us more benefits that we will ever get out of upgrading or buying a new piece of IT to be honest."

A serious issue around the introduction of the JD Edwards World ERP system within BGT was the approach taken to project management. In fact, no formalised approach to managing the project existed or was adopted across the BGT sites. It was reported that as a result of the lessons learned in their approach to introducing the JD Edwards World system, BGT then adopted a more formal approach to undertaking and managing a project. In fact, this formal approach to managing a project, focusing on the importance of: documentation, project objective, project scope, project personnel, and project time-frame, was developed as a result of the lack of preparations in these areas at the outset of the initial JD Edwards World ERP project.

The observations presented here prove that the same organisation (BGT in this case) can become very successful with regard to the implementation of an enterprise-wide ERP solution if they have a greater level of understanding (awareness) as to the true nature of what is required in an enterprise-wide ERP project. As a result, the organisation can leverage this increased awareness to ensure that the required preparations are made to undertake the implementation. This is characteristic of the organisation appreciating the concept of being *mindful* (Swanson & Ramiller, 2004) with regard to their implementation approach and the desired outcomes to be achieved.

It was a defining characteristic of the BGT case that over the last decade the organisation has learned the hard way with regard to the undertaking of an enterprise-wide ERP project, and according to the former Global Director of SCM,

BGT still has not implemented those lessons. It was not until 2000 that BGT started to become global and think globally. So when you put that on a timeline vs. when we implemented ERP (selection commenced in 1996), it presents an interesting gap.

In fact, it was immaterial to BGT which enterprise-wide ERP product they selected and implemented, due to the fact that it was the approach to implementation and the organisational mindset that was the cause of their problems throughout. In the end, improving the JD Edwards World system through dedicating additional resources and management bandwidth was the best option available to BGT to add organisational value.

Overall, based on the analysis conducted in this case, it was a defining characteristic of the BGT experience that:

1. There was a need for an organisational architecture and a global process infrastructure which would have been supported by the ERP system. In fact, a series of BPI initiatives facilitated retrofitting the ERP system to the global business processes, once these processes were designed.
2. Efforts to promote education and training amongst the business personnel improved the businesses appreciation of the system in-use, in support of their functional areas.
3. Processes needed to be put in place to attract highly skilled resources in an effort to establish and maintain support structures for the ERP system in-use, therefore freeing up more valuable resources to undertake value-added activities as opposed to support roles.
4. The importance of allocating adequate numbers of skilled and knowledgeable resources full-time to a project and ensuring that the project is viewed as a “priority one” initiative are paramount to its success.
5. Ensuring that a well defined set of business requirements are communicated and understood by the business at the outset, where the business does not simply undertake a “wish-list” exercise, is another critical aspect.

Research Question 3: Comparing the Cases

Both BGT and the Health Services share a number of common characteristics in terms of their experiences with their enterprise-wide ERP project initiatives. Based on the analysis conducted, both organisations found themselves undertaking an

IT initiative from the outset, where the required level of business support was not a feature of the project. Therefore, the priority of the project was not at a high enough level within the business community. Furthermore, the project lacked a set of clear and consistent (universally understood) strategic business objectives and the criticality of adoption was not communicated from the top level.

Based on the analysis conducted within the two cases studied, evidence supports the fact that a lack of a real business objective at the outset of the project left BGT and the Health Services in a situation where the outcome of the project was less than successful in terms of delivering the required system functionality. Therefore, the existence of an actual strategic business need and the ability to prioritize critical business process areas, based on this need, is critical to ensuring that a project will produce the desired successful outcome in terms of business value and categorised functionality. In fact, an awareness of the importance of this strategic business need is required in order to guide managerial preparations in setting realistic goals and objectives for the enterprise-wide ERP project. Furthermore, the existence of this strategic business need will also ensure that top management commitment and support will be a feature of the enterprise-wide ERP project.

Both BGT and the Health Services implemented the ERP package on a site by site basis, embracing "as-is" site specific business process. This approach was as a direct result of their lack of preparation at the outset with regard to Business Process Re-Engineering (BPR), where very little attempt was made to analyse existing business processes in an effort to prioritise requirements and introduce process improvements wherever possible across the entire organisation. This prioritisation of requirements and business process improvement was something that the Health Services never achieved and BGT began to introduce through a number of separate Business Process Improvement (BPI) initiatives a number of years after the initiation of their ERP project. Evidence relating to this issue highlighted the fact that neither BGT nor the Health Services thought as one single organisational entity and as a result there was a lack of an enterprise-wide business process infrastructure in existence at the outset of the project.

It is a fact that this lack of an enterprise-wide process infrastructure makes it impossible to introduce a standardisation of processes throughout an organisation, as the organisational mindset of a *company way of doing things*, is not defined. As an example, the autonomy of the Health Boards within the Health Services and in some instances their exclusion from Phase 1 of the PPARS project further compounded the impact of implementing site specific "as-is" business processes. Therefore, when a national roll-out became a reality in Phase 2 of the PPARS project, the volume of localised idiosyncrasies represented on the ERP system increased. Indeed, it was such an issue that finally led to the suspension of the PPARS project in 2005.

Based on the analysis conducted within the cases studied, evidence supports the fact that there was a lack of a coherent implementation methodology, emphasising clear and consistent project scope focusing on critical aspects of the business, appropriate documentation of requirements to be addressed, and clearly defined lines of authority, responsibility, and accountability, from the outset of their projects. As a result, this left BGT and the Health Services in a situation where the outcome of the project was less than successful in terms of being delivered on time and within budget. In fact, an awareness of the importance of project management is required in order to guide managerial actions to deliver the project in a realistic time-frame and within the budget set for the enterprise-wide ERP project.

In both BGT and the Health Services, the active involvement of business personnel on the project was a cause of serious problem. It was a feature of both organisations that personnel were not seconded onto the project team full-time and as a result their commitment to the project was reduced as they were also performing their daily roles within the organisation. Furthermore, no real formal team structure was put in place and the roles and responsibilities of project team members were poorly defined, leading to a lack of ownership for the project by team members. As a result, this lack of ownership led to a less than successful project outcome. However, a failure to allocate sufficient business resources to the enterprise-wide ERP project, in both these cases, also compounded the impact of the problem of standardisation, in that the business personnel were not adequately skilled to perform their roles on the project team, in terms of understanding the business and driving change to introduce standardisations at a national level. Therefore, it is obvious that a lack of preparedness for such an issue as standardising to an enterprise-wide business process infrastructure from the outset, led to an extended project timeframe, with an associated escalation in costs, and a poor *fit* between the software and the business, in both BGT and the Health Services. Within BGT and the Health Services, the rationale for adopting their initial approach to the implementation of the ERP package hinged on the organisational structure and the mindset of those involved in the project at the time of initiation. Therefore, these organisations demonstrated a lack of appreciation of what an enterprise-wide view of the organisation entails, for example in terms of business process infrastructure, where very little attention was attributed to standardising processes to drive out efficiencies in the business. Therefore, the principles of preparedness for ERP implementations were not fully understood within these two cases.

CONCLUSION

Although the Irish public have been treated to a lot of horror stories associated with PPARS, for example, an HSE employee receiving a €1 million pay cheque in error in 2004; Saint James Hospital experiencing a weakened payroll process and a threat to basic functioning due to PPARS; threatened public protests about the operation of PPARS by HSE employees; certain stakeholders not "buying-in" to the system, and so forth, it has been argued by those interviewed throughout this research project that a lot of positive changes have been introduced into the Irish Health Service as a result of PPARS. In fact, the National Assistant Director of the PPARS Project commented in 2004 that *the DOH&C have also, in the past three years, adopted a single solution policy for Finance and Hospital Information Systems, so literally PPARS is a ground breaking project, where the financial solution (FISP) and the Hospital Information Systems will follow along on much the same sort of values, characteristics, and so forth, with the ability, ultimately, to consolidate all of that information into a business warehouse and take out particular performance measures.*

Based on this assessment, it is truly difficult to establish whether there was merit in the PPARS project. On balance, PPARS is a story of ERP implementation failure. Despite some benefits being achieved, the weight of compelling reasons *why* PPARS failed is overwhelming for an external observer, although it is clear from talking to the participants that few were aware, until recently, of the true extent of the problems. Ultimately, the project was badly managed, badly resourced, badly presented to organisational personnel, and badly supported by top management. However, as evidenced by the following concluding statements, many of these problems have their roots in the fundamental misconception about what the integration of a national HRM system would entail for the Irish Health Services.

As a result, it can be argued that organisations experience problematic similarities with regard to their enterprise-wide ERP project implementations. However, organisations address these mistakes made and lessons learned in a variety of different ways, relative to their specific case, which invariably impacts on resources (both human and budgetary), the scope and timeframe of the project, the actual outcome of the project, and the business value-added of the implemented system. To summarise, and based on the analysis conducted in this article, it is certain that a problem in the execution phase of an enterprise-wide ERP project is caused by a lack of focus on one or many of the *principles of preparedness* at the early stages of the project. Therefore, implementation problems in an ERP project, experienced at later stages, originated earlier in the project life-cycle. As a result, attentions have to be focused on the early identification and correction of problems. Based on the analysis conducted and presented in this article, the argument can be made that a *mindful* (Swanson & Ramiller, 2004) approach to an enterprise-wide ERP project can in fact lead to fewer implementation problems.

REFERENCES

Benbasat, I., Goldstein, D.K., & Mead, M. (1987). The case study research strategy in studies of information systems. *MIS Quarterly*, *11*(3), 369-386.

Chen, I.J. (2001). Planning for ERP systems: Analysis and future trend. *Business Process Management Journal*, *7*(5), 374-386.

Eisenhardt, E.M. (1989). Building theories from case study research. *Academy of Management Review*, *14*(4), 532-550.

El Amrani, R., Rowe, F., & Geffroy-Maronnat, B. (2006). The effects of enterprise resource planning implementation strategy on cross-functionality. *Information Systems Journal*, *16*(1), 79-104.

Gargeya, V.B., & Brady, C. (2005). Success and failure factors of adopting SAP in ERP system implementation. *Business Process Management Journal*, *11*(5), 501-516.

Holland, C., & Light, B. (2001). A stage maturity model for ERP systems use. *DATABASE, 32*(2), 34-45.

Jahnke, A. (2002). Taking sides on critical IT issues. *CIO*. Retrieved July 23, 2008, from http://comment.cio.com/soundoff/020702.html

James, D., & Wolf, M.L. (2000). A second wind for ERP. *The McKinsey Quarterly, 2,* 100-107. Retrieved July 23, 2008, from www.mckinsely-quarterly.com

Kalakota, R., & Robinson, M. (2001). *E-business 2.0: Roadmap to success.* Reading, MA: Addison-Wesley.

Kim, Y., Lee, Z., & Gosain, S. (2005). Impediments to successful ERP implementation process. *Business Process Management Journal*, *11*(2), 158-170.

Law, C.C.H., & Ngai, E.W.T. (2007). ERP systems adoption: An exploratory study of the organizational factors and impacts of ERP success. *Information and Management*, *44*, 418-432.

Markus, M.L., Axline, S., Petrie, D., & Tanis, C. (2000). Learning from adopters' experiences with ERP: Problems encountered and success achieved. *Journal of Information Technology*, *15*(4), 245-265.

Markus, M.L., & Tanis, C. (2000). The enterprise systems experience—from adoption to success. In R.W. Zmud (Ed.), *Framing the domains of IT management: Projecting the future through the past.* Retrieved July 23, 2008, from www.Pinnaflex.com

Murphy, K.E., & Simon, S.J. (2002). Intangible benefits valuation in ERP projects. *Information Systems Journal*, *12*(4), 301-320.

Murray, D.V. (2005). *Building strategic management competences in multinational organisations: Cases on the role of enterprise systems in performance enhancement*. Unpublished PhD thesis, National University of Ireland, Cork.

O'Gorman, B. (2004). The road to ERP – has industry learned or revolved back to the start? In F. Adam & D. Sammon (Eds.), *The enterprise resource planning decade: Lessons learned and issues for the future* (pp. 22-46). Hershey, PA: Idea Publishing Group.

Olsen, K.A., & Saetre, P. (2007). IT for niche companies: Is an ERP system the solution? *Information Systems Journal, 17*(1), 37-58.

Patton, M.Q. (1990). *Qualitative evaluation and research methods*. Thousand Oaks, CA: Sage Publications.

Ross, J.W., & Beath, C.M. (2002). Beyond the business case: New approaches to IT investment. *Sloan Management Review*, *43*(2), 51-59.

Sammon, D., & Adam, F. (2002, June). Decision making in the ERP community. In *Proceedings of the 10th European Conference on Information Systems (ECIS)*, Gdansk, Poland.

Shang, S., & Seddon, P.B. (2002). Assessing and managing the benefits of enterprise systems: The business amanger's perspective. *Information Systems Journal, 12*(4), 271-299.

Sharif, A.M., Irani, Z., & Love, P.E.D. (2005). Integrating ERP using EAI: A model for post hoc evaluation. *European Journal of Information Systems, 14*(2), 162-174.

Shehab, E.M., Sharp, M.W., Supramaniam, L., & Spedding, T.A. (2004). Enterprise resource planning: An integrative review. *Business Process Management Journal*, *10*(4), 359-386.

Siriginidi, S.R. (2000). Enterprise resource planning in re-engineering business. *Business Process Management Journal, 6*(5), 376-391.

Stake, R.E. (2000). Case studies. In Denzin & Lincoln (Eds.), *Handbook of qualitative research*. London: Sage Publications.

Stefanou, C. (2000, August 10-13). The selection process of enterprise resource planning (ERP) systems. In *Proceedings of the 6th Americas Conference on Information Systems (AMCIS)*, Long Beach, CA (pp. 988-991).

Swanson, E.B., & Ramiller, N.C. (2004). Innovating mindfully with information technology. *MIS Quarterly*, *28*(4), 553-583.

Teltumbde, A. (2000). A framework for evaluating ERP projects. *International Journal of Production Research*, *38*(17), 4507-4520.

Ward, J., & Peppard, J. (2002). *Strategic planning for information systems*. Chichester: Wiley & Sons.

Watson, E., & Schneider, H. (1999, February). Using ERP systems in education. *Communications of the AIS*, *1*(9), 1-47.

Wood, T., & Caldas, M. (2001). Reductionism and complex thinking during ERP implementations. *Business Process Management Journal, 7*(5), 387-393.

Yin, R.K. (2003). *Case study research design and methods* (3rd ed.). Thousand Oaks, CA: Sage.

ENDNOTES

[1] SAP has more than 25 industries solutions tailored to the following industry groups: Consumer products and life sciences; Discrete manufacturing; Financial services; Process manufacturing; Public sector; Retail and wholesale distribution; Service industries. www.sap.com

[2] At present, the Health Services Executive (HSE) is structured into four administrative

areas, namely, HSE West (covers the former Mid-Western, Western and North-Western); HSE South (covers the former Southern and South-Eastern); HSE Dublin Mid-Leinster (covers the former Midland, South-Western and East Coast); HSE Dublin North-East (covers the former North-Eastern and Northern).

[3] as stated in the introduction, the project has been put on hold indefinitely since this interview was conducted

[4] "show-and-tell" was an initiative undertaken by BGT to demonstrate ERP systems capabilities to business personnel. It was an effort to bridge the gap between business and systems knowledge.

[5] This was due to the fact that local sites, faced with drastic shortage of certain resources, for example, special consultants in certain disciplines, did not want to reveal the special pay conditions they had granted to some of their staff.

This work was previously published in An Overview of Knowledge Management, edited by M. Khosrow-Pour *pp. 17-40 , copyright 2008 by IGI Publishing (an imprint of IGI Global).*

Chapter 4.12

Aurora Health Care:
A Knowledge Management Strategy Case Study

Thomas Ginter
Aurora BayCare Medical Center, USA

Jane Root
Aurora Medical Group, USA

ABSTRACT

Aurora Health Care, Wisconsin's largest employer and healthcare provider faces intense competition, consolidation, and reform. Its choice is to view these challenges as opportunities instead of problems. A key component to realizing Aurora's opportunities is an aggressive knowledge management system. They understand that to maximize their potential, they must get the most out of their knowledge management. The purpose of this chapter is to present to you a case study of knowledge management applications in the healthcare industry through the many lenses of Aurora Health Care. First we will describe the background of this accomplished healthcare provider. We will then look at their business and knowledge management strategies. Next will be a review of the major components: core competencies, knowledge base, culture, implementation, and key success indicators.

DOI: 10.4018/978-1-60566-348-7.ch010

INTRODUCTION

Successful healthcare providers will employ robust knowledge management systems that promote positive clinical outcomes, align clinical business aims, and enable effective assistance to the surrounding communities. This chapter will describe Aurora Health Care's knowledge management strategy. We will explain Aurora's history with a SWOT analysis completed by the authors. Then we will show the organization's business and knowledge management strategies. This is followed by communicating Aurora Health Care's knowledge management strategy and its major components: core competencies, base, culture, implementation, and key success indicators.

AURORA HEALTH CARE'S HISTORY

In 1984, Aurora Health Care, a not-for-profit Wisconsin integrated health care provider, was created

Table 1. SWOT Analysis of Aurora Health Care, prepared by Tom Ginter and Jane Root, May 2009.

Strengths	**Opportunities**
• Leadership • Financial Assets • Human Assets • Training • IT Infrastructure • Human Resources & Compensation • Centralized Decision Control	• Innovation • Access to Knowledge • Customer Service • Knowledge Reward System
Weaknesses	**Threats**
• Varied Business Unit Processes • System Interface • Knowledge Management Focus & Control • Best Practices	• Competition • Knowledge Loss • Poor Patient Outcomes

around one idea: there is a better way to provide health care. This concept has been a hallmark of the organization and central to its vision. Aurora Health Care believes there is a better way for:

- people to get the care they need in settings that are convenient and comfortable;
- families to receive the services and support they need to lead healthier lives;
- physicians to offer the latest technology and treatment options to their patients;
- talented people working in health care to fulfill their professional callings;
- employers to provide for the health care of their employees, more cost-effectively;
- building healthy communities.

Aurora simplifies the translation of this belief for its employees through a motto of their *#1 Priority*, “Our patients deserve the best care. When we achieve top performance in our clinical quality, patient satisfaction and caregiver engagement, patients receive a better care experience than they can get anywhere else,” (Aurora Health Care, 2009a).

Aurora Health Care serves a large geographic base with sites in more than 90 communities throughout eastern Wisconsin, including 13 hospitals, more than 100 clinics and over 130 community pharmacies. In excess of 3,400 physicians are affiliated with Aurora Health Care, including more than 700 who comprise Aurora Medical Group. The many strategic business units that form Aurora Health Care are dedicated to enhancing organizational knowledge. A portion of the Aurora Health Care mission statement is as follows: “We are committed to improving the quality of health care and health outcomes for people today, through the rapid and broad application of current knowledge,” (Aurora Health Care, 2009b).

AURORA KNOWLEDGE MANAGEMENT SWOT

An analysis of knowledge management strategy begins with a SWOT analysis to identify if Aurora Health Care is getting the most out of its knowledge management system. Table one represents a knowledge management SWOT analysis of Aurora Health Care.

Strength: Leadership

As identified in their mission statement, Aurora recognizes that organization knowledge is critical to improving the quality of healthcare and health outcomes. Leadership’s ability to manage know-how will help ensure effective performance. Examples of this begin at the top. Aurora has established several multidisciplinary councils to provide leadership and input on strategy, policy, clinical operations, and Care Management initiatives to Aurora Health Care senior leaders. In addition, the councils provide system-wide clinical leadership through collaboration with other senior leadership teams, along with identifying, sharing, and rapidly adopting best practices system-wide around quality, patient loyalty, employee engagement, and financial performance. These councils are the Physician Leadership Council, The Hospital Administrative Council, Aurora Nursing Leadership Council, and One Aurora Team.

To ensure future leaders have a base built upon best practices and value knowledge management, the organization established the Aurora Leadership Academy. This program aims to prepare Aurora's next generation of leaders from among current staff. During a 15-month period, the participants experience a series of leadership and skill-building opportunities. These activities are enhanced through a one-on-one relationship with an individually assigned mentor and through formal networking opportunities.

Strength: Financial Assets

Aurora's total net service revenue grew from $3.2 billion in 2007 to $3.5 billion in 2008. Revenue from inpatient services decreased 2.1% while revenue from outpatient hospital visits and visits to clinics rose 25.5%.

Strength: Human Assets

A good healthcare organization has a mix of highly mobile skilled, unskilled, and professional employees to perform care giving functions. Aurora Health Care is Wisconsin's largest employer. These employees have a strong corporate identity that operates in diverse business units. Leadership has defined a concept called "*Responsible Freedom*" for staff to maximize problem solving to enhance patient care and experience. Responsible freedom supports better ways to provide exceptional, patient centered experience. Each employee needs to know how to take independent action that benefits the customer and organization. Expectations for staff are to learn on a continual basis, be team players, respect diversity, and utilize cross-business unit, cross-cultural experience.

Strength: Training

Aurora Health Care as a whole is committed to continuous learning. The educational resources within the system are vast—and available to all employees. New hires are encouraged to create a "*Learning Plan*" with their immediate supervisor, which validates their scheduled class/educational event activities for the upcoming calendar year. All newly hired leadership positions (supervisor and higher) are required to attend the "Aurora Quest" program. This program is a series of sessions to expose new leaders in the organization to fundamentals as well as enhanced knowledge regarding leadership skills.

A learning culture has been established for staff to optimize best practice applications. The group responsible for this implementation is the Employee and Organizational Development (E&OD) department. The mission of E&OD is to be the collaborator with leaders and staff to identify and respond to training and development needs. This is accomplished by providing the following services:

- Leadership orientation and development programs
- Educational Assistance Program Administration
- In-service Recording Program Administration
- Title IV, U.S. Office of Education Student Financial Aid Program administration for Aurora schools
- Staff orientation and training programs with emphasis in the areas of:
    - Clinical patient care
    - Life Support Education

  - Office Professional Services
  - Service
  - Quality improvement
  - Diversity and cultural competence
- Internal consulting and executive coaching to leadership in the areas of:
  - Leadership and employee training
  - Service management
  - Workforce planning
  - Career development
  - Organization development, including:
    - Caregiver (Employee) Engagement
    - Team and partnership building and development
    - Change and conflict management

Strength: IT Infrastructure

Aurora seeks to lead in *the innovative use of IT in the health care market*. In support of this goal, Aurora Information Services works closely with the business groups to define and implement the Information Technology (IT) infrastructure component of Aurora's business strategy. In addition to the major IT projects, linked directly to the Aurora strategy, Information Services supports a large number of regional and departmental projects, and provides key infrastructure and operational support including: system operation and backup, the Aurora network, the help desk, user access and security, and desktop support. The Information Services website serves as a key source of information on many of these activities for both business and staff.

An overview of the electronic tools and technology used across Aurora:

- *Aurora iConnect:* the internal intranet that links all caregivers to information.
- *Employee Connection:* a link that allows individuals access to personalized information regarding compensation, benefits, emergency notification.
- *Learning Connection:* the link that monitors mandatory and elective education and training programs.
- *My Aurora:* the mechanism allowing electronic communication between patients and caregivers. This can be accessed both internally and externally.
- *Web Budgeting:* the electronic application that monitors budget trends and variances.
- *Web Management Reporting:* the electronic financial application with specific access parameters to information.
- *Brass Ring:* software application program that manages employment postings, applications and the applicant review process.
- *Cerner (Electronic Medical Record):* the patient medical record; includes numerous applications, security clearance levels and defined processes.
- *IREQ:* software application program that manages supply and services expense item purchases.
- *Authorization for expenditure (AFE):* software application program that manages capital item purchases.
- *Data Warehouse:* electronic application that collects different data sources through a repository.
- *Biorepository:* electronic application that processes the distribution of all biological products and related clinical information for clinical research and genetic knowledge enhancement.

Strength: Human Resources & Compensation

As with any successful business, Aurora relies on its mission, vision, and values to establish human resource and compensation philosophies. The philosophy supports hiring and retaining qualified and motivated employees to ensure appropriate patient care while managing human resources responsibly. Further elements involve accurate job descriptions, job analysis and evaluations, pay grades with established pay ranges, with individual incentive through performance measures based on merit. Individual workers receive pay incentive through a merit pay program conducted on an annual basis. Employees receive merit increases to their compensation when they meet or exceed job expectations. The annual performance through merit program will occur during scheduled performance evaluations that concentrate on employee general competency for organization, job specific standards, accomplishment on agreed upon goals, and skill competencies.

Strength: Centralized Decision Control

Aurora Health Care strives to mitigate varied business unit practices and ensure consistent best practices are uniformly used across the organization. Their motivation is to:

- Integrate care for patients.
- Standardize and support common practices that benefit patients.
- Constantly challenge one another to find better ways to achieve the highest quality and service for patients without competing with one another for patients and revenue.
- Work together to give people the care needed - when, where, and how patients want to access it.

Centralized decision control due to the enormity of Aurora's geographic span of services is sometimes hindered through centralized decision making. The time and energy to access decision authorities can mitigate how nimble decisions are made in local markets.

Weakness: Varied Business Unit Processes

With strategic business units spread over a large geographic base with sites in over 90 communities throughout eastern Wisconsin, including more than 28,000 employees and over 3,500 physicians, it is easy to appreciate the risk of varied business unit process. The organization works to mitigate mediocre know how by becoming *One Aurora*. This long-term strategy sets the vision to move from common practices partially applied to *Best Care Everywhere*. The vision and mission statements of the organization are well known to the general employee base. What is less known is the specific application for those statements to the everyday work environment. Application of best practices can at times be fragmented.

Weakness: System Interface

Within a large organization, it can be logistically challenging to make the necessary connections between departments and teams. It is essential to include representation from all appropriate entities that could impact any specific initiative. With a broad, comprehensive approach, there is less likely to be unintended consequences on effected departments. To maximize resources, it is important to align work and allow opportunity for various entities input to help support the strategies and initiatives.

Patients have provided feedback to Aurora Health Care that they want health care to be simple. Aurora has designed an integrated health delivery system work to make this possible. Offering a full range of care services, Aurora professionals include physicians, nurses, behavioral health therapists, pharmacists, social workers and other experts, working together to achieve the best outcomes for patients. The goal is to coordinate care across a broad spectrum of services and patient needs.

Weakness: Knowledge Management Focus & Control

The challenge of establishing knowledge management focus and control throughout a large healthcare provider in an industry that evolves daily is challenging. Knowledge management operations such as codification, knowledge oversight, selective encoding, and knowledge purging are typically problem prone.

Weakness: Best Practices

As with most complex organizations Aurora struggles with how to decide the benefit of exploiting known best practices or continuing the investment of further exploration and experimentation.

Opportunity: Innovation

Innovation is used to develop ideas, new opportunities and build the capacity to innovate within the Aurora organization. Aurora's strategic positioning as the premier innovator in the delivery of healthcare mandates that its staff have the capacity to innovate, develop new and better ways and recognize opportunities as they arise. Leadership understands that without new perspectives and a set of tools to help, idea generation can be difficult or even impossible. The innovation process uses a systematic approach that helps overturn beliefs that hinder, uses trends to identify emerging opportunities and evaluates and develops ideas into actionable opportunities.

Aurora Health Care has established innovation tools for idea generation by getting rid of old ideas and helping to get new ideas in play. The tools help employees remove barriers that hold them back when using traditional brainstorming techniques. A common approach and language for idea development help all understand what innovation is and how Aurora Health Care takes action based on a deep understanding of established strategy and goals. Decisions, once made, are implemented in a flawless manner. Aurora permits the use of creative tension and healthy debate to facilitate change. They know that the best ideas likely come from the organization's employees caring for customers every day. Innovation is ongoing and Aurora constantly measures and improves. To ensure a high level of performance, best practices are reviewed continuously. While patient needs change rapidly, the organization works to anticipate and change with them.

Opportunity: Access to Knowledge

Review of patient, financial and employee data is continuous. Leadership is expected to play an active role in this data review. The opportunity that exists involves the overwhelming amount of data required for collection, analysis, review, communication, and action.

Opportunity: Customer Service

Aurora Health Care has chosen and works toward a care model and philosophy that provides patient-centered care. This patient–centered concept comes in the form of individualized and personalized care developed from the patient's point of view and designed around what patients need to heal.

Opportunity: Knowledge Reward System

Front line staff has expressed the feeling of detachment from knowledge management reward measures. This connection is an opportunity for improvement.

Threat: Competition

Healthcare is very competitive, and the healthcare organization that does not value knowledge, risks loss of market share and efficient operations. Aurora Health Care has competition in each community it provides service.

Threat: Knowledge Loss

Failure to rapidly adapt "One Aurora" may lead to ineffectual encoding, fragmentation and ultimately mediocre know how. To mitigate this risk the organization works to effectively *on-board* new employees. This provides new staff with the necessary information, tools, and resources as they begin work with the organization. A good start for new employees is believed to make a big difference in how effective employees are on the job.

Threat: Poor Patient Outcomes

The healthcare industry is knowledge intense for several reasons. One reason is that the value associated with an individuals' health is of vital importance. It is therefore a tremendous expectation that those within the health industry do whatever necessary to positively contribute to maximizing healthcare delivery. In the focused review of the care management, the primary value is centered on patient outcomes. These patient-centered outcomes translate into the quality of care for the specific physician, entity and system. A subset of the patient condition outcome is patient loyalty. This *loyalty index* is another key component of the knowledge necessary for business success.

KNOWLEDGE MANAGEMENT STRATEGY

Next, the authors will describe in detail, the knowledge management strategy that is currently in place for Aurora Health Care. The strategy is focused on codification and internal development opportunities, along with an effective balance between exploitation and exploration (Russ et al., 2006).

Focus is Long Term

Aurora Health Care as a not-for-profit provider strives to maximize long-term societal benefits of activities and services. This requires a focus on disease prevention and treatment. They are Wisconsin's largest provider of charity care providing more than $25 million in community outreach and free preventive services. Their communities count on them and they feel the obligation to look ahead, preparing themselves, their programs and their facilities to meet the health care needs of tomorrow.

A Complex Knowledge Balancing Act

The identified challenges and responsibilities combine to make the delivery of health care services a complex and delicate balancing act. To address these challenges, the organization invests resources in developing knowledge through information systems that will put patient records at physicians' fingertips to help improve clinical outcomes. It means directing the energies of thousands of caregivers into finding and applying best practices to reduce the human and financial burden of illness. It also involves working with high schools and colleges to introduce and prepare young people for careers in health care. This action helps to alleviate personnel shortages that will cripple health delivery services in the decades ahead.

Addressing the challenges of today and tomorrow requires investing in clinical research and ensuring Aurora is on the forefront of applying new medical knowledge to the prevention and treatment of disease. Aurora Health Care also must enable the benefits from its economies of scale, and expanding services to provide people with the right care in the right place at the right time. It also calls for investing in the renovation and construction of facilities for tomorrow, even in the face of criticism that these investments contribute to today's health care cost burden.

Being a not-for-profit health care organization means Aurora Health Care must strive to balance what's in the long-term best interest of the people they serve, just as a doctor would for a patient.

Knowledge Codification

As stated, Aurora Health Care will only be satisfied when they give patients better access, better service, and better results than they can get anywhere else. They believe that working together, the people of Aurora will find a better way. This consistent approach reinforces and allows:

- Rapid adaptability
- Flexibility and efficient change
- Improved communications through common language

Aurora Health Care believes a consistent approach allows innovation, generates ideas to find better ways, overturns beliefs that hinder success, and uses trends to identify opportunities. Planning includes structured approaches and tools to design or establish processes. Data and IT tools are used to improve processes and reduce or eliminate waste. Control can also be used to detect and reduce or eliminate sporadic problems.

Internal Knowledge Development

Internal knowledge development is a key element toward the knowledge management strategy for Aurora Health Care. The organization has developed knowledge role definitions for leaders. They have created a structure for shared learning to drive improved results. This is accomplished by identifying subject champions; linking system teams to site teams to share results and lessons learned; establishing a team of experts as a problem solving resource; and developing and communicating feedback mechanisms on specific indicators.

They have also developed 60-day rapid action plans to improve outcomes, process, and efficiencies. Sites in the organization identify issues. A team is formed to review and provide feedback on the identified opportunities. Once the 60-day action plans are developed, the plans are made visible within the organization and system.

Balanced Knowledge Exploration/Exploitation

Aurora Health Care maintains a structured utilization/innovation scheme that applies focus on exploring new knowledge and exploiting knowledge that exists while codifying that knowledge. This knowledge is used to support new servicing of markets to achieve higher process and product effectiveness.

Next, the frameworks for connecting the business and KM strategies with the organization's core competencies and key success indicators (figure 1) will be described.

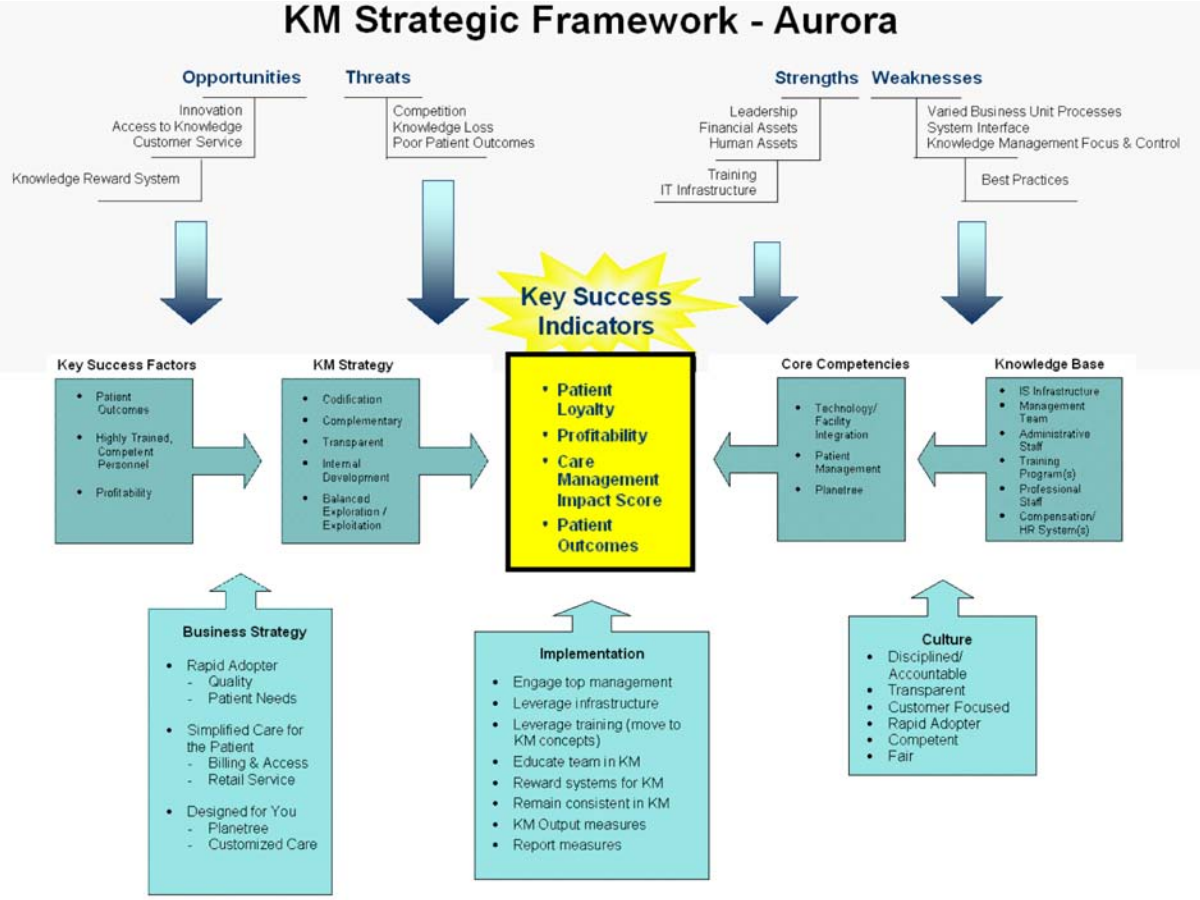
BUSINESS STRATEGY

The first building block described will be Aurora's business strategy.

Business Objectives Support Community Benefit

As a not-for-profit health care provider, Aurora has one overriding goal and that is to provide community benefit. They set a variety of business objectives to meet that goal. These objectives fall into two broad categories: finding better ways to work, and creating better value to offer patients, caregivers and communities. As they identify and achieve specific objectives in these areas, they succeed in generating the margin they need to fulfill the mission. At the same time, they keep moving closer to fulfilling the vision of providing people with better access, better service and better results than they can get anywhere else. They come full circle from mission to margin, and back again to

Figure 1. Aurora framework connection for business knowledge management (Source: by authors, prepared in May 2009, based on Russ et al., 2009).



the reason they exist, which is to improve the well being of the communities they serve.

Aurora Health Care's 2007 Strategic Plan defines their first key actions to successfully accomplish their strategy in the years to come:

- Advance Care Management
- Become One Aurora
- Develop a Patient Point of View
- Continue to Strengthen Aurora's Financial Performance

Three of these key actions have been mapped to their Long-term Strategy roadmap. Financial performance provides the foundation to achieve their Long-term Strategy. Strategic objectives come directly from Aurora Health Care's new Long-term Strategy:

- Simplified Care for the Patient
- Designed for the Customer
- Rapid Adopter

First Key Action: Advance Care Management – Integrate Care Management across care continuum and achieve their #1 Priority.

Measure top performance in quality – their #1 Priority – in the following ways:

- The Premier clinical performance measures, a database of the top performing hospitals in the country, provide Aurora Health Care with both quality and cost data for nine major diagnoses. Although a hospital-based measure, they will only be successful in achieving top quartile performance by utilizing the care continuum of their integrated delivery system and by everyone reducing costs.
- Aurora Health Care continues to track Care Management Impact Score. Similar to a school report card, each of their Care Management initiatives, their safety efforts, and their quality improvement efforts are scored as an "A", "B", "C", or "F" which, like a grade point average, earns points of 4, 3, 2, or 0.
- In addition to the #1 Priority measures, Aurora Health Care will provide a single accurate medication list to all Aurora care providers to improve patient safety and to simplify care for their patients.

Second Key Action: Become "One Aurora," with three areas of focus.

- Integrate clinical service lines across the system
- Simplify and design care for their patients
- Adopt clinical innovation into clinical practice

The first area of focus under becoming "One Aurora" is to integrate clinical service lines across the system. Currently Aurora Health Care's clinical service lines have been developed from a facility, market or regional perspective. At times, this has resulted in best practices being partially applied, fragmented care, confusion for patients, and differing prioritization or competition within the system.

The second area of focus under becoming "One Aurora" is to simplify and design care for patients. During the discovery phase of Aurora Health Care's Long-term Strategy work, they obtained hundreds of insights from their patients. Aurora Health Care heard how they could simplify and design their processes to better meet their patients' needs and selected the first five (5) system processes to improve in 2007:

- Patient billing
- Patient registration
- Managing resources responsibly (specific focus to be determined)
- Medicare length of stay
- Appropriately utilizing their diagnostic and inpatient resources

The third area of focus under becoming "One Aurora" is to adopt clinical innovation into clinical practice. Aurora Health Care will continue to integrate their clinical research to support the discovery and adoption of new knowledge within clinical service lines.

Third Key Action: Develop a Patient Point of View, with 3 areas of focus.

- Adopt and embrace Planetree
- Provide care to a defined patient group in a way that meets their needs
- Integrate retail into care delivery locations to better meet patients' needs

The first area of focus under developing a patient point of view is to adopt and embrace Planetree (a philosophy of patient-centered care in a healing environment). Aurora Health Care will measure success by:

- Increasing the percent of people who would recommend Aurora Health Care to family and friends (patient loyalty index).

- Increasing the percent of their patients who perceive that they received care in a coordinated, simple, and easy to use way.
- Increasing the system-wide employee engagement index by 5%.

The second area of focus under developing a "patient point of view" is to provide care to a defined patient group in a way that meets their needs. Health care typically groups patients based on their demographics (age – senior services, sex – women's health, etc.) or by their medical diagnosis (oncology, orthopedics, cardiac, etc.). An additive way of understanding their patients is by addressing their needs, behaviors, or preferences. Aurora Health Care is experimenting with new models of care delivery that include the focus on the needs of their patients, starting with offerings specifically asked for by very busy (time-starved) families. They will measure if these offerings make a difference in patients choosing Aurora for their needed services.

The third area of focus under "Develop a Patient Point of View" is to integrate retail into care delivery locations to better meet their patients' needs. How to integrate retail: Aurora Health Care's patients' experiences do not stop at their doors – they need to re-define and expand concepts of patient care beyond the hospital or physician visit. At times, patients and their families need to acquire retail products to support the care they provided. Consistent with their Long-term Strategy, they need to ensure the patient's experience in acquiring these products is as easy and convenient as possible.

Fourth Key Action: Continue to Strengthen Aurora's Financial Performance.

Aurora Health Care will improve profitability by increasing the operating margin by 0.1% in 2009 from base operations excluding start up facilities.

Next the core competencies will be described.

Core Competencies

Specific core competencies vary by position and job code. The general competencies for many caregivers include: understanding of clinical conditions, data collection, financial processes, medical records, use of information systems and communication skills. Intensity and level of expertise can be defined via the specific job standards associated with each defined role within the organization. As an example, a core competency within the Care Management is the ability to utilize the large amount of data they have exposure to and add value to it for the patients they serve.

The Planetree philosophy of care that is unique to Aurora Health Care (within business markets) can provide advantages as well. Planetree is a philosophy and model of personalizing, humanizing, and demystifying healthcare. This connection with a patient-centered focus allows capturing loyalty via the sharing of best practices through this international organization. All caregivers throughout the system, regardless of their actual direct patient contact, are accountable for knowledge and understanding regarding the Planetree philosophy.

Additionally, there is opportunity to capture a business lead on utilization of a *Just Culture* approach to patient safety. This approach focuses on investigation of the true cause of any error—individual, process, or system failure. Highlighting this as a cultural shift would be seen as a positive step. Even though many organizations can validate their processes for patient safety, this cultural focus sets the tone for significant system impact.

KNOWLEDGE BASE

In the complex environment of healthcare, a solid base to support administrative, declarative, pro-

Table 2. Aurora Health Care IT/IS knowledge management systems (Source: Developed by the authors in May 2009, based on Gottschalk, 2002)

Categories	**Core Knowledge**	**Advanced Knowledge**	**Innovative Knowledge**
Administrative Knowledge	-Microsoft Word -Microsoft Excel -Microsoft Office -IDXware -Lotus email -Accounting System -Capital Expense System	-Press Ganey Patient Loyalty Database -The Joint Commission Website	-National Committee for Quality Assurance Benchmark Database -Risk Management Database -Employee Injury Database
Declarative Knowledge	-Cerner PowerChart Office -Center for Medicare and Medicaid website -Wisconsin Administrative Code website -Wisconsin Department of Regulation and Licensing website -The Joint Commission on Healthcare Accreditation Standards -OSHA Codes	-Cerner patient database -Cerner report writer -Wisconsin Collaborative for Healthcare Quality website -National Committee for Quality Assurance website -American Medical Association website -Code Libraries -Aurora Health Care Experts	External Best Procedures
Procedural Knowledge	-Aurora iConnect internal website -Aurora Policy and Procedure website link	-Wisconsin Collaborative for Healthcare Quality website -National Committee for Quality Assurance website -American Medical Association website -CINAHL (Cumulative Index to Nursing and Allied Health Literature)	-Up-to-date -Zynx -Center for Disease Control website
Analytical Knowledge	-Lotus Sametime -Care Management AHC system database	-Institute for Healthcare Improvement website -Cancer, Trauma and Perinatal Registry databases	-Premier clinical performance website -Micromedex

cedural, and analytical knowledge is necessary. Aurora Health Care satisfies these base requirements through developing an intense information system infrastructure, and providing for a vision, understanding, and commitment to building a solid knowledge-base, as well as, with a firm development of knowledge roles and skills.

IS Infrastructure

A review of the information technology and systems utilized by the organization clearly indicates that Aurora Health Care relies heavily on both internal and external knowledge-based-systems. In the highly regulated environment of healthcare, the sharing of electronic information (data and meta-data) is a business necessity. The reimbursement system alone mandates compliance with electronic sharing of information. A positive impact of these requirements is that healthcare organizations can identify actions and opportunities for improved care and processes. When the opportunities promote action, there is value created for the patient and organization through knowledge management.

IT / IS Knowledge Based Systems

Knowledge Management Vision

The vision of Aurora Health Care is centered on the single idea: there is a better way to provide health care. The following segment of the vision describes their knowledge management philosophy:

"We are committed to improving the quality of health care and health outcomes for people today, through the rapid and broad application of current knowledge. We are also engaged in the education of health care professionals, and the ongoing quest for new knowledge through medical research, in order to contribute to the quality of health care in the future," (Aurora Health Care, 2009a).

Knowledge Management Understanding and Commitment

Within the employee base of the Aurora Health Care there is a strong understanding of the need for data and information review. There is continued assessment of the value this knowledge brings even when it is not commonly referred to or understood as Knowledge Management. Messages come from senior leadership for constant improvement and to maintain steady progress. This information is shared throughout every segment of the organization. The organization has identified knowledge champions that manage knowledge. These champions are the Chief Information Officer (CIO) and Vice President of Quality and Research. These two individuals lead the system teams that organize the work within many departments, specifically the technology and quality areas. Although very high-ranking employees, they are accessible and available to nearly every employee. From a clinician point of view they are well known. Another knowledge champion would be the Chief Financial Officer (CFO). This person is responsible for assisting all leadership with availability and understanding of financial data. The system also has established knowledge teams who collect and sort through data and processes involved in analyzing knowledge information for codification. There are local business unit teams for various initiatives that feed into larger regional or system teams.

Knowledge Roles and Skills

Development and implementation of new knowledge specific roles occur at the following levels:

The Individual

The development of new knowledge specific roles is truly based on individual motivation and interest. Every employee has the opportunity to identify areas in which they desire growth. This could be basic computer skills, to advanced analysis and interpretation of data. Based off of specific job duties and responsibilities, an employee is challenged to create their "Learning Plan" to improve their knowledge and skill set.

Team

Team development of new roles would be visible when a new initiative is identified. There would be opportunity to engage and lead the effort to establish protocols and processes regarding the identified initiative. There is significant support to have teams bring forward new ideas and share "best practices." There is recognition and support when an idea or process that has positive impact to the patient and/or organization is identified. These sharing opportunities can originate at the local and regional level, but are often taken to system teams.

Organizational

As information technology and quality initiatives continue to expand, so does the organization's need to respond to those challenges. The new perspective that comes with new leadership can quickly help the entire organization review old ways of thinking. This pause for review does not require sweeping change; it may only validate the right path.

Inter-Organizational

Within Aurora Health Care there is opportunity to network and engage in collaboration both inside and outside of the system. The system has both hospital and clinic based entities, which create opportunities for unique collaboration, learning and sharing. As a large health care organization, there is also the availability to work with outside systems for comparison and learning. This type of knowledge is limited due to the industry's reliance on regulatory agencies. Much of the data and information collected is subject to their review. This includes quality data and also financial data that impacts the business at all levels.

KNOWLEDGE MANAGEMENT CULTURE

Knowledge Philosophy

Within Aurora Health Care, there is significant effort to standardize and share best practices. Becoming "One Aurora" means that care will be integrated, with the goal of exceptional results for the patient. This is part of the long-term strategy that every employee receives training and education.

The philosophy of care is *patient-centered*. This means that all staff actions can be linked to the impact to the patient. Considerable time is focused on the specific quality outcomes employees are charged with obtaining. The focus on those outcomes and goals supports established behavioral expectations. The behaviors relate not only to individual expectations, but the expectations of departments, and strategic business units. The entities are established within various markets and regions as well as the overall system.

Knowledge Management Reward System

The reward system for achievement of knowledge management goals is seen at various levels. An example is the *Care Management Impact Score* which is a measure that combines both hospital and clinic based measures into one score. This score is part of the performance review of every employee within the Aurora Health Care system. The final score has an impact on the merit increase of an employee on an annual basis. This financial tie to initiatives places significant emphasis on achievement of the goals. Published accomplishments can be viewed on the Aurora internal website as well as in numerous mailings and publications.

Knowledge Networks

There is significant corporate support of informal networks. Staff at all levels is encouraged to connect and interact with peers in other regions and outside of the Aurora Health Care system. There are routine system based meetings, which promotes internal relationship building. It is a frequent event for staff to check with other internal and external parties for ideas on processes, solutions, or validation of an identified problem. These calls, emails and exchanges with colleagues are seen as value added.

KNOWLEDGE MANAGEMENT IMPLEMENTATION

The healthcare industry is knowledge intense for many reasons. Primarily, the public values individual health and the expectations for those within the healthcare industry are to positively contribute to healthcare delivery. This expectation requires effective implementation of knowledge.

Levers that Support Knowledge Management

Top Management Engagement

An expectation defined by Aurora Health Care leadership is that caregivers will continue to work together, taking responsibility for their actions, fulfilling their promises and helping one another to do their best work for their patients, because they believe in accountability, teamwork and respect. This value statement includes the following core beliefs:

- People are their greatest asset
- Aurora Health Care embraces their promise to their employees
- They are accountable to each other, to their patients, and to their communities
- They work with each other and with their patients and their families
- They welcome diversity of ideas and opinions
- They respect their patients' wishes. They effectively work with their patients and with each other within the context of cultural beliefs, behaviors and needs (cultural competence)

The organization has defined key expectations of its leadership team:

- Instill confidence, creativity and passion in others by
    - Building my own credibility, meaning: walking the walk, keeping promises, practicing the golden rule, treating staff fairly and equitably
    - Accentuating the positives in people's ability, and not dwelling on weaknesses
    - Praising employees for their efforts
    - Providing opportunities for growth - special projects, etc.
- Provide a vision with defined expectations and time frames
    - State clear expectations
    - Provide the "why" when outlining responsibilities
    - Challenge staff to go beyond their expected potential
    - Provide guidance in times of uncertainty
- Provide feedback regularly and hold employees accountable
    - Let staff know you are there and that you are interested in them
    - Seek to find times when staff are doing things right
    - Use informal coaching and just–in-time feedback
    - Give consistent, timely feedback
- Be fair and apply established practices consistently when addressing employee relation issues
    - Don't play favorites – apply rules and expectations to all staff
    - Don't assume guilt or fault during investigations – consider all sides until it's time to evaluate
    - Listen to all staff and all sides
- Treat others with dignity and respect by
    - Separating the behaviors from the individual – poor or inappropriate behavior does NOT give one license to treat the employee in a disrespectful or degrading manner. Disciplines and even "for cause" terminations should be delivered with dignity.
    - Remember the Aurora Promise to their employees. Aurora Health Care will provide them with the tools and resources to have them be successful in their jobs, to provide feedback and to be fair.

Highly Trained, Competent Personnel

As an organization, the employees, referred to as caregivers, are considered Aurora's greatest asset. To help define the commitment to the caregiver, a "*Promise*" was developed. It reads as follows:

"We promise to listen to and implement better ideas, recognize and reward contributions, offer competitive pay and benefits, and continue building a wide range of career opportunities.

We pledge to explain business issues and strategies, to anticipate and respond to change, and to provide needed technology and information. We will use resources wisely, operate cost-effectively, and maintain a sound financial base so we will be able to make investments in the future — improving health care for all of us. Together, we find new ways to deliver health care, from the simplest of preventive services to the most advanced, life-saving treatments. Every day each of us needs to use our knowledge, experience and creativity to find better ways of doing things. We improve current ways of providing care, combining science with common sense, and embrace best practices — setting new standards for quality care. Aurora's strength stems from the teamwork and collaboration among a talented and diverse group of professionals. That's why it's critical that Aurora continue to attract, keep and motivate talented people. Aurora provides the tools and resources we need to find better ways, and recognizes our successes. Working together, the people of Aurora can challenge conventional wisdom, solve problems through teamwork, develop innovative ideas, and implement best practices. Each caregiver is part of a leading-edge organization, doing important work for people and their families. We're passionate about caring, we're striving to provide better service, and every day…we find better ways," (Aurora Health Care, 2009a).

Human Resource Promise and Rewards

As an organization, everything Aurora does must be focused on providing the best patient care experience, which includes creating an engaging environment for their staff. The Aurora Pulse survey provides caregivers the opportunity to tell leadership how they are meeting this expectation. By asking caregivers to take the survey, leadership makes an implied contract that those results will be used to make Aurora a best place to work and to achieve great results for patients. They have committed to an annual survey and using the four-step *Making a Difference* process to provide:

- leaders with feedback and insight on how well caregivers think Aurora Health Care is doing in living the values, achieving the mission and vision, and following the strategy.
- caregivers with the opportunity to share their opinions regarding topics such as communication, recognition, and personal growth.
- caregivers with an opportunity to become engaged in discussions regarding survey results and development of action plans to improve and enhance current processes.

Caregivers have a chance to impact their day-to-day operations as they follow-through on the action plans and see the results of their activities.

Each Aurora Health Care caregiver has the opportunity to identify specific individual goals they can strive to accomplish per the corporate performance review process. Goal selection and accomplishment can be related to personal growth (learning) as it pertains to their specific role and job function. In addition, there are performance goals that are set via the department, region and system levels. There can be a monetary reward based on accomplishment.

From a recognition perspective, there is an established employee recognition program that allows acknowledgement of exemplary service or work. This program allows for the caregiver to be acknowledged in a setting of their peers, with specifics as to their accomplishment. In addition, there is a lapel pin called the Aurora Star that can be worn as a constant reminder.

Team recognition is often highlighted in the corporate messaging that occurs via the internal intranet system. The reward systems for achievement of care management goals are seen at various levels. The system *Care Management Impact Score* is a measure that combines both hospital and clinic based measures into one score. That score is part of the performance review of every employee within the Aurora Health Care system. The final system score has an impact on the merit increase on an annual basis. This financial tie to the initiatives places significant emphasis on achievement of the goals.

Other recognition for achievement is noted for individual physicians as well as regional and market teams. The published accomplishments can be viewed on the Aurora internal website as well as in numerous mailings and publications. Whenever possible, most leaders seek to publicly praise and recognize individuals for their contributions during meetings with peers.

A criticism of the reward system by front line staff is that they do not always feel they can have a significant direct impact on some of the measures. The clinical specifics involved in many of the initiatives are physician led. If the practitioner makes decisions that could change the overall goal achievement, front line staff feels disempowered. The leadership message that has helped to overcome this criticism is that every employee has the opportunity to contribute in some way to each and every goal.

Report Measures

Healthcare is ever changing. As most industries deal with technology changes, the research involved in disease management and cures is significant in meeting patient expectations to have the latest diagnostics and treatments available. This requires Aurora to maximize the ability to turn data and information into value-added knowledge.

A subset of the patient condition outcome is patient loyalty. The *Loyalty Index* is another key component of knowledge the organization requires for business success.

Another key benefit for the organization is financial stability. When Aurora Health Care manages the current patient population with a best practice approach, they have maximized that patient encounter and delivered the right care at the right time. This also translates to resources used wisely. Minimizing waste would be seen as a contribution toward future investments in strategies for continuous improvement.

Exploiting New Knowledge

Aurora Health Care is constantly being challenged to maintain the highest level of clinical care knowledge and standards. For the patient, this translates into high-end care within their local environment. To maximize this message, they rely on supporting technologies. To be considered "innovative" and "cutting edge" requires people, processes and equipment.

Leveraging Knowledge at All Levels

Nearly all teams within Aurora, feel that information can come from many sources and levels—the patient, the employee, the system and externally. The size of Aurora Health Care provides connectivity that is difficult to quantify. The organization has the opportunity to study a massive patient population base along with its employee group. They can look for value in small, intricate details, or large system processes.

Integrating Knowledge From Various Areas

The integration of knowledge for Care Management is founded in the structure. With the regional teams, there is clear flow of data/information and subsequent knowledge to the system and from the system. Aurora Health Care improved knowledge of company goals at all levels by linking each employee to the email system. This was a major success factor in improving the sharing of information. The corporate strategies, goals and initiatives are part of that knowledge. Although every employee does not have access to their own computer, they do have computer access close to their work environment. The cultural adjustment in this initiative involved clarifying the expectation that electronic communication was a standard, not an option.

Knowledge Used as Competitive Advantage

The organization's large patient base provides a tremendous amount of data and information. If used effectively, that information can provide significant advantages in looking at what a large number of patients want. Aurora Health Care was not the first healthcare entity to embrace LEAN principles to gain leverage over competition. Maximizing operational efficiency can be impressive for the patients—they see organization, communication and connectivity.

PROCESSES TO IMPLEMENT KNOWLEDGE MANAGEMENT

Key Points for Success

- Engage top management in knowledge management concepts and practices.
- Increase knowledge management awareness – begin small – utilize high priority project.
- Leverage existing infrastructure and identify hardware/software and information gaps.
- Leverage current training and consolidate to knowledge management concepts.
- Select Implementation team (provide education on knowledge management concepts).
- Create a CoP for small project.
- Adjust culture and knowledge management strategies through incentive and rewards.
- Utilize consistent approach.
- Allocate the resources and define the timeframe for the project.
- Have knowledge management outputs related to:
  - Quality – Performance
  - Financial improvement
  - Liability reduction
- Validate and report the results.
- Develop a pool of experts necessary for knowledge management applications at Aurora. Examples include the following:
  - Six Sigma: Six Sigma is a disciplined and rigorous analytical approach to quality improvement. It is typically used to decrease variation and eliminate defects for key business processes. Six Sigma is a proven methodology for improving the quality and financial performance of businesses.
  - Flawless Implementation: The Flawless Implementation model is used to help ensure that Aurora Health Care's opportunity to succeed is not by chance but rather by consistently and appropriately applying a disciplined management process. The Flawless Implementation model focuses on identifying and sharing lessons learned and best practices, ultimately improving quality in all that they do. The model has a well-defined cycle of four phases that include Plan, Brief, Implement and Debrief.
  - Tools for Innovation:
    - **Closely held beliefs:** All industries have closely held beliefs about, "how things are done here." The beliefs tool helps to view Aurora Health Care's

organization from the customers' perspectives in order to identify the deeply held beliefs and conventions that drive their behavior. By identifying the belief, they can "flip" it to see what other facets emerge and what opportunities exist with a fresh eye.

- **Trends and Convergences:** Trends can affect what will happen to a business today and in the future. When more than one trend converges with others, it can create even greater changes. The trends tool helps them to learn how to recognize and take advantage of trend convergences and generate opportunities with the new insights.
- **Idea Generation:** Combining multiple insights and discoveries generates ideas. By exploring the intersection of various insights, Aurora Health Care begins to see things with new eyes and new opportunities emerge. By clustering related ideas, larger domains of opportunities emerge.
- **Idea Elaboration:** Not all ideas are good ones. By taking an idea "through the wringer" it helps to more clearly define the idea and its scope and to assess the risks and benefits of the idea before implementing it. The idea elaboration tool guides an idea through the evaluation process to determine if it is worthwhile.
- **Statistical Process Control (SPC):** Once Innovation and/or Quality Planning and/or Quality Improvement work has been accomplished it is critical that the new process(s) are managed so that they are safe, stable, predictable and capable of meeting customer requirements. Statistical Process Control (SPC) is used to determine how a process is performing. Statistical Process Control, through the use of control charts, serves to reveal the "Voice of the Process," a term used to describe what the process is telling them. Time-ordered sequence data is used to objectively and statistically determine how a process is performing.
- **Baldrige Criteria** (Malcolm Baldrige National Quality Award): Baldrige is a business model used to evaluate an organization's approaches to addressing key business processes and their connection to results achieved. Consistent approaches provide for the alignment of resources to improve communication through a common language, productivity and effectiveness in achieving strategic goals. The criteria are intended to ensure that the strategies used are balanced among customers, objectives or goals.
- The Baldrige criteria are not prescriptive in what tools an organization uses or how they are deployed. In other words, it does not say that an organization needs to use Six Sigma or Plan Do Study Act. The selection of tools, techniques and systems usually depends on factors such as size, organizational

relationships, staff capabilities and responsibilities. What the criteria look for is systematic approaches used consistently throughout the organization that achieve the desired or expected results.

- **LEAN:** The purpose of LEAN is to identify and eliminate waste in order to facilitate process improvement and ensure that all activities create value to the customer. LEAN is a process used to create customer value – goods and services with higher quality and fewer errors or defects. This includes creating and/or improving value to customer, eliminating non-value added activities (waste), increasing efficiency and reducing cost, standardizing processes, reducing hand-offs, and improving quality and cycle time.
- **Plan Do Study Act** (PDSA) The PDSA process is a defined process for improvement. Through a series of steps each change is analyzed using data to assess outcomes in achievement of desired results.

KNOWLEDGE MANAGEMENT KEY SUCCESS INDICATORS

The Patient Loyalty Index

Today's health care consumer is much more savvy than ever in the history of health care delivery. They have certain expectations and it's our job to understand what those expectations are and work to exceed those expectations. The most important reason Aurora Health Care believes in increasing loyalty is that it's just the right thing to do. Aurora is in the business of caring for people. Each employee is considered a caregiver, as Aurora Health Care strives to personalize, humanize and demystify the patient's experience.

When Aurora can provide this patient-centered experience, it means they are providing the patient and their loved ones with what they need during their healing process. This results in loyal patients who trust their care. Patients use more of their services and they tell others about Aurora Health Care.

The benefits of patient loyalty are numerous and include:

- Increased revenue
- Positive word of mouth
- More donations to hospital
- Increased referral behavior
- Resistance to competition
- Increased use of other Aurora services

Aurora measures loyalty via review of key questions on their patient satisfaction survey. The Loyalty Index is the mean score of the *likelihood to recommend* Aurora Health Care to their family and friends on the Press Ganey surveys or *definitely yes* on the Hospital Consumer Assessment of Healthcare Providers and Systems (HCAHPS) survey. The mean score is closely monitored because research indicates that it is a good predictor of loyalty.

PROFITABILITY

As with most business entities, financial objectives are established. The big-picture focus within Aurora is to generate enough margin to accomplish its not-for-profit mission. The impact of effectively managing resources is a direct tie to its knowledge management. The immediate benefit of active knowledge management is the direct impact to each patient. The organization can see "results" when processes, protocols and guidelines are followed. This translates into a better quality of life for the patient as well as fiscal accountability for the organization. When resources are managed well, Aurora Health Care is able to focus funds on future opportunities such as disease prevention and research. Prudent financial management also allows capital fund availability to support high-cost IT and medical equipment technology needs.

Care Management Impact Score

As identified in early portions of this chapter, the commitment to quality care is evident throughout Aurora Health Care. A measurement of the outcomes related to quality initiatives is demonstrated via an assigned score. How that score is calculated is as follows:

Each of the twenty-seven (27) care management initiatives, safety efforts, and the quality improvement efforts are scored as an A, B, C, or F based on performance. If Aurora meets national targets, it is graded a B, if it is better than national targets, it is graded an A. If it is less than internal targets, it is graded a C or F. Like a grade point average, they earn 4 points for an A, 3 points for a B, 2 points for a C, and 0 points for an F. All points are summed and then divided by the number of initiatives to equal a care management impact (grade point average).

The care management impact score is like a grade point average for performance on clinical improvement and safety efforts. National targets/averages are set at a "B" level or a 3.0 grade point average. Their objective is to be at a 3.1 level or higher. The stretch objective is to be at a 3.4 level or higher.

Aurora believes that continuous support of a learning environment will support continued scores higher than the national targets.

PATIENT OUTCOMES

Care management is the philosophy of improving patient care through prevention, early detection and disease management. The purpose of care management is to keep patients healthy and out of the hospital. If hospitalization is required, patients can be assured that the care received will be safe and efficient. Successful implementation requires a focused, coordinated approach to delivering health care in the right place, at the right time, for the right price and with the best possible results.

Aurora's care management is unique. In its integrated health care system, patient care can be fully coordinated among many different providers, facilities, and services on an on-going basis. Aurora's care management provides staff with knowledge management tools and immediately accessible information they need to obtain the best results for patients by employing the best practices in medical care and treatment.

The Care Management approach to patient care is the foundation of how the Aurora system measures patient outcomes. The continuous monitoring of key indicators allows adjustment and reaction to achieve the best possible outcome. Comprehensive data is available at individual physician, site, and department levels. This allows for customized analysis, which promotes continuous learning.

Each Care Management initiative has specific goals. These goals are based on research-proven best practices from around the country. They regularly keep track of progress in achieving these goals. A number of national organizations focus on healthcare quality measures. They report Aurora Health Care results along with those of other participating hospitals and health care systems.

SUMMARY

Aurora Health Care's business strategy is based on objectives to support its benefit to the community. These objectives translate into key actions of advanced care management, aligning business practices across its organization, conducting business from a patient's point-of-view, and strengthening its financial performance. These key actions are mapped into a long-term strategy of simplified care for the patient, service designed by the customer, and rapid adoption of best practices.

The knowledge management strategy is structured to provide knowledge balance, codification, and internal development opportunities, along with effective exploitation and exploration. As a not-for-profit healthcare provider, Aurora Health Care strives to maximize long-term societal benefits of activities and services. This requires a long-term focus on disease prevention and treatment. A complex knowledge-balancing act of identified challenges and responsibilities is structured to ensure the best long-term interest of the people they serve. They believe that working together the people of Aurora will "find a better way." A consistent knowledge codification approach reinforces this belief and allows them to rapidly adopt innovation, be flexible with efficient change, and use common language to improve communication. Internal knowledge development is a key element toward knowledge management strategy at Aurora Health Care. The organization has developed knowledge roles and functions for leaders. They have a structure for shared learning to drive results. Aurora maintains a structured utilization/innovation scheme that applies focus on exploring new knowledge and exploits knowledge that exists while codifying that knowledge.

Core competencies are important to any knowledge management system. Aurora Health Care ensures core competencies that relate to operations, customer service, and safety. Specific core competencies vary by position and job code. Among the general competencies for many Aurora employees are: understanding clinical conditions, data collection, financial processes, medical records, use of information systems, and common communication skills. Aurora Health Care utilizes a philosophy of care that makes a connection with a patient-centered-focus. This supports capturing patient loyalty via the sharing of best practices in customer service. Aurora also uses a "just culture" method toward patient safety. This approach focuses on investigation of the true cause of any error made by an individual, process, or system.

In the complex environment of healthcare, a solid base system that supports administrative, declarative, procedural, and analytical knowledge is necessary. Aurora Health Care satisfies these base requirements through an intense information system infrastructure, knowledge, vision, understanding, and commitment, with a firm development of knowledge roles and skills. Aurora relies on both internal and external knowledge based systems. The sharing of electronic information (data and meta-data) is a must in healthcare. Knowledge management is identified in Aurora Health Care's Vision Statement. This vision is centered on the single idea: there is a better way to provide healthcare. The organization has instilled a strong understanding of the need for data and information review. Aurora's senior leadership requires constant improvement ensuring that the organization maintains steady progress. This message is shared throughout every segment of the organization. Knowledge roles and skills development, and implementation of new knowledge occurs at the individual, team, organization, and inter-organizational levels.

Knowledge management culture is an important ingredient to the strength of Aurora Health Care. Knowledge management philosophy, reward system, and networking, support the knowledge management culture. Aurora seeks exceptional results for its patients. All employees receive training on how to standardize and share best practices throughout the organization. Employees are incentivized toward knowledge management as a part of their annual merit increase. Knowledge management key success indicators are incorporated into each employee's annual performance review. This formal tie places significant emphasis on achievement. Staff at all levels are encouraged to connect and interact with peers inside and outside of Aurora.

The healthcare industry is knowledge intense for many reasons. Primarily, the public values individual health and the expectation for those within the healthcare industry is to positively contribute to healthcare delivery. This expectation requires the effective implementation of knowledge. Aurora Health Care knowledge management implementation begins with its levers that support knowledge. Top management has expectations for all staff regarding teamwork, responsibility of actions, fulfilling promises, and helping one another to do their best work for the patient. Human resource policies and practices support implementation through formal employee feedback and recognition of exemplary service and work. Aurora Health Care is constantly challenged to maintain the highest level of clinical care knowledge and standards. To meet this challenge, they rely on supportive technologies. Employees within Aurora feel that information can come from many sources and levels, such as the patient, employee, organization, and outside the organization. It is imperative to have the knowledge management systems that leverage this information into actual implementation. They use many tools to process and implement knowledge. Examples include Six Sigma, flawless implementation, tools for innovation, statistical process control, Baldrige Criteria, LEAN principles, and Plan-Study-Do-Act.

ACKNOWLEDGEMENTS

The authors wish to thank Philip Mattek for his work on the Aurora Framework Connection for Business KM Source (Figure 1), displayed on page 12.

Thank you to Patrick Falvey, Ph.D., Senior Vice President & Chief Integration Officer for Aurora Health Care for his support of this project.

The authors also wish to thank Kim M. Stencil for her assistance in editing the aforementioned information.

The authors wish also to thank Kelly Anklam for her assistance in editing this chapter.

Finally, a special thank you goes to the editor of this book for his thorough feedback and insightful comments.

As always, the authors take the responsibility for any mistakes.

REFERENCES

Care, A. H. (2009). *2007 Strategic Plan.* Retrieved from https://iconnect.aurora.org/ DotNetNuke/Default.aspx?tabid=2324

Care, A. H. (2009). *2009-2011 Strategic Plan Chart.* Retrieved from http://heiwebaz031. aurora.org/DotNetNuke/portals/216/2009-2011_Strategic_Plan_Chart%20Final.pdf

Care, A. H. (2009). *Aurora and the quality of health care.* Retrieved from http://www.aurorahealthcare.org/aboutus/quality/details/default.aspx

Care, A. H. (2009). *Aurora at a Glance*. Retrieved from http://iconnect.aurora.org/ portal/default.do?appId=EB416

Care, A. H. (2009). *Aurora Health Care – 2008 Report to the Community.* Retrieved from http://www.aurorahealthcare.org/aboutus/annualreports/2008/financial_ stewardship.html

Care, A. H. (2009). *Aurora Health Care's Mission*. Retrieved from http://www.aurorahealthcare.org/aboutus/mission.asp

Care, A. H. (2009). *Aurora Pulse*. Retrieved from http://iconnect.aurora.org/ portal/default.do?appId=EB109

Care, A. H. (2009). *Aurora Service – Aurora Star.* Retrieved from http://ahcweb03. aurora.org/aurora_service/aurora_star.htm

Care, A. H. (2009). *Care Management/Quality.* Retrieved from http://iconnect. aurora.org/portal/default.do?appId=EB084

Care, A. H. (2009). *Content Search "Aurora's Promise to Caregivers."* Retrieved from https://iconnect.aurora.org/portal/default.do?appId=EBGOO&appParam=q%3Dpromise

Care, A. H. (2009). *Content Search "Aurora Quest."* Retrieved from http://iconnect. aurora.org/portal/default.do?appId=EBGOO&appParam=q%3Daurora%20quest

Care, A. H. (2009). *Content Search "Innovative use of IT in the healthcare market."* Retrieved from https://iconnect.aurora.org/portal/default.do?appId=EBGOO&appParam =q%3Dthe%20innovative%20use%20of%20IT%20in%20the%20health%20care%20market

Care, A. H. (2009). *Content Search, "Just Culture."* Retrieved from http://iconnect. aurora.org/portal/default.do?appId=EBGOO&appParam=q%3Djust%20culture

Care, A. H. (2009). *Content Search "Learning Plans."* Retrieved from https://iconnect. aurora.org/portal/default.do?appId=EBGOO&appParam=q%3Dlearning%20lesson%20plan

Care, A. H. (2009). *Content Search "loyalty index."* Retrieved from https://iconnect. aurora.org/portal/default.do?appId=EBGOO&appParam=q%3Dloyalty%20index

Care, A. H. (2009). *Content Search "on boarding resources."* Retrieved from https://iconnect. aurora.org/portal/default.do?appId=EBGOO&appParam=q%3Donboarding%20process

Care, A. H. (2009). *Content Search "Planetree Demystifying HealthCare."* Retrieved from http://iconnect.aurora.org/portal/default.do?appId=EBGOO&appParam=q%3D planetree%20 demystifying%20healthcare

Care, A. H. (2009). *Operating Principles.* Retrieved from http://iconnect.aurora.org/DotNetNuke/LinkClick.aspx?link=Operating+Principles+(formerly+Leadership)+FINAL.doc&tabid=1630

Care, A. H. (2009). *Patient Stories.* Retrieved from http://www.aurorahealthcare.org/ aboutus/stories/stories.asp

Care, A. H. (2009). *Responsible Freedom*. Retrieved from http://www.aurora healthcare.org/jobs/why-aurora/respfreedom.asp

Care, A. H. (2009a). *Number One Priority.* Retrieved from http://iconnect.aurora.org/portal/default.do?appId=EB416

Care, A. H. (2009b). *Aurora Health Care fact sheet*. Retrieved from http://www.aurorahealthcare.org/aboutus/media/factsheet.asp

Gottschalk, P. (2002). Toward a model of growth stages for knowledge management technology in law firms. *Information Science*, *5*(2), 79–123.

Hospital Consumer Assessment of Healthcare Providers and Systems. (2009). *HCAHPS – Facts Page*. Retrieved from http://www.hcahpsonline.org/facts.aspx

Press Ganey. (2009). *Home|Press Ganey.* Retrieved from http://www.pressganey.com

Russ, M., Fineman, R., & Jones, J. K. (2009). How do we get there: Strategy action framework–"Action Engine."

Russ, M., Jones, J. K., & Fineman, R. (2006). Toward a taxonomy of knowledge-based strategies: Early findings. *International Journal of Knowledge and Learning*, *2*(1&2), 1–40. doi:10.1504/IJKL.2006.009677

All web sites used in this case study were accessed between January 3, 2009 and June 30, 2009.

This work was previously published in Knowledge Management Strategies for Business Development, edited by M. Russ, pp. 216-239, copyright 2010 by Information Science Reference (an imprint of IGI Global).

Chapter 4.13

Organisational Factors and Technological Barriers as Determinants for the Intention to Use Wireless Handheld Technology in Healthcare Environment:

An Indian Case Study

Raj Gururajan
University of Southern Queensland, Australia

ABSTRACT

Traditional technology adoption models identified 'ease of use' and 'usefulness' as the dominating factors for technology adoption. However, recent studies in healthcare have established that these two factors are not always reliable on their own and other factors may influence technology adoption. To establish the identity of these factors, a mixed method approach was used and data were collected through interviews and a survey. The survey instrument was specifically developed for this study so that it is relevant to the Indian healthcare setting. Authors identified clinical management and technological barriers as the dominant factors influencing the wireless handheld technology adoption in the Indian healthcare environment. The results of this study showed that new technology models will benefit by considering the clinical influences of wireless handheld technology, in addition to known factors. The scope of this study is restricted to wireless handheld devices such as PDAs, smart telephones, and handheld PCs.

DOI: 10.4018/978-1-60566-030-1.ch007

INTRODUCTION

In the last few years, high expectations, technological developments, and effective and efficient services have been shown to be prerequisites for improvements in the healthcare domain (Rogoski, 2005). Latest trends in the healthcare sector include the design of more flexible and efficient service provider frameworks aimed at providing health services to all stakeholders. In order to implement such frameworks, wireless technology is increasingly being used in the healthcare sector (e.g. data management automation). A decrease in the cost of wireless devices and improved awareness of the benefits that ensue by using related wireless applications are two of the contributing factors towards the increased use of wireless technology in this sector (Gururajan, Quaddus, et al., 2005). Even though the future of this technology and its usability is promising, its adoption is still in its infancy, which is attributed to the complex and critical nature of the healthcare environment. In the current competitive and complex business environment, technology developments have played a critical role in delivering high quality of care (Reinecke, 2004). However, there is limited knowledge and empirical research on the effectiveness and adoption of wireless technology in general, and in the Indian healthcare system in particular.

Recent research has established that investment in emerging Information Technology (IT), including Information Systems (IS), can lead to productivity gains only if they are accepted and effectively used by respective stakeholders. Consequently, acceptance and utilization of IT/IS in the healthcare environment have been central themes in the information systems literature. Therefore, the fundamental focus of this research is to investigate and examine the influence of internal and external determinants on the usefulness of wireless technology. Further, this research also assesses how its acceptance contributes to the adoption of wireless technology. I believe that this research is the first of its kind attempted in the Indian healthcare domain and it employs empirical evidence to explore the impact of wireless technology and its usefulness in the Indian healthcare system. The Indian healthcare domain is at the forefront in adopting the latest medical technologies and applications, as evidenced by media reports and, as such, it constitutes an excellent context for validating existing adoption theories and extending them.

The main contribution of this research includes the identification of a set of drivers and barriers to using wireless technology in a given Indian healthcare setting. In addition to this, for the first time, a set of clinical factors influencing the adoption of wireless technology has been identified and validated using a second order regression model.

BACKGROUND

The concept of wireless technology in healthcare is discussed in many studies (Dyer, 2003; Hu et al., 2002; Sausser, 2003; Simpson, 2003; Wisnicki, 2002). For example, Wisnicki (2002) provides details of how broadband technology, an essential component of wireless technology, can be used in healthcare. While prior studies agree that wireless applications have the potential to address the endemic problems of healthcare, very limited information can be found about the determinants of such applications (Gururajan et al., 2005; Gururajan et al., 2004). In general, the majority of the works reviewed are descriptive about the benefits of wireless handheld devices in healthcare in general, and medicine in particular. There is only a small number of studies that provide evidence-based information concerning these devices in healthcare (Fischer et al. 2003; Sax et al. 2005). Furthermore, five major studies in the area of healthcare (evaluated by (Spil & Schuring, 2006) testing the Technology Acceptance Model (TAM) produced findings which were inconsistent with the body of knowledge in non-healthcare settings. With ‘Perceived Ease of Use’ and ‘Perceived Usefulness’ as the major TAM attributes, these studies found that in the health environment, ‘Perceived Usefulness’ is an important attribute in technology adoption, while ‘Perceived Ease of Use’ was found to have no effect (Spil & Schuring, 2006). This is different to findings reported in non-health IS studies, where both attributes were found to be reliable technology adoption predictors. Therefore, further empirical investigation is required to explain the reasons why this variation exists in healthcare.

TAM in Healthcare Context

In healthcare literature, the discussion on wireless technology falls into three periods. For example, studies prior to and including 2000 discussed the status of wireless technology and the possible role the technology can play in healthcare. Studies between 2000 and 2003 discussed how wireless technology can be deployed in healthcare and the potential benefits the technology can bring to healthcare. It should be noted that these studies were only 'discussion' type studies. The majority of these studies did not provide any empirical evidence as to the use or acceptance of wireless technology in healthcare domains. Studies from 2004 to the current date have collected data to establish the usefulness of wireless technology in healthcare. These studies, to some extent, have focussed on the PDAs as these devices have been found to be useful in the nursing domain for clinical data management.

The studies between 2000 and 2003 discussed various capabilities of wireless technology in clinical domains. For example, how broadband technology can be used in healthcare was discussed by (Wisnicki, 2002); the ability to address the prevailing healthcare staff crisis by adopting intelligent solutions using agent and wireless technology that can identify the need and match the need with available resources in a timely and efficient manner was outlined by Davis (2002); better compliance with the rigorous regulatory framework was highlighted by Wisnicki (2002); reduction in medication errors and hence the benefits that can be realised was discussed by Turisco (2000); provision for greater flexibility and mobility of healthcare workers in performing their work was portrayed by Athey & Stern (2002); and effective management of the increasingly complex information challenges and improved access to information from anywhere at anytime was discussed by Stuart & Bawany (2001). Our review clearly identified that all these studies were only implying the potential of wireless technology and did not provide any empirical evidence.

While prior studies agreed that wireless applications have the potential to address the endemic problems of healthcare, very limited information can be found about the determinants of such wireless applications in order to establish the adoption of technology in a given healthcare context (Gururajan et al., 2005; Gururajan et al., 2004). During the period of 2004–2006, studies emerged in the area of technology acceptance, specifically focussing on the acceptance of wireless technology in healthcare domains. These studies were empirical in nature and were testing the available models of technology acceptance or a variation in order to ascertain whether previous models hold good for a new technology in a specific domain. These studies were reported in a book titled *E-Health Systems Diffusion and Use,* published by Idea Group Publishing in 2006 (Spil & Schuring, 2006). In addition, there is a need to explore whether further attributes exist which may influence the adoption of wireless applications in the healthcare environment.

In essence, the recent studies appear to suggest that the current models of technology acceptance or its derivatives are not suitable to predict the adoption factors of wireless technology in a healthcare environment. Strong support can also be derived from three specific studies that have tested TAM models in healthcare. The first study, conducted by Jayasuriya (1998), established that ease of use was not significant in a clinical domain. The second study by Chau & Hin (2002) echoed similar sentiments. The third study by Hu et al. (1999) also found similar findings. Further, recent studies conducted by Howard et a. (2006) also established that ease of use was not significant in determining factors of adoption in a clinical domain in regard to wireless technology. Further, Ivers & Gururajan (2006) also found that there are other factors beyond the TAM models influencing the acceptance of technology.

Interviews conducted by Gururajan and Moloney et al. (2005) with 30 Queensland nursing staff members revealed that clinical usefulness of wireless technology is far more significant than ease of use factor as established in TAM. Another focus group discussions between Gururajan and Quaddus et al. (2005) and Western Australian senior health managers by also indicated that aspects of clinical usefulness such as integration of clinical data may be a more significant factor than the ease of use factor. Howard et al. (2006) also identified clinical usefulness is far more influencing than the ease of use factor while determining factors of adoption of wireless technology in the Indian healthcare domain.

However, the recent findings that the ease of use factor is not strongly significant in the healthcare domain when determining wireless technology adoption warrants explanation—as this is different to many other reported studies in the generic IS domain where both attributes (ease of use and perceived usefulness) were reported to be reliable predictors.

This variation requires further empirical investigation in order to explain the reason behind this variation specific to healthcare. Therefore, there is a need to identify attributes that assist in the adoption of wireless applications in the healthcare environment. We argue that the initial validity of TAM was predominantly established by testing the model with students as surrogates in a generic software application domain. This environment is very different to the healthcare environment, where skills are at different levels. Further, the healthcare environment is complex, sensitive and time critical. These could be some of the reasons why TAM did not perform as expected in healthcare settings.

Therefore, there appears to be a basis to identify factors that contribute to the adoption of technologies in healthcare settings. Given that wireless technologies have started making inroads in healthcare, the overarching purpose of the research is to identify the factors that influence the adoption of wireless technology in the Indian healthcare system. The rationale of the purpose is justified by the fact that India is a leader in software technologies, especially medical applications. Further, India is emerging as a 'health tourism' nation, due to the advancement in medical technology and reduction in cost in offering high quality health services—as highlighted by various print media. However, our initial review of available literature indicated that this area is under-researched. Collectively, these aspects led to the following research question:

- What are the determinants for the adoption of wireless technology by physicians in the Indian healthcare system?

The first stage of this study is focused on answering the research question qualitatively and the second stage on answering the research question quantitatively. Details as to how the research question was answered are provided in the research methodology section below.

METHODOLOGY

The research question dictates the need for quantitative research methods, while the behavioural component of the same investigation dictates qualitative research methods. The rationale for this approach is based on the notion that behavioural components require a thorough understanding of how users apply wireless technology in a given setting in order to understand behavioural issues. To extract 'tacit' aspects, this is best accomplished by applying a qualitative approach. A quantitative instrument can then be developed to extract the quantitative aspects, such as the opinion scores.

Health professionals view the term 'wireless technology' in different ways, either as a product or a process. The combined domain of wireless technology and healthcare is relatively new in the Indian IS domain. While IS studies have discussed the impact of Information & Communication Technology (ICT) tools and associated behavioural intentions on healthcare users, limited information can be found as to how the combination of wireless technology and healthcare settings would influence users who are already conversant with novel and advanced medical technologies (Spil & Schuring, 2006). The workplace or organizational factors that influence such combinations are yet to be explored in detail. Such an exploration has close association with the choice of research method, as these methods pave the way for proper inquiry into the factors that determine technology acceptance in a given setting. On this basis, the suitability of one research method over another has to be carefully weighed. Consequently, this study identified an exploratory approach to be suitable for the initial investigation. This approach is particularly favourable in confirming the direction of the study, variables chosen for the study, and in helping refine the literature. The exploratory study can also possibly eliminate some variables, while providing opportunities for including emerging variables.

Qualitative Data Collection

As argued, for the first stage of this research the investigators used a qualitative approach to collect initial sets of themes for the adoption of wireless technology in the Indian healthcare system. For this purpose, 30 physicians operating in Indian healthcare were identified randomly. These physicians were aware of wireless technology, or were using some form of wireless technology in their workplace. They were derived from both public and private hospitals. I included certain administrative type physicians in order to identify aspects pertaining to the use of wireless technology in administration. Demographic details were not recorded to guarantee anonymity. These physicians were interviewed over a period of six months by an independent member (external to the team) who identified the attributes for the adoption of wireless technology by physicians in the Indian healthcare system. This approach was deliberate to address criticisms of 'bias' in the interview process. Further, due to linguistic issues, I required a person with proficiency in both the Indian language and English. The interview questions were derived from existing literature and our experience of conducting similar studies in Australia. The interviews were conducted over a 45-60 minute period and recorded using a digital recorder. Once they were recorded, the interviews were transcribed.

Quantitative Data Collection

This study developed a survey instrument from the interview data. The main reason for this digressed attitude was that previously tested instruments in the technology domain were not relevant to a healthcare setting and were found to be inadequate in answering the research question. The data from the interviews were used to develop specific ranges of questions to gather a more detailed view from the wider population. This survey instrument was pilot tested to capture the information reflecting the perceptions and practice of those adopting wireless technology in the Indian healthcare system. Particularly, it focussed on what internal and external environmental factors affect the adoption of wireless technology and the extent of this influence. The survey was then distributed to over 300 physicians randomly chosen from the telephone book, and a total of 200 responses were received. The survey responses were then entered into a spreadsheet file. A Visual Basic interface was written to generate numerical codes for various elements of the survey for data analysis using SPSS. The coded spreadsheet file was then copied onto a SPSS file format.

Table 1. The factors driving and inhibiting wireless technology adoption in healthcare

Drivers	**Barriers**
• Save-time • Improve-clinical-workflow • Efficiency-in-communication • Delivery-of-high-qual-info • Better-quality-of-service • Save-effort • Improve-clinical-performance • More-contact-time-with-patients • Improved-delivery-of-information • Reduce-overall-cost • Positive-impact-on-patient-safety • Reduce-inaccuracies • Improve-public-image • Reduce-medical-errors • Easy-access-to-data • Attract-more-practitioners • Reduce-workload	• Legal barriers • Administrative purpose • Communication with physicians • Patient education • Communication with colleagues • Obtain lab results • Note taking • Electronic medical records • Device usage barrier • Benefit evaluation barrier • Resource barrier • Electronic prescribing

DATA ANALYSIS

Qualitative data was analysed using the NVivo (version 7) application, which helped identify the initial themes from the interviews. Quantitative data were analysed using SPSS, which helped identify the factors and their correlation for the adoption of wireless technology in the Indian healthcare setting.

Qualitative Data Analysis

Prior to coding schemes on the qualitative data, reliability was assured through saturation of themes during interviews. Qualitative data was manually coded to extract themes that had an impact on wireless technology acceptance as stated by the physicians. In total, 63 themes were extracted from the interviews. The initial themes include awareness, cost factors, advantages and disadvantages, medical errors, information sharing, current state of technology, usefulness and role of wireless technology, and technology awareness. On the basis of the interviews and the literature review, the themes were classified into drivers and barriers as shown in the following table. Drivers were themes that exhibited positive tone, and barriers were themes with negative tone. The classification of drivers and barriers was subjective. I did not conduct in-depth discourse analysis on the data as this stage was expected to provide only the scope for the quantitative study. This purpose of developing the list of drivers and inhibitors was to provide a direction for the development of the survey instrument for the collection of quantitative data in order to capture the wider community views and to generalize the outcome of the research. This grouping is presented in Table 1.

It is to be noted that the content of the Table 1 is consistent with findings of previous studies conducted by Gururajan et al. (2004; 2005). This prompted conducting a quantitative study in order to establish causality among dependent and independent variables, as well as external validity and generalisability.

Quantitative Data Analyses

In order to ensure statistical reliability, suitable tests were run on the entire instrument, as well as selected group of variables. For example, the reliability test returned a Cronbach alpha value of 0.965 for the instrument, indicating high reliability (Zikmund, 1994). I ran this test because the instrument was generated from the interview data and, hence, it was necessary to establish statistical

Table 2. The factors driving and inhibiting wireless technology adoption in healthcare from data analysis of survey result

Drivers	Loading values	Barriers	Loading values
improve-clinical-workflow	.798	poor technology barrier	.605
tech-support	.764	time for training barrier	.572
delivery-of-high-qual-info	.760	tech expertise barrier	.554
save-time	.757	benefit evaluation barrier	.503
better-quality-of-service	.749	legal barriers	.465
save-effort	.743	solutions barrier	.444
improved-delivery-of-information	.732	system migration barrier	.442
efficiency-in-communication	.730	technical support barrier	.436
more-contact-time-with-patients	.725	lack of support barrier	.352
improve-clinical-performance	.702	device access barrier	.316
more-training	.699	device comfort barrier	.248
improve-public-image	.695	funding barrier	-.225
easy-access-to-data	.692	security as barrier	.224
positive-impact-on-patient-safety	.679	device usage barrier	.208
reduce-inaccuracies	.659		
reduce-workload	.657		
reduce-medical-errors	.650		
reduce-overall-cost	.634		
attract-more-practitioners	.600		
Org-culture	.464		

reliability. In addition, reliability tests were also run for three factor groupings, namely, drivers, inhibitors of adoption, and other technology factors. The reliability tests returned values of 0.941, 0.447 and 0.536, respectively, indicating that the data were suitable for factor analysis testing.

I did not run any demographic analysis as the main aim of the research was to identify the determinants for the adoption of wireless technology. Therefore, it was decided that a correlation matrix would be suitable followed by a factor analysis. The correlation matrix was conducted on the questionnaire items and found to be acceptable. The matrix is not reported in this study because factor analysis provides the correlation implicitly.

As a second step, survey data were analysed for factor analysis using SPSS. I used the exploratory factor analysis techniques for this purpose. For the purpose of the study, a principal component analysis (PCA) was conducted using a Varimax rotation with a factor loading of 0.5. I ran the factor analysis with 2 factor components in order to verify the driver and barrier themes extracted from the interview qualitative data. It is evident from Table 2 that the two factor component matrix identified drivers and the barriers for the adoption of wireless technology in the Indian healthcare setting. This finding is consistent and aligned with the findings of the qualitative data collection stage (i.e. first stage) of this research.

Subsequent to the two component factor analysis, I ran another analysis on the driver factors

Table 3. The factors driving wireless technology adoption in healthcare from data analysis of survey result

	Organizational	Management	Clinical
save-effort	.716		
reduce-overall-cost	.708		
reduce-inaccuracies	.703		
save-time	.667		
easy-access-to-data	.659		
attract-more-practitioners		.769	
improve-public-image		.680	
tech-support		.680	
reduce-workload			.817
improve-clinical-performance			.797

alone to identify factor groups emerging from the data. This resulted in three major groups emerging within the drivers as indicated in Table 3.

I titled these three groups of factors as 'organisational', 'management' and 'clinical'. It should be noted that these titles are subjective and based on the questionnaire items. For example, saving effort, reducing cost, etc. are organisations issues and, hence, the title 'organisational'. Thus, the organisational components include wireless technology drivers that can generate specific benefits for organisations. The management components represent the benefits that healthcare managers can realise using wireless technology. The clinical components encompass clinical drivers of using wireless technology.

A similar factor model was generated for the inhibitors. The model resulted in Table 4:

Similar to the drivers, the inhibitors also resulted in three specific categories. The 'technology' category includes technology factors that inhibit wireless adoption in Indian healthcare. The 'resource' category encompasses resource barriers that are currently being encountered in

Table 4. The factors inhibiting wireless technology adoption in healthcare from data analysis of survey result

	Technology	Resource	Usage
poor technology barrier	.625		
time for training barrier	.582		
solutions barrier	.575		
benefit evaluation barrier	.528		
tech expertise barrier	.527		
system migration barrier	.511		
funding barrier		-.749	
resource barrier		-.690	
technical support barrier			.542
device usage barrier			.519

Table 5. The factors 'clinical usefulness' of wireless technology adoption in healthcare from data analysis of survey result

	General Communication	Clinical Communication	Records Management
Obtain lab results	.837		
Administrative purpose	.770		
Electronic prescribing	.670		
Medical database referral	.632		
Patient education		.727	
Communication with colleagues		.707	
Communication with patients		.676	
Drug administration		.596	
Communication with physicians		.548	
Electronic Medical Records			.764
Generating exception list			.738
Note taking			.617
Disease state management			.563

the healthcare setting. Finally the 'usage' category is comprised of inhibiting factors, which are associated with usage issues.

In addition to the two factor groups, namely drivers and inhibitors, I also identified a third, and named this 'clinical usefulness'; its components are shown in Table 5.

This factor group yielded three components. The first component deals with the general communication aspects facilitated by wireless technology in healthcare settings. The second component refers to clinical communication using wireless technology. The third component is specific to records management. In summary, the data analyses yielded three specific categories of factors which can affect the adoption of wireless technologies in the healthcare setting. These comprise adoption drivers, inhibitors, and clinical usefulness.

The factor analysis provided me with initial answers to the research questions: the factors that determine the adoption of wireless technology.

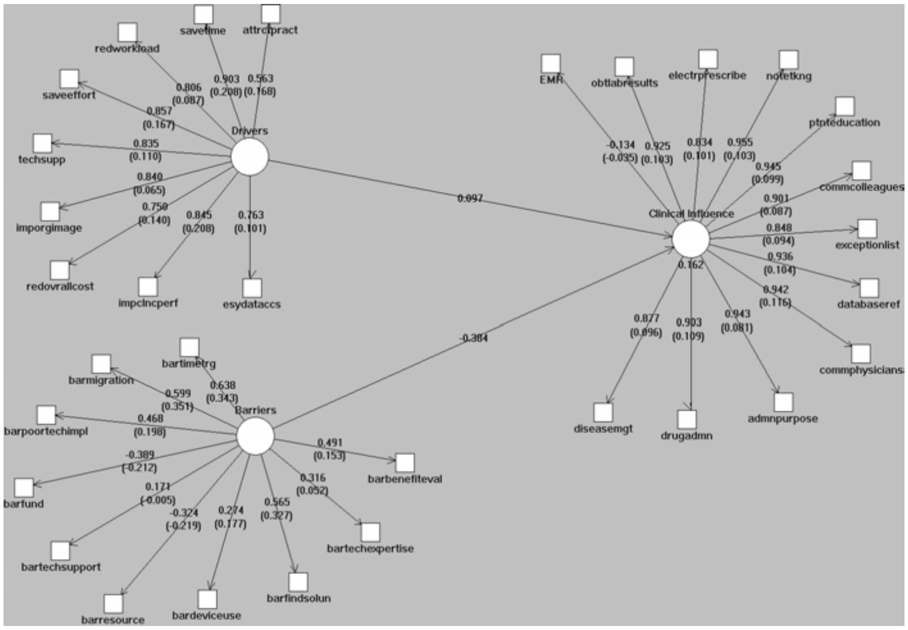
Hypotheses Formulation and Testing

Based on the evidence collected, the three sets of factors, namely, drivers, barriers and clinical usefulness, contribute to the adoption of wireless technology in healthcare. I hypothesise that the drivers positively impact clinical usefulness, whereas the barriers have a negative impact on it. While the drivers and barriers include factors beyond the technology aspects, their respective influences are restricted to the clinical domain as this is where the usefulness of wireless technology can be experienced. Therefore, the following two hypotheses were generated for testing:

H1: Drivers of wireless technology positively impact clinical usefulness.
H2. Barriers to wireless technology negatively impact clinical usefulness.

I digressed away from the traditional regression modeling because I felt that the data may be insufficient to run a traditional regression model. Further, the intention of the study is NOT to develop a cause and effect model, but to determine

Figure 1. PLS model of adoption of wireless technologies in Indian healthcare



the factors identified. Therefore, a Partial Least Square (PLS) model was developed in order to test the hypotheses. The rationale for using PLS includes: PLS is used for confirmatory factor analysis (CFA); the pattern of loadings of items on the latent constructs is explicit; PLS provides strong convergent and discriminant validity; p-value of t-value is significant (over 0.50 level) for constructs; and measurement items load highly on theoretically assigned factors and not highly on other factors.

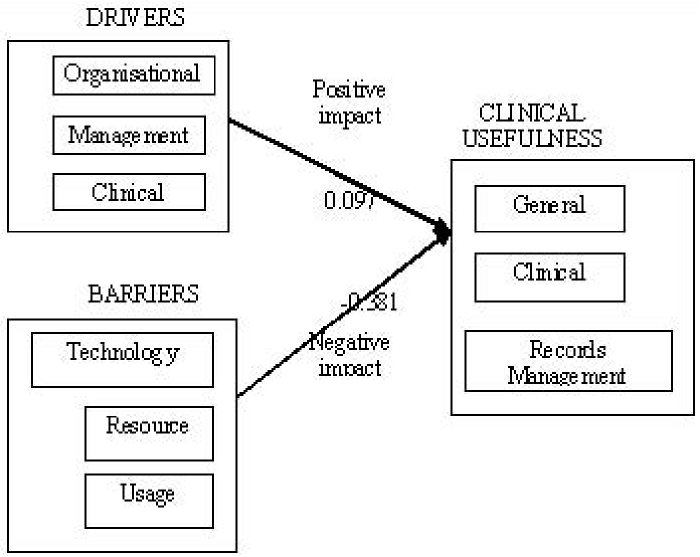
PLS MODEL DEVELOPMENT

In order to develop the PLS model, a PLS Graph prototype was used. Initially, the individual drivers, barriers and clinical usefulness were tested for CFA scores and these were found to be reliable. When the CFA was found to be satisfactory, a model was built with clinical infuences as dependent variable on drivers and barriers. The factors of these three constructs were linked using PLS Graph software and the model was run. The final outcome is shown in Figure 1 below.

Figure 1 shows that the factor loading (the number on the path: for example, for the construct Drivers, the 'esydataccs' has 0.763) and the factor weight (the number in the parantheses: for example, 0.101) for almost all factors are reliable. The drivers and clinical usefulness load very highly (over 0.8 for most of the items), indicating a high reliability. Further, all variables have a t-value of over 1.96 to indicate high convergent validity.

Upon construct validation, a simple PLS (consolidated) model was developed to test the hypotheses. The model consists of clinical usefulness as the dependent variable, and drivers and barriers as independent variables. The model was run with PLS Graph program and the screenshot shown in Figure 2 displays the values along the link from Drivers to Clinical Usefulness, and Bariers to Clinical Usefulness. As hypothesised, drivers exhibited a positive loading (0.097) and the barriers exhibited a negative loading (-0.384). The number below the circle Clinical Usefulness is the construct R^2, which is calculated and dis-

Figure 2. Result of model testing



played for each dependent variable. The lower the R^2, the minimum the error in the model. In the model the R2 values for the dependent variable 'Clinical Usefulness' is 0.167. This is not high and, hence, the error is minimal. This is shown in Figure 2.

IMPLICATIONS

Clearly, wireless technology can be used to facilitate access to clinical information and communications between clinicians, maximise clinician time, increase patient safety, and accomplish the strategic and business goals of health organisations. Taken together, these factors have a direct impact on clinical usefulness and its effectiveness. However, achieving clinical usefulness with wireless handheld devices can be a challenge and has several implications.

Firstly, the highest security standards must be achieved. This includes direct end-to-end data encryption, authentication, authorisation, maintenance of audit logs and session management (Chen et al. 2004). While high security standards are essential, their implementation is likely to affect usability. For example, the download and encryption of patient information from the server where it is stored into a wireless handheld device may not be prompt. Sax et al. (2005) argue that clinicians may experience increasingly longer time lags when they carry out increasingly more complex procedures. This is likely to adversely affect clinical usefulness and, hence, decrease user acceptance.

Closely associated with security is also the issue of patient confidentiality, which is of significant importance and concern. Although wireless handheld devices have locking security features and password protection functions which activate during periods of inactivity, the frequent use of these functions during the clinicians' busy daily schedules may have an impact on clinical usefulness. (see Figure 1 and Figure 2)

Secondly, the design of an effective human-computer interface, while challenging, constitutes a key factor for the acceptance of the technology and its routine use by healthcare workers (Chen et al. 2004). This is an important development consideration as the relevant information should be easy to navigate and read, and has to be presented in an organised fashion when required within the resource limitations (e.g. screen size and bandwidth) of a wireless handheld environment. Usability factors are not only likely to constitute an acceptance barrier, but can also be the cause of medical errors. Bates et al. (2001) argue, 'While it may be easy and common to blame operators for accidents [or errors], investigation often indicates that an operator "erred" because the system was poorly designed' (p. 301). Therefore, medical errors can also occur due to poor usability. Taken together, these factors would contribute to reduce medical errors. By implication, it is important to involve users in the design of the wireless applications, thereby maximising their clinical usefulness.

Thirdly, simply acquiring and implementing wireless technology alone would be insufficient to accomplish clinical usefulness and, subsequently, drive adoption and diffusion. Wireless technology should be integrated with process improvement and organisational change. Process improvement requires the optimisation of clinical processes and should be supported by technology, rather than driven by it (Smith 2004). Ultimately, this is likely to generate significant patient outcomes and financial improvements with health organisations.

Fourthly, as suggested by the empirical evidence collected in this study, cost constitutes an important factor which will affect the integration and, subsequently, the success of wireless handheld devices in the healthcare setting (Sax et al. 2003). Typically costs include the software, the server, upgrades of healthcare organisations' existing networks and legacy systems, the costs of the handheld units themselves, as well as maintenance and support. While existing research in this area argues that such technology has the potential to decrease charting time and medical errors and enhance patient care quality, there is no evidence that comparisons of costs before and after the implementation of wireless technology have been made. This suggests that further research is required, but also, most importantly, it shows that, indirectly, costs have the potential to affect clinical usefulness and threaten widespread adoption.

FUTURE RESEARCH

This research is an exploratory study to identify clinical influences of wireless technology applicable to the Indian healthcare system. While data were obtained on perceived opinions, actual measurement of usefulness of wireless technology in a clinical setting was not conducted. Currently, another project is being conducted that would enable measurement of clinical influences of using wireless technology in an objective manner. This new project will provide some insights into the efficiency gains of using wireless technology and the challenges people encounter in using this technology.

This study is confined to the Indian healthcare setting, which limits the generalisability of its findings. However, this study is also the first of its nature and, as a result, it has prepared the groundwork for further research which can confirm (or refute) whether the findings reported in this study are applicable to other settings. Data are collected using the same instruments in Australia, Taiwan and India. It is anticipated the data collection to be completed by in 2009.. This exercise, it is hoped, will enable to extend the notion to broader populations.

REFERENCES

Athey, S., & Stern, S. (2002). The impact of information technology on emergency health care outcomes. *The Rand Journal of Economics*, *33*(3), 399–388. doi:10.2307/3087465

Bates, D. W., Cohen, M., Leape, L. L., Overhage, M., Shabot, M. M., & Sheridan, T. (2001). Reducing the frequency of errors in medicine using information technology. *Journal of the American Medical Informatics Association*, *8*(4), 299–308.

Chau, P. Y. K., & Hu, P. J.-H. (2002). Investigating healthcare professionals' decision to accept telemedicine technology: An empirical test of competing theories. *Information & Management*, *39*, 297–311. doi:10.1016/S0378-7206(01)00098-2

Chen, E., Mendoca, E. A., McKnight, L. K., Stetson, P. D., Lei, J., & Cimino, J. J. (2003). PalmCIS: A Wireless Handheld Application for Satisfying Clinician Information Needs. *Journal of the American Medical Informatics Association*, *11*(1), 19–28. doi:10.1197/jamia.M1387

Chismar, W. R., & Wiley-Patton, S. (2006). Predicting Internet Use: Applying the Extended Technology Acceptance Model to the Healthcare Environment. In T.A.M. Spil & R.W. Schuring (Eds.), *E-Health Systems Diffusion and Use: The Innovation, the User and the USE IT Model*. Hershey, PA: Idea Group Publishing.

Davies, F. D., Bagozzi, R. P., & Warshaw, P. R. (1989). User acceptance of computer technology: A comparison of two theoretical models. *Communications of the ACM*, *35*(8), 982–1003.

Davis, R. (2002). Pursue front end solutions to revenue problems. *Healthcare Financial Management*, *56*(8), 30–36.

Davis, S., & Bostrom, R. (1993). Training end users: An experimental investigation of the roles of the computer interface and training methods. *MIS Quarterly*, (1): 61–85. doi:10.2307/249510

Dyer, O. (2003). Patients will be reminded of appointments by text messages. *British Medical Journal*, *326*(402), 281.

Fischer, S., Stewart, T. E., Mehta, S., Wax, R., & Lapinsky, R. (2003). Handheld Computing in Medicine. *Journal of the American Medical Informatics Association*, *10*(2), 139–149. doi:10.1197/jamia.M1180

Gururajan, R., et al. (2005). *Drivers and Barriers to adoption of wireless handheld system in WA healthcare: Selected views*. Paper presented at the HIC 2005, Melbourne, Australia.

Gururajan, R., Moloney, C., & Kerr, D. (2005). *Drivers for wireless handheld technology: views from Queensland nurses*. Paper presented at the Australian Business & Behavioural Sciences Association (ABBSA) Conference, Cairns, Australia.

Gururajan, R., Quaddus, M., Fink, D., Vuori, T., & Soar, J. (2005). *Drivers and Barriers to adoption of wireless handheld system in WA healthcare: Selected views*. Paper presented at the HIC 2005, Melbourne, Australia.

Gururajan, R., Toleman, M., & Soar, J. (2004). *Necessity for a new technology acceptance model to predict adoption of wireless technology in healthcare*. Paper presented at the Let's Make a Difference with Health ICT, HIC Conference, July 25-27.

Horan, T. A., Tule, B., & Hilton, B. N. (2006). Understanding physician use of online systems: An empirical assessment of an electronic disability evaluation system. In T.A.M. Spil & R.W.Schuring (Eds.), *E-Health Systems Diffusion and Use: The Innovation, the User and the USE IT Model.* London: Idea Group Publishing.

Howard, A., Gururajan, R., Hafeez-Baig, A., & Howard, S. (2006). *Clinical Usefulness of Wireless Technology in Healthcare: An Indian Study.* Paper presented at the Australasian Conference on Information Systems, University of South Australia, Australia.

Hu, P. J., Chau, P. Y. K., & Liu Sheng, O. R. (2002). Adoption of telemedicine technology by health care organisations: An exploratory study. *Journal of Organizational Computing and Electronic Commerce*, *12*(3), 197–222. doi:10.1207/S15327744JOCE1203_01

Hu, P. J., Chau, P. Y. K., & Tam, K. Y. (1999). Examining the technology acceptance model using physician acceptance of telemedicine technology. *Journal of Management Information Systems*, *16*(2), 91–112.

Ivers, B., & Gururajan, R. (2006). *Management issues in telecommunications: videoconferencing & telehealth.* Paper presented at the International Conference on Recent Trends in Information Systems Proceedings, India.

Jayasuriya, R. (1998). Determinants of microcomputer technology use: Implications for education and training of health staff. *International Journal of Medical Informatics*, *50*, 187–194. doi:10.1016/S1386-5056(98)00067-7

Lapointe, L., Lamothe, L., & Fortin, J. (2006). The dynamics of IT adoption in a major change process in healthcare delivery. In T.A.M. Spil & R.W. Schuring (Eds.), *E-Health Systems Diffusion and Use: The Innovation, the User and the USE IT Model*. London: The Idea Group Publishing.

Mingers, J. (2001). Combining IS research methods: Towards a pluralist methodology. Information Systems Research, 12(3), 240-259.

Myers, M. D. (1997). Qualitative research in Information Systems. *MIS Quarterly*, *21*(2), 241–242. doi:10.2307/249422

Reinecke, I. (2004) *Managing Information in Health*. Melbourne National Health Information Summit.

Rogoski, R. (2005). Wireless by Design. *Health Management Technology*, (January): 1–7.

Sausser, G. D. (2003). Thin is in: web-based systems enhance security, clinical quality. *Healthcare Financial Management*, *57*(7), 86–88.

Sax, U., Kohane, I., & Mandl, K. D. (2005). Wireless Technology Infrastructures for Authentication of Patients: PKI that Rings. *Journal of the American Medical Informatics Association*, *12*(3), 263–268. doi:10.1197/jamia.M1681

Simpson, R. L. (2003). The patient's point of view—IT matters. *Nursing Administration Quarterly*, *27*(3), 254–256.

Smith, C. (2004). New Technology Continues to Invade Healthcare: What are the Strategic Implications/Outcomes? *Nursing Administration Quarterly*, *28*(2), 92–98.

Spil, T. A. M., & Schuring, R. W. (2006). E-Health system Diffusion and Use. Hershey, PA: Idea Group Publishing.

Stuart, D., & Bawany, K. (2001). *Wireless Services: United Kingdom* (Operational Management Report No. DPRO-90741). Gartner.

Suomi, R. (2006). Introducing electronic patient records to hospitals: Innovation adoption paths. In T.A.M. Spil & R.W.Schuring (Eds.), *E-Health Systems Diffusion and Use: The Innovation, the User and the USE IT Model*. Hershey, PA: IGI Global.

Turisco, F. (2000). Mobile computing is next technology frontier for health providers. *Healthcare Financial Management*, *54*(11), 78–82.

Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. (2003). User Acceptance of Information Technology: Toward A Unified View. *MIS Quarterly*, *27*(3), 425–478.

Wisnicki, H. J. (2002). Wireless networking transforms healthcare: physician's practices better able to handle workflow, increase productivity (The human connection). *Ophthalmology Times*, *27*(21), 38–41.

Zikmund, W. (1994). *Business research methods* (International Ed.), Orlando, FL: The Dryden Press.

KEY TERMS AND DEFINITIONS

Health Informatics: In healthcare, information flow is critical. Thus, various aspects of information systems, such as the storage aspects in databases, quality of information captured and transmitted, usage of information sources also become critical. Thus, the management of information within health is considered as Health Informatics within the context of this article.

Technology Adoption: In order for a technology to be used, it should be adopted first. There are a number of adoption models available in the field of Information Systems. These models predominantly look at the behavior aspects leading to adoption. In this paper, technology adoption is discussed with healthcare professionals using a technology in clinical settings.

Wireless technology: Wireless technology is a technology that uses Infrared, Bluetooth and other radio frequency techniques to transmit data emerging from computers and other devices. In the scope of this chapter, the wireless technology is discussed as a system that consists of connectivity without wires for data transmission.

This work was previously published in Handbook of Research on Advances in Health Informatics and Electronic Healthcare Applications: Global Adoption and Impact of Information Communication Technologies, edited by K. Khoumbati; Y.K. Dwivedi; A. Srivastava; B. Lal, pp. 109-123, copyright 2010 by Medical Information Science Reference (an imprint of IGI Global).

Chapter 4.14

Drivers for Wireless Technology Acceptance in Indian Healthcare

Raj Gururajan
University of Southern Queensland, Australia

ABSTRACT

The outcomes of clinical usefulness as a driver of wireless technology for Indian healthcare are reported here. Using both qualitative and quantitative techniques, 30 physicians were interviewed and 200 health professionals were surveyed. The outcomes established that in addition to technology factors, other factors such as clinical factors, administration factors and communication factors play a crucial role in determining the uptake of wireless technology for healthcare. These factors were further validated using a PLS model.

INTRODUCTION

In the last few years, high expectations, technological developments, and effective and efficient services have been shown to be prerequisites for improvements in the healthcare domain (Rogoski, 2005). Latest trends in the healthcare sector include the design of more flexible and efficient service provider frameworks aimed at providing health services to all stakeholders. In order to implement such frameworks, wireless technology is increasingly being used in the healthcare sector (e.g. data management automation). A decrease in the cost of wireless devices and improved awareness of the benefits that ensue by using related wireless applications are two of the contributing factors towards the increased use of wireless technology in this sector (Gururajan, R., Quaddus, M. et al., 2005). Even though the future of this technology and its usability is promising, its adoption is still in its infancy, which is attributed to the complex and critical nature of the healthcare environment. In the current competitive and complex business environment, technology developments have played a critical role in delivering high quality of care (Reinecke, 2004). However, there is limited knowledge and empirical research on the effectiveness and adoption of wireless technology in general, and in the Indian healthcare system in particular.

Recent research has established that investment in emerging Information Technology (IT), including Information Systems (IS), can lead to productivity gains only if they are accepted and effectively used by respective stakeholders. Consequently, acceptance and utilization of IT/IS in the healthcare environment have been central themes in the information systems literature. Therefore, the fundamental focus of this research is to investigate and examine the influence of internal and external determinants on the usefulness of wireless technology. Further, this research also assesses how its acceptance contributes to the adoption of wireless technology. It is believed that this research is the first of its kind attempted in the Indian healthcare domain and it employs empirical evidence to explore the impact of wireless technology and its usefulness in the Indian healthcare system. The Indian healthcare domain is at the forefront in adopting the latest medical technologies and applications, as evidenced by media reports and, as such, it constitutes an excellent context for validating existing adoption theories and extending them.

The main contribution of this research includes the identification of a set of drivers and barriers to using wireless technology in a given Indian healthcare setting. In addition to this, for the first time, a set of clinical factors influencing the adoption of wireless technology has been identified and validated using a second order regression model.

LITERATURE REVIEW

The concept of wireless technology in healthcare is discussed in many studies (Dyer, 2003; Hu et al., 2002; Sausser, 2003; Simpson, 2003; Wisnicki, 2002). For example, Wisnicki (2002) provides details of how broadband technology, an essential component of wireless technology, can be used in healthcare. While prior studies agree that wireless applications have the potential to address the endemic problems of healthcare, very limited information can be found about the determinants of such applications (Gururajan, Raj et al., 2005; Gururajan et al., 2004). In general, the majority of the works reviewed are descriptive about the benefits of wireless handheld devices in healthcare in general, and medicine in particular. There is only a small number of studies that provide evidence-based information concerning these devices in healthcare (Fischer et al. 2003; Sax et al. 2005). Furthermore, five major studies in the area of healthcare (evaluated by (Spil & Schuring, 2006) testing the Technology Acceptance Model (TAM) produced findings which were inconsistent with the body of knowledge in non-healthcare settings. With ‘Perceived Ease of Use’ and ‘Perceived Usefulness’ as the major TAM attributes, these studies found that in the health environment, ‘Perceived Usefulness’ is an important attribute in technology adoption, while ‘Perceived Ease of Use’ was found to have no effect (Spil & Schuring, 2006). This is different to findings reported in non-health IS studies, where both attributes were found to be reliable technology adoption predictors. Therefore, further empirical investigation is required to explain the reasons why this variation exists in healthcare. In addition, there is a need to explore if further attributes exist which may influence the adoption of wireless applications in the healthcare environment.

TAM in Healthcare Context

In healthcare literature, the discussion on wireless technology falls into three periods. For example, studies prior to and including 2000 discussed the status of wireless technology and the possible role the technology can play in healthcare. Studies between 2000 and 2003 discussed how wireless technology can be deployed in healthcare and the potential benefits the technology can bring to healthcare. It should be noted that these studies were only 'discussion' type studies. Majority of these studies did not provide any empirical evidence as to the use or acceptance of wireless technology in healthcare domains. Studies from 2004 till current date have collected data to establish the usefulness of wireless technology in healthcare. These studies, to some extent have focussed on the PDAs as these devices have been found to be useful in nursing domain for clinical data management.

The studies between 2000 and 2003 discussed a number of potentials of wireless technology in clinical domains. For example, how broadband technology can be used in healthcare was discussed by Wisnicki (2002), ability to address prevailing healthcare staff crisis by adopting intelligent solutions using agent and wireless technology that can identify the need and match the need with available resources in a timely and efficient manner was outlined by Davis, R. (2002), better compliance with the rigorous regulatory framework was highlighted by Wisnicki (2002), reduction in medication errors and hence the benefits that can be realised was discussed by Turisco (2000), provision for greater flexibility and mobility of healthcare workers in performing their work was portrayed by Athey & Stern (2002), effective management of the increasingly complex information challenges and improved access to those information from anywhere at anytime was discussed by Stuart & Bawany (2001). Our review clearly identified that all these studies were only implying the potential of wireless technology and did not provide any empirical evidence.

While prior studies agreed that wireless applications have the potential to address the endemic problems of healthcare, very limited information can be found about the determinants of such wireless applications in order to establish the adoption of technology in a given healthcare context (Gururajan et al., 2005; Gururajan et al., 2004). During the period of 2004—2006, studies emerged in the area of technology acceptance, specifically focussing on the acceptance of wireless technology in healthcare domains. These studies were empirical in nature and were testing the available models of technology acceptance or a variation in order to ascertain whether previous models hold good for a new technology in a specific domain. These studies were reported in a book titled 'E-Helth Systems Diffusion and Use', published by Idea Group Publishing in 2006 (Spil & Schuring, 2006). These studies are summarised below:

Predicting Internet Use: Applying the Extended Technology Acceptance Model to the Healthcare Environment (Chismar & Wiley-Patton, 2006)—This study empirically established that only perceived usefulness is significant and ease of use was not significant.

The dynamics of IT adoption in a major change process in health delivery (Lapointe et al., 2006)—This study established that TAM as devised by (Davies et al., 1989) is not adequate for health systems because adoption/resistance factors may be group related as opposed to the fundamental basis of TAM which is individualistic, influence of intra and inter organisational factors, linkages to cultures, environmental factors as well as the complexity of the environment.

Introducing electronic patient records to hospitals: Innovation adoption paths (Suomi, 2006)—This study found that relative advantage, strong network externalities available, rich availability of information through different communication channels are key factors for innovation and adoption. It should be noted that these are not discussed in the TAM models.

User acceptance and diffusion of innovations summarised (Spil & Schuring, 2006)—This summary established that perceived usefulness is a predictor of technology acceptance in healthcare. Ease of use was not found to be significant.

Understanding physicians' use of online systems: an empirical assessment of an electronic disability evaluation system (Horan et al., 2006)—This study found that in order to diffuse technology in an organisation, it is important to ascertain physicians' behaviour, their workflow practices and their perceptions regarding the value of specific information systems.

In essence, the recent studies appear to be indicating that the current models of technology acceptance or its derivatives are not suitable to predict the adoption factors of wireless technology in healthcare environment. Strong support can also be derived from three specific studies that have tested TAM models in healthcare. The first study conducted by Jayasuriya (1998) established that ease of use was not significant in a clinical domain. The second study by Chau & Hu (2002) echoed similar sentiments. The third study by Hu et al. Hu et al. (1999) also found similar findings.

Further, recent studies conducted by Howard et al. (2006) also established that ease of use was not significant while determining factors of adoption in a clinical domain in regard to wireless technology. Further, Ivers & Gururajan (2006) also found that there are other factors beyond the TAM models influencing the acceptance of technology.

Interviews conducted with 30 Queensland nursing staff members by Gururajan, R., Moloney, C. et al. (2005) revealed that clinical usefulness of wireless technology is far more significant than ease of use factor as established in TAM. Another focus group discussion with the Western Australian senior health managers by Gururajan, R., Quaddus, M. et al. (2005) also indicated that aspects of clinical usefulness such as integration of clinical data may be a significant factor than the ease of use factor. Howard et al. (2006) also identified clinical usefulness is far more influencing than the ease of use factor while determining factors of adoption of wireless technology in the Indian healthcare domain.

However, the recent findings that the ease of use factor not showing strong significance in healthcare domain while determining wireless technology adoption warrants explanation as this is different to many other reported studies in the generic IS domain where both attributes (ease of use and perceived usefulness) were reported to be reliable predictors.

This variation requires further empirical investigation in order to explain the reason behind this variation specific to healthcare. Therefore, there is a need to identify attributes that assist in the adoption of wireless applications in healthcare environment. It is argued that the initial validity of TAM was predominantly established by testing the model with students as surrogates in a generic software application domain. This environment is very different to the healthcare environment, where the skills are at different levels. Further, the healthcare environment is complex, sensitive and time critical. These could be some of the reasons why TAM did not perform as expected in healthcare settings.

In addition, in the recent variant of TAM, namely, UTAUT, Venkatesh et al (2003) reviewed eight prominent models of user acceptance and managed to create a unified view. The unified model comprised of seven constructs. The first four—performance expectancy, effort expectancy, social influence and facilitating conditions—were theorised to be direct determinants. The last three—attitude towards technology, self efficacy and anxiety—were theorised to be indirect. All the seven constructs were found to be significant determinants of technology usage by Venkatesh et al (2003).

In terms of attitude, Venkatesh et al. (Venkatesh et al., 2003) defined it as an individual's overall affective reaction to using a system. The model depicts four constructs relating to this determinant—attitude towards behaviour, intrinsic motivation, affect towards use and affect. Spil & Schuring (2006) verified that in three cases the relation between attitude and behavioural intention is significant. Therefore, this determinant cannot be indirect. If there is significance between attitude and behaviour intention, then there is a direct relationship.

Therefore, there appears to be a basis to identify factors that contribute to the adoption of technologies in healthcare settings. Given that wireless technologies have started making in-roads in healthcare, the overarching purpose of the research is to identify the factors that influence the adoption of wireless technology in the Indian healthcare system. The rationale of the purpose is justified by the fact that India is a leader in software technologies, especially medical applications. Further, India is emerging as 'health tourism', due to the advancement in medical technology and reduction in cost in offering high quality health services—as highlighted by various print media. However, our initial review of available literature indicated that this area is under-researched. Collectively, these aspects led to the following research question:

- What are the determinants for the adoption of wireless technology by physicians in the Indian healthcare system?

The first stage of this study is focused on answering the research question qualitatively and the second stage on answering the research question quantitatively. Details as to how the research question was answered are provided in the research methodology section below.

METHODOLOGY

An examination of existing IS studies indicated that there is a necessity for a suitable research method. Most of the reviewed studies follow a quantitative approach which involves an instrument being administered onto a domain with perhaps a lesser understanding of the domain issues. For this study it was felt that if technology issues are to be studied with respect to a specific domain, then user involvement with the technology issues forms a major part in establishing the adoption (or inhibiting) factors. By necessity, this would occur prior to administering quantitative instruments (e.g. survey). This, in turn, requires an understanding of research philosophy, values of inquiry that would guide the study, and the choice of relevant research techniques required to conduct the investigation in order to answer the research questions.

Further, there appears to be limited information available in the Indian IS domain to guide the principles of this study. This study is relatively new and, hence, requires a rigorous justification as to the choice of research methods employed. It is also believed that due to aspects associated with various regulatory issues impacting the Indian health system, unique factors of technology acceptance, as well as usefulness, may emerge. Our initial meetings with Indian physicians also suggested that there is a divide in terms of technology usage between private and public hospitals, where private hospitals are rich in technology use and public hospitals are not. On the other hand, in many traditional studies in IS, either quantitative or, to some lesser extent, qualitative methods are used—but not both. In recent years this has been cited as a weakness (see (Mingers, 2001) for a detailed argument on this). Taking this into account, this study investigates the suitability of both approaches in order to answer the research question.

It is recognised that the foundation for any research will be grounded on the researcher's fundamental philosophical view of the world (Myers, 1997). The choice of tools, including research techniques, instruments, and methods such as qualitative and quantitative, are not inherently linked to a particular philosophical position, as these positions are generic in nature. It is the contextual framework within which they are applied that provides consistency to an inquiry. While the choice of tools and methods are not linked to the philosophical view, the articulation—which is commonly the process of explaining choices of research methods and its related choice of research instruments—helps determine the philosophical disposition. This is usually achieved by asking questions on the beliefs, perceptions, experiences, advantages and disadvantages in order to determine this disposition. This may even include a researcher's personal experience within that domain, or their expertise in explicating the information using any approach that may be suitable to that domain. This has prompted us to follow a qualitative approach as the first phase of the study. It is argued that this approach facilitates direction to the second phase of the study where quantitative evidence can be collected to establish causality between the dependent and the independent variables.

The research question dictates the need for quantitative research methods, while the behavioural component of the same investigation dictates qualitative research methods. The rationale for this approach is based on the notion that behavioural components require a thorough understanding of how users apply wireless technology in a given setting in order to understand behavioural issues. To extract 'tacit' aspects, this is best accomplished by applying a qualitative approach. A quantitative instrument can then be developed to extract the quantitative aspects, such as the opinion scores.

Health professionals view the term 'wireless technology' in different ways, either as a product or a process. The combined domain of wireless technology and healthcare is relatively new in the Indian IS domain. While IS studies have discussed the impact of Information & Communication Technology (ICT) tools and associated behavioural intentions on healthcare users, limited information can be found as to how the combination of wireless technology and healthcare settings would influence users who are already conversant with novel and advanced medical technologies (Spil & Schuring, 2006). The workplace or organizational factors that influence such combinations are yet to be explored in detail. Such an exploration has close association with the choice of research method as these methods pave the way for proper inquiry into the factors that determine technology acceptance in a given setting. On this basis, the suitability of one research method over another has to be carefully weighed. Consequently, this study identified an exploratory approach to be suitable for the initial investigation. This approach is particularly favourable in confirming the direction of the study, variables chosen for the study, and in helping refine the literature. The exploratory study can also possibly eliminate some variables, while providing opportunities for including emerging variables.

Qualitative Data Collection

As argued, for the first stage of this research the investigators used a qualitative approach to collect initial sets of themes for the adoption of wireless technology in the Indian healthcare system. For this purpose, 30 physicians operating in Indian healthcare were identified randomly. These physicians were interviewed by an independent member (external to the team) who identified the attributes for the adoption of wireless technology by physicians in the Indian healthcare system. This approach was deliberate to address criticisms of 'bias' in the interview process. Further, due to linguistic issues, a person with linguistic proficiency in both Indian language and English is required. The interview questions were derived from existing literature. The first stage of the data collection concentrated on Indian hospitals with some form of wireless technology already in use. The physicians were also chosen based on their wireless technology awareness or working experience. They were drawn from both private and government hospitals. The interviews were conducted over a 45-60 minute period and recorded using a digital recorder. Once they were recorded, the interviews were transcribed.

Quantitative Data Collection

This study developed a survey instrument from the interview data. The main reason for this digressed attitude was that previously tested instruments in the technology domain were not relevant to healthcare setting and were found to be inadequate in answering the research question. The data from the interviews were used to develop specific ranges of questions to gather a more detailed view from the wider population. This survey instrument was pilot tested to capture the information reflecting the perceptions and practice of those adopting the wireless technology in the Indian healthcare system. Particularly, it focussed on what internal and external environmental factors affect the adoption of wireless technology and the extent of this influence. The survey was then distributed to over 300 physicians randomly chosen from the telephone book and a total of 200 responses were received. The survey responses were then entered into a spreadsheet file. A Visual Basic interface was written to generate numerical codes for various elements of the survey for data analysis using SPSS. The coded spreadsheet file was then copied onto a SPSS file format.

DATA ANALYSIS

Qualitative data was analysed using the NVivo (version 7) application, which helped identify the initial themes from the interviews. Quantitative data were analysed using SPSS, which helped identify the factors and their correlation for the adoption of wireless technology in the Indian healthcare setting.

Qualitative Data Analysis

Qualitative data was manually coded to extract themes that had an impact on wireless technology acceptance as stated by the physicians. In total, 63 themes were extracted from the interviews. The initial themes include awareness, cost factors, advantages and disadvantages, medical errors, information sharing, current state of technology, usefulness and role of wireless technology, and technology awareness. On the basis of the interviews and the literature review, the themes were

Table 1. The factors driving and inhibiting wireless technology adoption in healthcare

Drivers	**Barriers**
• Save-time • Improve-clinical-workflow • Efficiency-in-communication • Delivery-of-high-qual-info • Better-quality-of-service • Save-effort • Improve-clinical-performance • More-contact-time-with-patients • Improved-delivery-of-information • Reduce-overall-cost • Positive-impact-on-patient-safety • Reduce-inaccuracies • Improve-public-image • Reduce-medical-errors • Easy-access-to-data • Attract-more-practitioners • Reduce-workload	• Legal barriers • Administrative purpose • Communication with physicians • Patient education • Communication with colleagues • Obtain lab results • Note taking • Electronic medical records • Device usage barrier • Benefit evaluation barrier • Resource barrier • Electronic prescribing

classified into drivers and inhibitors as shown in the following table. This list of drivers and inhibitors was expected to provide a direction for the development of the survey instrument for the collection of quantitative data to capture the wider community views and to generalize the outcome of the research. This grouping is presented in Table 1.

The content of the Table 1 is consistent with findings of previous studies conducted by Gururajan et al. (2004; 2005). This prompted conducting a quantitative study in order to establish causality among dependent and independent variables, as well as external validity and generalisability.

Quantitative Data Analyses

In order to ensure statistical reliability, suitable tests were run on the entire instrument, as well as selected group of variables. For example, the reliability test returned a Cronbach alpha value of 0.965 for the instrument indicating high reliability (Zikmund, 1994). This test was conducted because the instrument was generated from the interview data and, hence, it was necessary to establish statistical reliability. In addition, reliability tests were also run for three factor groupings, namely, drivers, inhibitors of adoption and other technology factors. The reliability tests returned values of 0.941, 0.447 and 0.536, respectively, indicating that the data were suitable for factor analysis testing.

As a second step, survey data were analysed for factor analysis using SPSS. It is evident from the table below that two factor component matrix identified drivers and the barriers for the adoption of wireless technology in the Indian healthcare setting. This finding is consistent and aligned with the findings of the qualitative data collection stage (i.e. first stage) of this research.

The drivers were further tested for factor groupings. The analysis resulted in Table 3.

The driving factors of adoption yielded three categories of factors, namely, 'organisational', 'management' and 'clinical'. The organisational components include wireless technology drivers that can generate specific benefits for organisations. The management components represent the benefits that healthcare managers can realise using wireless technology. The clinical components encompass clinical drivers of using wireless technology.

A similar factor model was generated for the inhibitors. The model resulted in Table 4:

Similar to the drivers, the inhibitors also resulted in three specific categories. The 'technology' category includes technology factors that inhibit wireless adoption in the Indian healthcare. The 'resource' category encompasses resource barriers that are currently being encountered in the healthcare setting. Finally the 'usage' category is comprised of inhibiting factors, which are associated with usage issues.

In addition to the two factor groups, namely drivers and inhibitors, A third factor was also identified and named as 'clinical usefulness' and its components are shown in Table 5.

This factor group yielded three components. The first component deals with the general communication aspects facilitated by wireless technology in healthcare settings. The second component refers to clinical communication using wireless technology. The third component is specific to records management. In summary, the data analyses yielded three specific categories of factors which can affect the adoption of wireless technologies in the healthcare setting. These comprise adoption drivers, inhibitors, and clinical usefulness.

Hypotheses Formulation and Testing

Based on the evidence collected, the three sets of factors, namely, drivers, barriers and clinical usefulness, contribute to the acceptance of wireless technology in healthcare. It is hypothesised that the drivers positively impact clinical usefulness,

Table 2. The factors driving and inhibiting wireless technology adoption in healthcare from data analysis of survey result

Drivers	Loading values	Barriers	Loading values
improve-clinical-workflow	.798	poor technology barrier	.605
tech-support	.764	time for training barrier	.572
delivery-of-high-qual-info	.760	tech expertise barrier	.554
save-time	.757	benefit evaluation barrier	.503
better-quality-of-service	.749	legal barriers	.465
save-effort	.743	solutions barrier	.444
improved-delivery-of-information	.732	system migration barrier	.442
efficiency-in-communication	.730	technical support barrier	.436
more-contact-time-with-patients	.725	lack of support barrier	.352
improve-clinical-performance	.702	device access barrier	.316
more-training	.699	device comfort barrier	.248
improve-public-image	.695	funding barrier	-.225
easy-access-to-data	.692	security as barrier	.224
positive-impact-on-patient-safety	.679	device usage barrier	.208
reduce-inaccuracies	.659		
reduce-workload	.657		
reduce-medical-errors	.650		
reduce-overall-cost	.634		
attract-more-practitioners	.600		
Org-culture	.464		

Table 3. The factors driving wireless technology adoption in healthcare from data analysis of survey result

	Organizational	Management	Clinical
save-effort	.716		
reduce-overall-cost	.708		
reduce-inaccuracies	.703		
save-time	.667		
easy-access-to-data	.659		
attract-more-practitioners		.769	
improve-public-image		.680	
tech-support		.680	
reduce-workload			.817
improve-clinical-performance			.797

whereas the barriers have a negative impact on it. While the drivers and barriers include factors beyond the technology aspects, their respective influences are restricted to the clinical domain as this is where the usefulness of wireless technology can be experienced. Therefore, the following two hypotheses were generated for testing:

H1:*Drivers of wireless technology positively impact clinical usefulness.*

H2: *Barriers to wireless technology negatively impact clinical usefulness.*

A Partial Least Square (PLS) model was developed in order to test the hypotheses. The rationale for using PLS includes: PLS is used for confirmatory factor analysis (CFA); the pattern of loadings of items on the latent constructs is explicit; PLS provides strong convergent and discriminant validity; p-value of t-value is significant (over 0.50 level) for constructs; and measurement items load highly on theoretically assigned factors and not highly on other factors.

PLS MODEL DEVELOPMENT

In order to develop the PLS model, a PLS Graph prototype was used. Initially, the individual drivers, barriers and clinical usefulness were tested for CFA scores and these were found to be reliable. When the CFA was found to be satisfactory, a model was built with clinical infuences as dependent variable on drivers and barriers. The factors of these three constructs were linked using PLS Graph software and the model was run. The final outcome is shown in Figure 1.

Figure 1 shows that the factor loading (the number on the path: for example, for the construct Drivers, the 'esydataccs' has 0.763) and the factor weight (the number in the parantheses: for example, 0.101) for almost all factors are reliable. The drivers and clinical usefulness load very highly (over 0.8 for most of the items), indicating a high reliability. Further, all variables have a t-value of over 1.96 to indicate high convergent validity.

Upon construct validation, a simple PLS (consolidated) model was developed to test the hypotheses. The model consists of clinical usefulness as the dependent variable, and drivers and barriers as independent variables. The model was run with PLS Graph program and the screenshot shown in Figure 2 displays the values along the

Table 4. The factors inhibiting wireless technology adoption in healthcare from data analysis of survey result

	Technology	Resource	Usage
poor technology barrier	.625		
time for training barrier	.582		
solutions barrier	.575		
benefit evaluation barrier	.528		
tech expertise barrier	.527		
system migration barrier	.511		
funding barrier		-.749	
resource barrier		-.690	
technical support barrier			.542
device usage barrier			.519

Table 5. The factors 'clinical usefulness' of wireless technology adoption in healthcare from data analysis of survey result

	General Communication	Clinical Communication	Records Management
Obtain lab results	.837		
Administrative purpose	.770		
Electronic prescribing	.670		
Medical database referral	.632		
Patient education		.727	
Communication with colleagues		.707	
Communication with patients		.676	
Drug administration		.596	
Communication with physicians		.548	
Electronic Medical Records			.764
Generating exception list			.738
Note taking			.617
Disease state management			.563

link from Drivers to Clinical Usefulness, and Bariers to Clinical Usefulness. As hypothesised, drivers exhibited a positive loading (0.097) and the barriers exhibited a negative loading (-0.384). The number below the circle Clinical Usefulness is the construct R^2, which is calculated and displayed for each dependent variable. The lower the R^2, the minimum the error in the model. In the model the R2 values for the dependent variable 'Clinical Usefulness' is 0.167. This is not high and hence the error is minimal. This is shown in Figure 2.

IMPLICATIONS

Clearly, wireless technology can be used to facilitate access to clinical information and communications between clinicians, maximise clinician time, increase patient safety, and accomplish the strategic and business goals of health organisations. Taken together, these factors have a direct impact on clinical usefulness and its effectiveness. However, achieving clinical usefulness with wireless handheld devices can be a challenge and has several implications.

Firstly, the highest security standards must be achieved. This includes direct end-to-end data encryption, authentication, authorisation, maintenance of audit logs and session management (Chen et al. 2004). While high security standards are essential, their implementation is likely to affect usability. For example, the download and encryption of patient information from the server where it is stored into a wireless handheld device may not be prompt. Sax et al. (2005) argue that clinicians may experience increasingly longer time lags when they carry out increasingly more complex procedures. This is likely to adversely affect clinical usefulness and, hence, decrease user acceptance.

Closely associated with security is also the issue of patient confidentiality, which is of significant importance and concern. Although

Figure 1. PLS model of adoption of wireless technologies in Indian healthcare

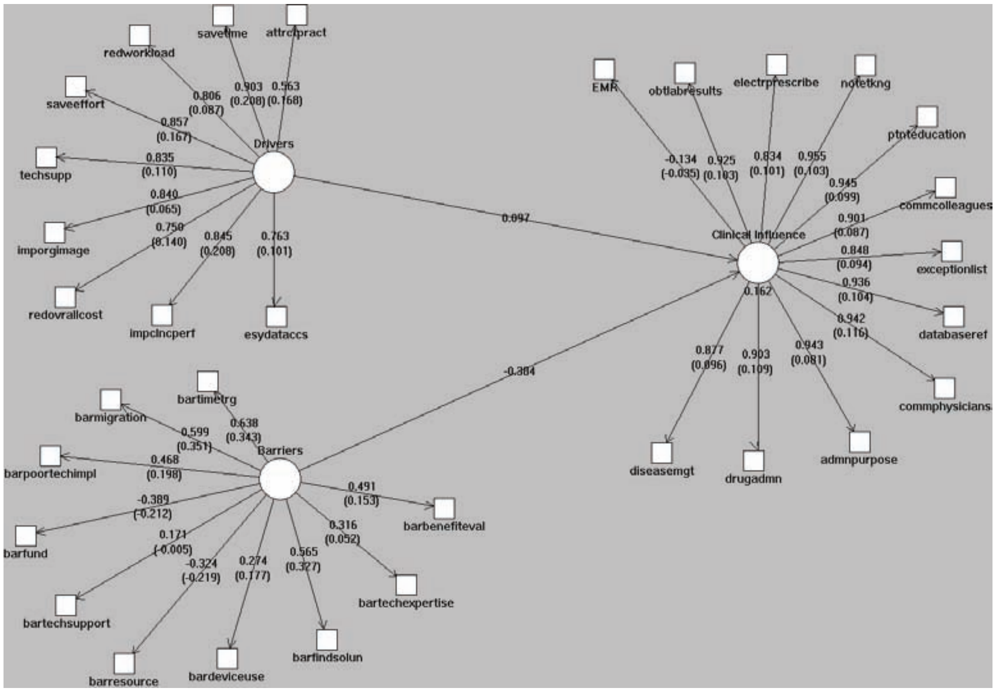
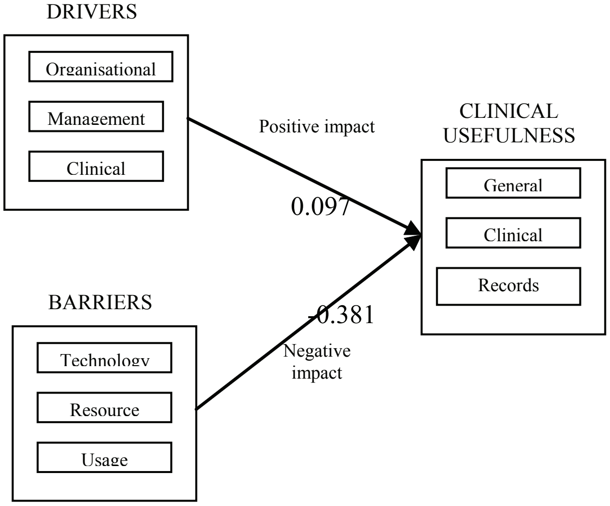


Figure 2. Result of model testing



wireless handheld devices have locking security features and password protection functions which activate during periods of inactivity, the frequent use of these functions during the clinicians' busy daily schedules may have an impact on clinical usefulness.

Secondly, the design of an effective human-computer interface, while challenging, constitutes a key factor for the acceptance of the technology and its routine use by healthcare workers (Chen et al. 2004). This is an important development consideration as the relevant information should be easy to navigate and read, and has to be presented in an organised fashion when required within the resource limitations (e.g. screen size and bandwidth) of a wireless handheld environment. Usability factors are not only likely to constitute an acceptance barrier, but can also be the cause of medical errors. Bates et al. (2001) argue, 'While it may be easy and common to blame operators for accidents [or errors], investigation often indicates that an operator "erred" because the system was poorly designed' (p. 301). Therefore, medical errors can also occur due to poor usability. Taken together, these factors would contribute to reduce medical errors. By implication, it is important to involve users in the design of the wireless applications, thereby maximising their clinical usefulness.

Thirdly, simply acquiring and implementing wireless technology alone would be insufficient to accomplish clinical usefulness and, subsequently, drive adoption and diffusion. Wireless technology should be integrated with process improvement and organisational change. Process improvement requires the optimisation of clinical processes and should be supported by technology, rather than driven by it (Smith 2004). Ultimately, this is likely to generate significant patient outcomes and financial improvements with health organisations.

Fourthly, as suggested by the empirical evidence collected in this study, cost constitutes an important factor which will affect the integration and, subsequently, the success of wireless handheld devices in the healthcare setting (Sax et al. 2003). Typically costs include the software, the server, upgrades of healthcare organisations' existing networks and legacy systems, the costs of the handheld units themselves, as well as maintenance and support. While existing research in this area argues that such technology has the potential to decrease charting time and medical errors and enhance patient care quality, there is no evidence that comparisons of costs before and after the implementation of wireless technology have been made. This suggests that further research is required, but also, most importantly, it shows that, indirectly, costs have the potential to affect clinical usefulness and threaten widespread adoption.

CONCLUSION

This research, perhaps for the first time, identified derivers for technology acceptance for using wireless technology in an Indian healthcare context. While this is an exploratory study to identify clinical influences of wireless technology applicable to the Indian healthcare system, the bottom-up method identified drivers that are quite different to that of traditional technology acceptance models. In fact, this study revealed that technology acceptance is quite different in healthcare compared with that of IS studies. While the data were obtained on perceived opinions, it was not possible to actually measure the usefulness of wireless technology in a clinical setting. Currently, another project is being designed to enable the measurement of clinical influences of using wireless technology in an objective manner. It is expected that this new project will provide valuable insights into the efficiency gains of using wireless technology and the challenges people encounter in using this technology.

This study is confined to the Indian healthcare setting, which limits the generalisability of its findings. However, this study is also the first of its nature and, as a result, it has prepared the groundwork for further research which can confirm (or refute) whether the findings are applicable to other settings such as Taiwan as data collection is in progress. This data collection is expected to be completed by December 2009. This exercise, it is hoped, will enable to extend the notion to broader populations.

REFERENCES

Athey, S., & Stern, S. 2002. The impact of information technology on emergency health care outcomes. RAND Journal of Economics, 33(3), 399 - 388.

Bates, D.W., Cohen, M., Leape, L.L., Overhage, M., Shabot, M.M. & Sheridan, T. 2001. 'Reducing the Frequency of Errors in Medicine Using Information Technology', Journal of the American Medical Informatics Association, 8 (4), pp. 299-308

Chau, P. Y. K., & Hu, P. J.-H. 2002. Investigating healthcare professionals‘ decision to accept telemedicine technology: An empirical test of competing theories. Information and Management, 39, 297-311.

Chen, E., Mendoca, E.A., McKnight, L.K., Stetson, P.D., Lei, J. & Cimino, J.J. 2004. 'PalmCIS: A Wireless Handheld Application for Satisfying Clinician Information Needs', Journal of the American Medical Informatics Association, 11 (1), pp. 19-28

Chismar, W. R., & Wiley-Patton, S. (2006). Predicting Internet Use: Applying the Extended Technology Acceptance Model to the Healthcare Environment. In T. A. M. Spil & R. W. Schuring (Eds.), E-Health Systems Diffusion and USe: The Innovation, the USer and the USE IT Model. London: Idea Group Publishing.

Davies, F. D., Bagozzi, R. P., & Warshaw, P. R. 1989. User acceptance of computer technology: A comparison of two theoretical models. Communications of the ACM, 35(8), 982-1003.

Davis, R. 2002. Pursue front end solutions to revenue problems. Healthcare Financial Management, 56(8), 30 - 36.

Davis, S., & Bostrom, R. 1993. Training end users: An experimental investigation of the roles of the computer interface and training methods. M I S Quarterly(March), 61-85.

Dyer, O. 2003. 'Patients will be reminded of appointments by text messages', British Medical Journal, 326 402 , 281.

Dyer, O. 2003. Patients will be reminded of appointments by text messages. British Medical Journal, 326(402), 281.

Fischer, S., Stewart, T.E., Mehta, S., Wax, R. & Lapinsky, R. 2003. 'Handheld Computing in Medicine', Journal of the American Medical Informatics Association, 10 (2), pp.139-149.

Gururajan, R. et al. 2004. 'Necessity for a new technology acceptance model to predict adoption of wireless technology in healthcare', paper presented at the Let‘s Make a Difference with Health ICT, HIC Conference, 25-27 July .

Gururajan, R. et al. 2005. 'Drivers and Barriers to adoption of wireless handheld system in WA healthcare: Selected views', paper presented at the HIC 2005, Melbourne.

Gururajan, R., Moloney, C., & Kerr, D. 2005. Drivers for wireless handheld technology: views from Queensland nurses. Paper presented at the Australian Business & Behavioural Sciences Association (ABBSA) Conference, Cairns, Australia.

Gururajan, R., Quaddus, M., Fink, D., Vuori, T., & Soar, J. 2005. Drivers and Barriers to adoption of wireless handheld system in WA healthcare: Selected views. Paper presented at the HIC 2005, Melbourne.

Gururajan, R., Toleman, M., & Soar, J. 2004, 25-27 July. Necessity for a new technology acceptance model to predict adoption of wireless technology in healthcare. Paper presented at the Let‘s Make a Difference with Health ICT, HIC Conference.

Horan, T. A., Tule, B., & Hilton, B. N. (2006). Understanding physician use of online systems: An empirical assessment of an electronic disability evaluation system. In T. A. M. Spil & R.

W.Schuring (Eds.), E-Health Systems Diffusion and Use: The Innovation, the User and the USE IT Model. London: Idea Group Publishing.

Howard, A., Gururajan, R., Hafeez-Baig, A., & Howard, S. 2006. Clinical Usefulness of Wireless Technology in Healthcare: An Indian Study. Paper presented at the The Australasian Conference on Information Systems, University of South Australia.

Hu, P. J., Chau, P. Y. K., & Liu Sheng, O. R. 2002. Adoption of telemedicine technology by health care organisations: An exploratory study. Journal of organisational computing and electronic commerce, 12(3), 197-222.

Hu, P. J., Chau, P. Y. K., & Tam, K. Y. 1999. Examining the technology acceptance model using physician acceptance of telemedicine technology. Journal of Management Information Systems, 16(2), 91-112.

Ivers, B., & Gururajan, R. 2006. Management issues in telecommunications: videoconferencing & telehealth. Paper presented at the International Conference on Recent Trends in Information Systems Proceedings, India.

Jayasuriya, R. 1998. Determinants of microcomputer technology use: Implications for education and training of health staff. International Journal of Medical Informatics, 50, 187-194.

Lapointe, L., Lamothe, L., & Fortin, J. (2006). The dynamics of IT adoption in a major change process in healthcare delivery. In T. A. M. Spil & R. W. Schuring (Eds.), E-Health Systems Diffusion and Use: The Innovation, the User and the USE IT Model. London: The Idea Group Publishing. London: Idea Group Publishing.

Mingers, J. 2001. 'Combining IS research methods: Towards a pluralist methodology', Information Systems Research, 12 (3) , 240-259.

Mingers, J. 2001. Combining IS research methods: Towards a pluralist methodology. Information Systems Research, 12(3), 240-259.

Myers, M. D. 1997. Qualitative research in Information Systems. MIS Quarterly, 21(2), 241-242.

Reinecke, I. 2004. 'Managing Information in Health', Melbourne National Health Information Summit.

Reinecke, I. (2004). Managing Information in Health. Melbourne National Health Information Summit.

Rogoski, R. 2005. 'Wireless by Design', Health Management Technology January , 1-7.

Sausser, G. D. 2003. Thin is in: web-based systems enhance security, clinical quality. Healthcare Financial Management, 57(7), 86-88.

Sax, U., Kohane, I. & Mandl, K.D. 2005. 'Wireless Technology Infrastructures for Authentication of Patients: PKI that Rings', Journal of the American Medical Informatics Association, 12 (3), pp. 263-268.

Simpson, R. L. 2003. The patient's point of view -- IT matters. Nursing Administration Quarterly, 27(3), 254-256.

Smith, C. 2004. 'New Technology Continues to Invade Healthcare: What are the Strategic Implications/Outcomes?', Nursing Administration Quarterly, 28 (2), pp. 92-98.

Spil, T. A. M., & Schuring, R. W. 2006. E-Health system Diffusion and Use. Hershey: IDea Group Publishing.

Stuart, D., & Bawany, K. (2001). Wireless Services: United Kingdom (Operational Management Report No. DPRO-90741): Gartner.

Suomi, R. (2006). Introducing electronic patient records to hospitals: Innovation adoption paths. In T. A. M. Spil & R. W.Schuring (Eds.), E-Health Systems Diffusion and Use: The Innovation, the User and the USE IT Model

Turisco, F. 2000. Mobile computing is next technology frontier for health providers. Healthcare Financial Management, 54(11), 78 - 82.

Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. 2003. User Acceptance of Information Technology: Toward A Unified View. MIS Quarterly, 27(3), 425-478.

Wisnicki, H. J. 2002. Wireless networking transforms healthcare: physician‘s practices better able to handle workflow, increase productivity (The human connection). Ophthalmology Times, 27(21), 38 - 41.

Zikmund, W. 1994. Business research methods. International edn. , Orlando, FL: The Dryden Press.

This work was previously published in International Journal of Healthcare Delivery Reform Initiatives, Vol. 1, Issue 1, edited by M. Guah, pp. 48-52, copyright 2009 by IGI Publishing (an imprint of IGI Global).

Chapter 4.15

A Centrist Approach to Introducing ICT in Healthcare:

Policies, Practices, and Pitfalls

David J. Finnegan
University of Warwick, UK

Wendy L. Currie
University of Warwick, UK

EXECUTIVE SUMMARY

The challenge to provide a nation-wide healthcare service continues unabated in the 21st century as politicians and managers drive through policies to modernize the UK National Health Service (NHS). Established around 60 years ago to offer free healthcare at the point of delivery to all citizens, the NHS now accounts for the largest portion of public expenditure after social security, with total spending around £84 billion in 2006/2007. Over the past 3 decades, the political agenda within healthcare has moved from one of professional dominance, where clinicians and their representative bodies dominated the leadership and management of healthcare organisations, to one where politicians have imposed new ideas in the form of market mechanisms and the "new public management" which extend the use of private sector firms. The political justification for these reforms is to make the NHS more efficient and cost effective and to develop an ethos of patient choice.

INTRODUCTION

The challenge to provide a nation-wide healthcare service continues unabated in the 21st century as politicians and managers drive through policies to modernize the UK National Health Service (NHS) (Harrison, 2004). Established around 60 years ago to offer free healthcare at the point of delivery to all citizens, the NHS now accounts for the largest portion of public expenditure after social security, with total spending around £84 billion in 2006/2007 (National Audit Office, 2006a, 2006b). Over the past 3 decades, the political agenda within healthcare has moved from one of professional dominance, where clinicians and their representative bodies dominated the leadership and management of healthcare organisations, to one where politicians have imposed new ideas in the form of market mechanisms and the "new public management" which extend the use of private sector firms (Burgoyne, Brown, Hindle, & Mumford, 1997; Callaghan & Wistow, 2006). The political justification for these reforms is to make the NHS more efficient and cost effective and to develop an ethos of *patient choice* (Department of Health, 2002).

Described as a *monolithic* organization (Mohan, 2002), implementing business and technical change in the NHS is difficult to manage given the competing interests of key stakeholders: politicians, clinicians, hospital managers, administrators, pressure groups, and patients (Pollock, 2005). A significant policy challenge currently facing the NHS is the implementation of a 10-year (£12.4bn estimated cost) government-led initiative to provide a National Programme for Information Technology (NPfIT) as a significant part of the NHS modernisation agenda (National Audit Office, 2006a).

The NPfIT comprises four main elements, each of which constitutes a nationwide large-scale information technology (IT) implementation: (1) a National Care Records Service for capturing, storing, retrieving, and modifying patient medical records on a national database; (2) the Choose & Book system, where GPs and patients can book hospital appointments using a computer system; (3) the Picture Archiving and Communications System (PACs) to capture and send digital images of x-rays and scans; and (4) an Electronic Prescription Service (EPS) to enable patients to collect their prescriptions from hospital and high street pharmacies more efficiently.

While NPfIT represents a serious commitment from government to use IT to drive through public sector reform, the history of embarking on large-scale public sector IT projects is mixed. A recent National Audit Office Report (2006b) identified 24 successful IT-enabled business change projects, but recognised that other public sector IT projects have not been successful. Criteria for the successful evaluation of projects included: senior management commitment, robust procurement processes, and carefully matching user requirements with desired benefits. These findings suggest that evaluating the implementation of NPfIT must be placed in the wider context of policy-making, procurement, processes, and people, and not simply examined as an isolated "technical" initiative introduced across healthcare organisations. This is supported by prior research which shows that evaluating the implementation of large-scale IT projects is a complex task which involves a combination of clinical, managerial and technical expertise, particularly if they are designed to transform or "re-engineer" existing clinical and/or administrative working practices (McNulty & Ferlie, 2002, 2004; Willcocks & Currie, 1997; Wyatt, 2005).

By tracking cross-national public policy on information and communication technology (ICT) over the past 2 decades, we observe the growing importance of linking ICT as a "change agent" for modernising publicly-funded healthcare services. In the U.S., research studies have focused upon introducing IT-enabled business change in healthcare, noting that conflicts may arise between stakeholder groups which resist changing highly institutionalized working practices (Scott, Ruef, Mendel, & Caronna, 2000). Similarly, in the Netherlands, Sweden, and UK, cost-containment programs and healthcare system reorganisations have been vigorously implemented with outcomes both expected and unexpected (Harrison, 2004).

This study focuses on the policies, practices, and pitfalls of introducing NPfIT, which is a centrist and politically-driven initiative intended to *"help deliver a better NHS that gives public and patients services that fit the twenty-first century"* (Department of Health, 2002, p. 2). We begin by looking at the policy antecedents of NPfIT, which led to its launch in 2002. We then discuss a case study on the electronic prescription service, which is one element of the NPfIT. Here, we are concerned to explore the issue of "best practice" in relation to the EPS, highlighting both its strengths and weaknesses. We conclude by discussing the debate surrounding NPfIT on whether a centrist approach to ICT implementation is preferable to a decentralised or localised approach. We develop our conclusions based upon our empirical and archival data collection and analysis.

Building out the National Programme for Information Technology

The antecedents of NPfIT began with the Department of Health (1998) report on "Information for Health," which identified the key strands in the recently elected 1997 Labour government policy to introduce lifelong electronic records of patients. This was followed by further government reports including the "NHS Plan (Department of Health, 2000) outlining an information strategy for the "modern NHS" and "Building the Information Core" (Department of Health, 2001) on how to implement the NHS plan. These publications contain important policy recommendations that influenced the publication of the Wanless Report (Department of Health, 2002) that spearheaded the NPfIT.

From these earlier documents on IT in healthcare, we can observe the changing policy recommendations of government and how IT has become infused with the wider policy agenda to reform the NHS. A consistent theme in UK healthcare over the past 3 decades has been continuous policy change and reform. Successive governments have used healthcare in their political armoury to demonstrate to the electorate that improving healthcare services is a key priority (Klein, 2001; Pollock, 2005). The NHS has witnessed numerous attempts at restructuring with some examples being, the introduction of strategic health authorities (SHAs), primary care trusts (PCTs), foundation hospitals, practice-based commissioning, the private finance initiative (PFI) and patient choice.

To facilitate these changes, IT-enabled change is perceived to play a critical role as, "Better IT is needed in the NHS because the demand for high-quality healthcare continues to rise and the care now provided is much more complex, both technically and organizationally" (Connecting for Health, 2004). Moreover, the NHS is an information-intensive industry. There are over 300 million consultations in primary care annually. In 2003, there were around 650 million prescriptions dispensed in the community; and nearly 5.5 million people were admitted to hospital for planned treatment. In addition, there were 13.3 million outpatient consultations, and nearly 13.9 million people attended Accident and Emergency (A&E), of whom 4.3 million were emergency admissions (Connecting for Health, 2004, p. 7). Management and administration costs in the NHS are around £170 million, and a further £14 bn is spent on IT (National Audit Office, 2006a).

Notwithstanding the increase in the annual NHS budget, the concept of IT-enabled business change remains contentious. From a period of virtually no computers in the 1960s and 1970s, the NHS has developed a vast array of disparate IT systems. Primary care is relatively advanced compared with secondary care, as GPs have tended to invest in IT systems for patient administration and medical record keeping. Similarly, retail pharmacies have invested in IT to improve the efficiency and operations of their business. Conversely, IT investment in secondary care has been slow. Among the first IT systems were patient administration systems (PAS) in the early 1960s. This was followed by laboratory and radiology systems in the 1970s, and hospital information support systems (HISS) and resource management in the 1980s (Brennan, 2005). As computer technology proliferated during the 1980s and 1990s, the NHS began to develop an IT strategy to maximise the potential data and information management benefits from IT in healthcare.

This culminated in the late 1990s with a succession of government reports advocating the development of lifelong electronic patient records (EPRs) (Department of Health, 1998; Hendy, Reeves, Fulop, Huchings, & Masseria, 2005). The NHS Executive aimed to transform IT-enabled healthcare services by establishing a target for all NHS hospitals to have EPR introduced by 2005 (Department of Health, 2002). Recognising that, "historically, the NHS has not used or developed IT as a strategic asset in delivering and managing healthcare" the Wanless Report (Department of Health, 2002) advocated a much higher annual IT spend to compare with other industries like financial services. The report produced comparative figures to show that, whereas financial services spend around £9k *per employee per annum* on ICT, the figure for healthcare was only £1k. The Wanless Report therefore recommended the development of "stringent and centrally managed national standards for data and IT management" which resulted in the policy to develop NPfIT in October 2002 (Wanless, 2002).

However, as with all large scale IT-enabled business change, the success or otherwise of the policy or strategic plan is in its implementation and evaluation (Currie, 1989; Doolin, 2004; Hendy et al., 2005; Herzlinger, 1989). Many past IT projects have failed to deliver the desired benefits, but have produced a number of important lessons for decision-makers. These lessons are well documented in the literature and involve the lack of alignment between the business and IT strategy (Luftman, 2000); a lack of ownership and leadership of the IT project among senior decision makers (Brown, 2001); poor risk assessment skills (Heathfield, Pitty, & Hanka, 1998); over-scoping of the functional and technical specification leading to IT projects becoming over-budget and late (NAO, 2004); poor communication between program/project managers and potential users of the system (Currie, 1997); and inadequate resources to deliver/implement IT system (Wyatt, 1998).

In this regard, the NPfIT is not simply a large-scale, 10-year IT implementation, but a long-term, root and branch change initiative that will transform clinical and administrative working practices across a variety of healthcare settings. Unlike other industries such as finance and manufacturing, where rapid change is a key characteristic, healthcare, especially hospitals, for example, display highly institutionalized structures and practices, which, by definition, are more amenable to *incremental* rather than *abrupt, discontinuous change* (Scott et al., 2000). So against the current background of relative stability and persistence in working practices (institutionalised practices) and efforts to introduce large-scale business and IT change (market reforms), this exploratory study offers an evaluation of the implementation of one particular element of NPfIT: the Electronic Prescription Service (EPS).

METHOD

Data Collection and Analysis

Three methods of data collection were used. First, the researchers undertook a full literature review of the academic, government, and practitioner material on ICT policy and practice in healthcare. This literature was supplemented by clinical studies on patient safety, particularly those surrounding prescribing and adverse drug reactions (ADRs). Literature on e-health and electronic health/patient records was sought to inform the research enquiry. Second, the researchers attended conferences, workshops, and exhibitions on healthcare and ICT policy and practice. Data was gathered at the annual Egton Medical Information Systems (EMIS) national user group conference on the development, implementation and evaluation of ICTs in healthcare (EMIS being a major system used by GPs and other clinicians) and more specifically on the EPS. This data source is essential for providing up-to-date material about the communities of practice using ICT and other related topics (e.g., IT in policy healthcare, patient safety, hospital management, professional best practice, and performance measurement and risk assessment). Third, the researchers visited six GP practices and four retail pharmacies to conduct interviews with key stakeholders of the EPS. Our primary data collection was undertaken between January and September 2007. GP practices were selected in the South of England (3) and West Midlands (3) and retail pharmacies split equally between the two regions.

Research protocol for conducting social science research followed Yin (1994) and Miles and Huberman (1994) which include advice and techniques on developing a conceptual framework, pilot study design, formulating research questions, case study definitions (i.e., boundary and territory), sampling, ethical issues and bias, and cross-case analysis.

Since qualitative research methods, that is, ethnographies, may generate voluminous amounts of data, it is essential to deploy techniques that structure and organise the data for analysis. This study delineated the data into key research themes. Examples of potential themes include: ICT policy in healthcare, IT strategy, implementation and evaluation, patient safety, process, performance and risk assessment, and project management. The decision to adopt interviews as the key source of data collection enabled researchers to visit interviewees "on-site" to elicit data and information on the EPS "in practice." Since clinicians are unlikely to fill out questionnaire surveys (by post or over the Internet) due to time constraints and other reasons, our decision to adopt an interview protocol using face-to-face interviews on site enabled us to observe the material surroundings of the technology implementation. The data obtained from interviews and archival sources was analysed using a conceptual framework developed from prior research (Currie & Finnegan, 2007). We present our conceptual framework and results below.

A CONCEPTUAL MODEL FOR EVALUATING AN ELECTRONIC PRESCRIPTION SERVICE

This study delineates the EPS into four key themes for analysis as shown in Table 1: patient safety, process, performance, and public perception. Each theme incorporates important clinical and social science research questions in relation to the implementation and evaluation of the EPS. Increased automation of the prescription service demands particular attention to issues of patient safety, both at the clinical level and the practical level of using the EPS. We give an overview of three elements to patient safety in relation to monitoring data that may highlight adverse responses to medicine: the use of personalised medicines in prescribing and the need for more effective communication between stakeholder groups. This discussion focuses mainly on clinical concerns about patient safety in deploying EPSs. Next, we consider the process of using the EPS across healthcare organisations. A processual analysis of ICT encompassing all the three implementation stages is important since a static representation is unable to pinpoint issues of interoperability, at both the human and technical levels.

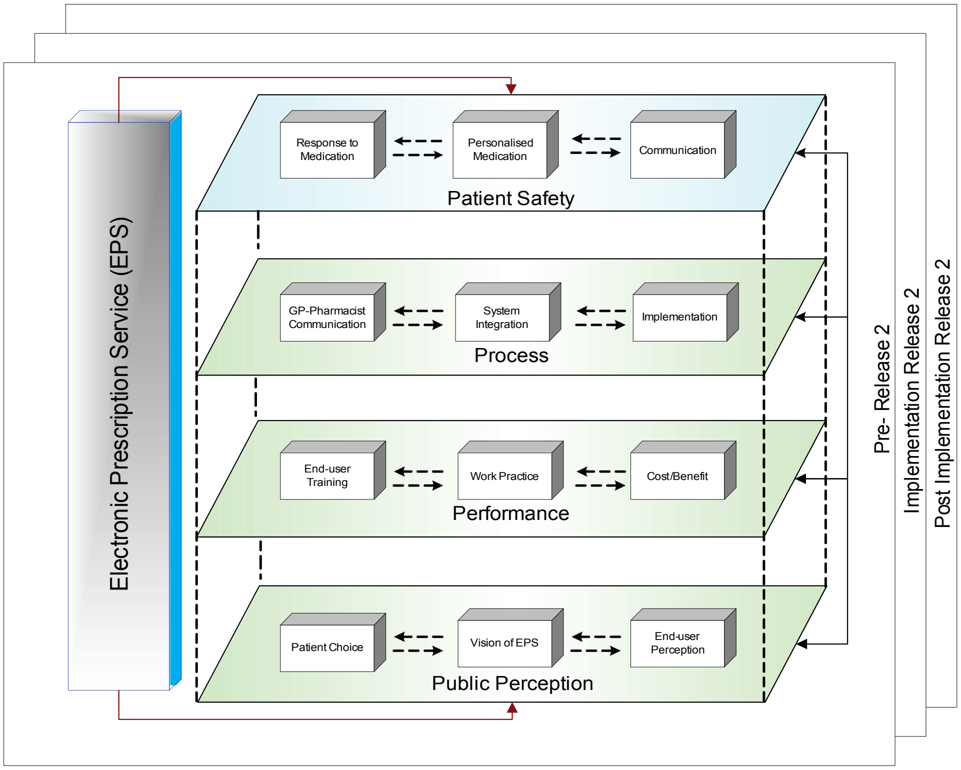
Patient Safety

There are two elements to patient safety that are critical to EPS implementation. The first involves clinical practice and the second, the administrative processes and performance of moving from paper to electronic health records. Ensuring optimal patient safety in prescribing requires relevant information on patient, medicine, and disease to be current at the time of issuing the prescription and effective communication with the patient regarding safe use of the medicine and clear advice regarding adverse reactions and when early health advice contact may be needed. This advice is needed to complement the

Table 1. Empirical data collection

	Type of Organization	Location	Size of GP Practice	Interviewee
1	GP Surgery	West Midlands	5 GP Practice serving ca 6000 patients	3 GPs
2	GP Surgery	West Midlands	4 GP Practice serving ca 4000	2 GPs
3	GP Surgery	West Midlands	4 GP Practice serving ca 5000	2 GPs
4	GP Surgery	Central London	8 GP Practice serving ca 11,500	3 GPs
5	GP Surgery	Central London	7 GP Practice serving ca 9,000	4 GPs
6	GP Surgery	East Sussex	4 GP Practice serving ca 4,500	2 GPs
7	Retail Pharmacy	West Midlands	5000 – 6000 customers	1 Pharmacist
8	Retail Pharmacy	West Midlands	4000 – 5000 customers	1 Pharmacist
9	Retail Pharmacy	Central London	6000-9000 Customers	2 Pharmacists
10	Retail Pharmacy	Central London	5500-8000 Customers	2 Pharmacists

Figure 1. Conceptual framework for evaluating electronic prescription service implementation



voluminous information in medicine packaging inserts. Adverse drug reactions (ADRs) are one of the largest preventable problems facing health services in the UK and beyond (Acute hospital portfolio—medicines management 2005/2006 (www.healthcarecommission.org.uk), contributing up to 7% of hospital admissions in the UK, at an estimated 2004 NHS cost of at least £0.5billion *per annum* (Pirmohamed et al., 2004) and over 100,000 deaths annually in the USA. Furthermore ADRs during long term treatment often lead to poor concordance with treatment (Davidsen et al., 1988) and increased pressures on primary and secondary care services. Serious adverse reactions are reported to contribute to around 1 in 20 admissions to hospital. Many of these are thought to be preventable within current medical knowledge and practice. Here, we are concerned with the potential risks and benefits of EPS in the context of the broad categories of preventable serious ADRs.

1. Failure to record and act on previous history of adverse response to the medicine in question, whether this is immune-mediated or predictable from current knowledge, for example, penicillin allergy, nonsteroidal anti-inflammatory drug (NSAID) dyspepsia. There are two major concerns here. First there is still an early stage in the development of robust electronic health records (EHRs) across diverse public and private primary and secondary care services and secure services in psychiatry and HIV management. Second, there are administrative delays in data being entered on electronic systems. Therefore, the new EPSs need a failsafe prompt to patients regarding previous and recent medicine related reactions before a prescription is issued.
2. Failure to personalise medicines within current medical knowledge, for example, to recognise that B-blockers exacerbate Chronic Obstructive Airways Disease (COAD), that there is need for caution in renal and liver impairment, prescribing in pregnancy, drug interactions. Limiting risk of drug interactions, therefore, means that the prescribing decision must be in the light of an up-to-date clinical history, current evidence based guidelines and "medicines reconciliation" at the time of each prescription issue/renewal. Concern about effective ways to improve current NHS problems with "medicines reconciliation" is currently the focus of joint action by National Institute for Clinical Excellence (NICE) and the National Patient Safety Association (NPSA) to develop new standards (http://guidance.nice.org.uk). There is increasing evidence on the impact of ethnicity on response to and risk of medicines. Ethnicity is not obvious from patient's name and formal prospective recording of ethnicity in primary care has only recently been introduced. To avoid an increase in preventable adverse drug reactions, the new EPS should replace the prescribers' previous role in checking risk markers before prescriptions are issued. Examples include checking whether there is dyspepsia or the haemoglobin has fallen before reissuing aspirin; checking. plasma sodium in patients on anti-depressant treatment with Selective Serotonin Reuptake Inhibitors; checking plasma potassium in patients before prescribing Angiotensin Converting Enzyme (ACE) inhibitors, angiotensin receptor blockers and potassium sparing diuretics; checking for infection and white blood count before reissuing carbimazole. These checks in some cases involve targeted interaction with patients, in others making sure that safety blood testing is in place and that results are integrated with EPS.
3. Failure to communicate effectively risks to the patient so that if adverse effects do occur the patient is prompted to seek medical attention early so that risk of progression to

> serious ADRs is minimised, for example, aspirin and dyspepsia. The new EPS removes a direct patient prescriber contact step. It is therefore vital that alternative, evidence-base validated, communication steps are in place regarding specific alerts for patients, re high probability and high risk adverse reactions and what steps the patients should take to prevent/limit progression of possible ADRs. Pharmacogenetics is now impinging on clinical practice as a way to reduce risk of ADRs with clinical licensing of suitable tests and clinical application of PG testing to high risk cancer chemotherapy, for example, to assess genetic variability in the enzyme thiopurine s-methyltransferase. Within the software life of the new EPS, trigger tools will be increasingly needed to make sure that need for and results of relevant new clinical tests are integrated within the EPS.

Process

The EPS has undergone a rigorous design, test, and build process to ensure that the system is capable of coping with the 1.3 million prescriptions handled each day across England. This process has been informed by the creation of a number of user groups, comprising GPs, pharmacists and patients, who meet regularly to discuss specific issues. In order to reduce the probability of any implementation issues affecting patients, the EPS is being introduced alongside the existing paper-based system. Initially, this will allow users to become familiar with the new software and processes before any significant changes affecting patients are introduced. The EPS process is intended to save time for GPs with regard to administering prescriptions, and is anticipated to bring a range of other benefits for patients and pharmacists. From a pharmacy perspective, it will reduce the possibility of incorrect medicines being dispensed to patients, by alleviating the need to manually input prescription data, and also give scope to improve pharmacy workflow and stock control. A significant benefit of the EPS is to reduce the paper administration with current prescribing and dispensing processes by enabling prescriptions to be generated, transmitted and received electronically. Dispensers will further submit reimbursement endorsements electronically to support claims for payment for medication and appliances supplied. Paper-based prescriptions will thus be reduced over time.

The EPS is being delivered in two main stages: Release 1 and Release 2. Moving from Release 1 to 2 is not expected to cause patients confusion. An addition is a barcode on the prescription form (which does not contain any patient details). When a GP prints out this "barcoded" form, an electronic copy of the prescription is automatically sent to the EPS. The barcode on the form contains a unique reference number which matches the prescription to the electronic copy. When a patient takes this prescription to a pharmacy that has also implemented Release 1, the dispenser will scan the barcode to retrieve the prescription details onto their system. If a patient takes a prescription form to a pharmacy that has not yet implemented Release 1 of the service, they can still obtain their medication in the usual way.

When Release 2 is implemented, the GP will be able to apply an electronic signature to the electronic prescription, making the need for a paper version obsolete. If they wish to, patients will be able to nominate a pharmacy for their prescriptions to be sent to automatically, meaning they will not need to visit their GP to collect repeat prescriptions. Patients will still be able to request a paper copy of their prescription if they prefer. Release 1 of the service is now in use at a number of GP and pharmacy "initial implementer sites." Wider rollout of Release 1 has commenced and it is planned for the Electronic Prescription Service to be fully operational across England potentially by the end of 2007. While patients currently collect repeat prescriptions from dispensers without having to go into the GP surgery, the EPS is intended to streamline this service by reducing pharmacy waiting times enabling dispensers to prepare prescriptions in advance. Other benefits for prescribing staff and dispensers include: signing and cancelling prescriptions electronically, nominating dispensing contractors using the EPS rather than by post, reducing the need to re-key data, managing stock control, and managing the submission of reimbursement endorsements electronically.

Performance

Performance is very much related to effectiveness of the process, its monitoring, and constant evaluation. To evaluate the performance of the EPS, we used process mapping tools to capture an end-to-end picture of the system. End-user perceptions, ownership and training are crucial elements to achieve "best practice" performance. Performance evaluation is not merely based on quantitative assessments but also on qualitative data to highlight the user perceptions of the strengths and weaknesses of the system.

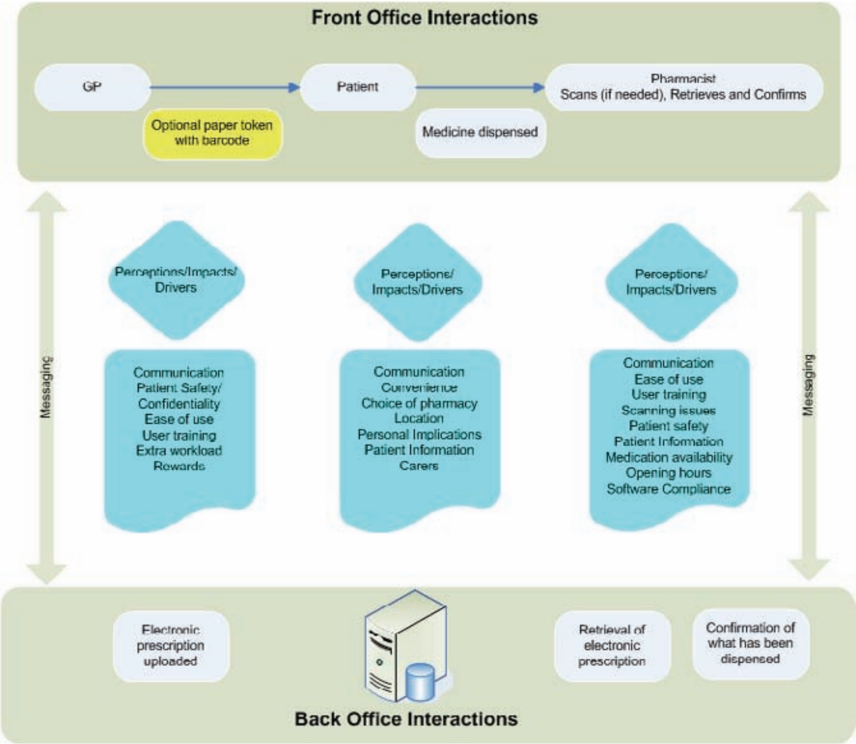
A preliminary study to understand the contemporary environment of EPS was carried out. Our interviews with GPs and retail pharmacists in London and the West Midlands about Release 1 of the EPS and also to gain insights into the Pre Release 2 of EPS highlighted the following performance issues:

1. A clear schedule is needed for the availability of EPS compliant systems from the suppliers
2. Dispensing practices need for EPS compliant software may create financial pressure on PCT
3. Neighbouring PCTs may be applying different registration rules causing confusion for pharmacists
4. Server problems and download times may affect the prescription download
5. All the GP practices would need to be equipped with modern printing technology in order to avoid the scanning issues if paper tokens are provided
6. EPS implementation may increase the Choose & Book system problems experienced in GP practices and vice-versa
7. EPS R2 may increase GP workload without offering any operational benefits
8. PCTs may be dragged into resolving pharmacy system EPS problems because of their responsibility for Role Based Access Control (RBAC) card issue
9. Pharmacists may be given extra work load and may choose to use the paper version of the repeat medication—the usefulness of EPS for repeat medication needs further investigation
10. The impacts of EPS on communication between the GPs and Pharmacists needs to be investigated further. Especially during and post implementation of release 2
11. The aligning of implementation of release 2 whilst release 1 is running in parallel is crucial

Public Perception

Incorporating the public perceptions in the evaluation highlighted issues relating to the vision of EPS and patient choice. The three phases of the EPS implementation—Pre Implementation, Implementation, and Post Implementation—are all relevant as public perceptions may change during each stage. Public perceptions are also related to the ease of use of the system. Part of the rationale for EPS is to provide patients with a more efficient and effective way of getting their medication. The stakeholders identified by Connecting for Health include: general practitioners, community pharmacies, patient and public groups, and an EPS implementation board. One of the key concerns identified by patient groups, for example, is around security of the system. Access to the EPS is controlled through the use

Figure 2. A process map of the EPS



of smartcards and pin numbers enabling different users varying degrees of access appropriate to their role. The PCT has overall responsibility to issue smartcards to users.

Figure 2 gives an example of the EPS. This diagram captures the formal process of the EPS incorporating key stakeholder groups (i.e., GPs, pharmacies, patients). The Front Office interactions present the interactions between the three key stakeholders namely the GP, the Patient, and the Pharmacist. The Back Office interactions highlight the processes needing to be qualified to complete the EPS cycle. While a linear presentation of the EPS is an "ideal type" (Weber, 1947) of the activity under scrutiny, it is recognised that, in reality, formal systems run in parallel with informal systems (Currie, 1989). An understanding of key issues identified in our conceptual framework (i.e., patient safety, process, performance, and public perceptions) must therefore be evaluated in conjunction with those actions and behaviours that reside alongside the explicit ICT design. Failure to recognise this is routinely found to be the cause of numerous ICT failures in both the private and public sectors (Currie, 1995; Willcocks & Lester, 1999).

Figure 2 offers a conceptual tool for evaluating the three phases (pre, during, and post) of the EPS implementation. Interviews with GPs suggested that EPS was one of the least contentious elements of the NPfIT. One GP commented,

The initial problems with the EPS have largely been technical, rather than human. For example, we had some issues with the printers here as they needed to be laser jet printers. Inkjet didn't work. The new printers seem to work now and can produce a barcode without smudge.

While this example may seem trivial, the consequences of poor images through using the wrong type of printer has major implications for the effectiveness of the EPS. Clearly, smudged images could lead to human error at the retail pharmacy and this could have implications for patient safety.

Another GP said, “Our system is not yet compatible but we are told we can get it updated. There has not been sufficient support from above for EPS I think.”

The GPs in the sample tended to think the centrist approach to NPfIT and EPS more specifically was not the most appropriate way to introduce ICTs into healthcare. Part of the problem of this approach is because decision making on ICTs is influenced by financial and practical considerations within a market which is becoming increasingly fragmented. For example, the GPs and pharmacies were independent businesses with profit/loss statements. So the decision to purchase new technology was linked to financial considerations which could conflict with the implementation timescales set out by Connecting for Health.

DISCUSSION AND CONCLUSION

This exploratory research into the EPS, which is part of the NPfIT highlighted some interesting issues concerning patient safety, the process of executing prescriptions, performance indicators, and how GPs and the public perceive ICT-enabled change. While EPS is designed to give patients more flexibility and choice in how they collect their prescriptions, we identified some issues relating to how GPs would interact with retail pharmacies to improve this service. Our conceptual model points to the criticality of evaluating the EPS as an ongoing implementation rather than at particular points in time. For example, the successful transaction between a patient receiving their prescription and collecting it at a retail pharmacy depends not simply on their own input in this process, but whether the GP and pharmacy have invested in technology that facilitates this process. As we saw from the interview data, a simple issue of using the wrong type of printer is likely to disrupt the service, particularly where retail pharmacies are unable to read the data printed.

At the macro level, the EPS is designed as a nation-wide ICT solution, yet our research suggests that its implementation is likely to be patchy rather than seamless across GP and retail pharmacies. The staged approach used by Connecting for Health, where particular sites will be first-mover implementers of the EPS may offer some advantages to others who can learn from past mistakes and errors. However, the standardised approach to this large-scale ICT implementation will also depend on how it will be developed and upgraded and this will depend on the cooperation between GP and pharmacies, particularly as these groups run their own businesses and thus develop their own ICT policies and practices.

An interesting issue relates to the translation at local level of centrist ICT policies, of which NPfIT belongs. Clearly, for EPS to work effectively, GP practices and pharmacies need to invest in the appropriate technology. But as with all technical expenditure, an evaluation of the likely return on investment (ROI) is needed. The perception of whether EPS will result in additional business for pharmacies, or even GP surgeries, is therefore likely to be central to the purchasing decision, as improved service delivery is not an end in itself.

Our conceptual framework offers a general and integrated approach to evaluating the EPS, recognising that each of the four levels represent serious challenges to ICT implementation. We suggest that even minor changes to work practices, for example, are likely to engender significant resources, not least because GPs, retail pharmacies, and patient groups are likely to interpret change differently. Equally, cost savings and performance enhancements may not be perceived as benefits in their own right by different stakeholders. One of the critical elements in large scale ICT change is how to manage expectations. This softer and less tangible aspect of change management is rarely given enough priority by policy-makers, managers, and suppliers, as technology "solutions" are often over-sold to clients. As such, the imposition of performance targets invariably results in a mis-match between client expectations and the supplier's ability to deliver on ICT policy issues. This has resulted in many critical judgements on the NPfIT in the media, often highlighting the failure to meet strict implementation targets. While these issues are relevant, more important concerns relate to managing change as a continuous, iterative process rather than as a linear one. Such an approach does not separate strategy from implementation, but recognises that these areas are linked. Managers need, therefore, to continuously assess how ICTs are changing working practices and whether business processes are being integrated or disjointed as a result.

In summary, we suggest our case data highlights some relevant issues that need to be evaluated on a continuum rather than as a staged activity. Our conceptual model is multidimensional and the variables contained within each layer may change over time, as new issues and concerns are raised. We concur with the findings of the National Audit Office (2006a, 2006bb) that clinical buy-in is imperative in the NPfIT initiative, but we also suggest that concepts of "patient choice" also need to be clarified, particularly as patient experiences do not include ICT design, yet do include participation in using systems, such as EPS, even where there are problems and pitfalls. An evaluation of EPS, and NPfIT more generally, should therefore include not only a silo assessment of how each stakeholder group interacts with technology, but how all the pieces of the jigsaw fit together in terms of patient safety, process, performance, and the public.

ACKNOWLEDGMENT

The authors would like to thank professor Donald Singer, Warwick Medical School, for his comments relating to patient safety issues.

REFERENCES

Bloomfield, B.P. (1991). The role of information systems in the UK national health service: Action at a distance and the fetish of calculation. *Social Studies of Science, 21*, 701-34.

Brennan, S. (2005). *The NHS IT project.* Radcliffe Publishing Ltd.

Brown, T. (2001, November). Modernization or failure? IT development projects in the UK public sector. *Financial Accountability and Management, 17*(4), 363-381.

Burgoyne, J.G., Brown, D.H., Hindle, A., & Mumford, M.J. (1997). A multidisciplinary identification of issues associated with contracting in market-orientated health service reforms. *British Journal of Management, 3*(39), 39-49.

Cabinet Office Transformational Government, Enabled by Technology (2005). Cm 6683. London: The Stationary Office.

Callaghan, G.D., & Wistow, G. (2006). Publics, patients, citizens, consumers? Power and decision making in primary healthcare. *Public Administration, 84*(3), 583-601.

Collins, T. (2003, February 6). Doctors attacks health IT codes. *Computer Weekly, 6*, 4.

Connecting for Health. (2004). Business Plan. Retrieved July 22, 2008, from http://www.connectingforhealth.nhs.uk

Cross, M. (2005, October), Special report: Public sector IT failures. *Prospect*, 48-52.

Currie, W.L. (1989). The art of justifying new technology to top management. *Omega.*

Currie, W.L. (1995). *Management Strategy for IT.* London: Pitman.

Currie, W. (1997). Computerising the stock exchange: A comparison of two information systems. *New Technology, Work and Employment*, *12*(2), 75-83.

Currie, W.L. (2004). The organizing vision of application service provision: a process-oriented analysis. *Information and Organization, 14,* 237-267.

Currie, W.L., & Guah, M.W. (2007, September). A national program for it in the organisational field of healthcare: An example of conflicting institutional logics. *Journal of Information Technology*, 1-13.

Currie, W., & Parikh, M. (2006, June). Value creation in Web services: An integrative model. *Journal of Strategic Information Systems, 15***(2),** 153-174**.**

Currie, G., & Suhomlinova, O. (2006). The impact of institutional forces upon knowledge sharing in the UK NHS: The triumph of professional power and the inconsistency of policy. *Public Administration, 84*(1), 1-30.

Davenport, T.H. (1993). *Process innovation: Reengineering work through information technology.* Boston, MA: Harvard Business School Press.

Davidsen, F et al. (1988). Adverse drug-reactions and drug non-compliance. *European Journal of Clinical Pharmacology, 34,* 83-86.

Department of Health. (2000). NHS plan: An information strategy for the modern NHS. London: Department of Health.

Department of Health. (2002). Delivering 21st century IT support for the NHS. London: Department of Health.

Department of Health. (2007). *The NHS in England: The operating framework for 2007/8.* London: Department of Health.

Doolin, B. (2004). Power and resistance in the implementation of a medical management information system. *Information Systems Journal, 14,* 343-362.

Finnegan, D., & Willcocks, L. (2004). Knowledge management in the introduction of CRM Systems: Tacit/non-codified knowledge transfer, subcultures and impacts. In *Proceedings of The International Management Technology Conference*, Orlando, Florida
Finnegan, D.., & Willcocks, L. (2005, May). Knowledge issues in the introduction of CRM systems: Tacit knowledge, psychological contracts, subcultures and impacts. In *Proceedings of The European Conference in Information Systems,* Regensburg.

Finnegan, D., & Willcocks, L. (2006). Knowledge issues in the implementation of CRM systems. *Journal of Enterprise Information Management, 19*(6).

Finnegan, D.J., & Willcocks, L.P. (2007). *Implementing CRM.* UK: Wiley.

Ham, C. (2004). *Health policy in Britain*. Palgrave: MacMillan.

Hammer, M., & Champy, D. (1990). Reengineering the corporation. Boston, MA: Harvard Business School Press.

Harrison, M.I. (2004). *Implementing change in health systems: Market reforms in health systems in the UK, Sweden and The Netherlands.* London: Sage.

Heathfield, H., Pitty, D., & Hanka, R. (1998). Evaluating information technology in healthcare: Barriers and challenges. *British Medical Journal, 316*, 1959-1961.

Hendy, J., Reeves, B.C., Fulop, N., Huchings, A., & Masseria, C. (2005). Challenges to implementing the national program for information technology: A qualitative study. *British Medical Journal*, 1-6.

Herzlinger, R.E. (1989, March-April). The failed revolution in healthcare – the role of management. *Harvard Business Review,* 95-103.

Huang, J.C., Poulson, B., Newell, S., & Pan, S-L. (2001). ERP systems implementation: A knowledge-focused perspective. *Journal of Decision Systems, 10*(1), 99-117.

Hussain, M.B., Puntmann, V.O., Mayr, M., Khong, T., & Singer, D.R.J. (2006, December). The role of oxidant stress in angiotensin II-mediated contraction of human resistance arteries in the state of health and the presence of cardiovascular disease. *Vascul Pharmacology, 45*(6), 395-399.

Hussain, M.B., Singhal, S., Markus, H.S., & Singer D.R. (2004). Abnormal vasoconstrictor responses to angiotensin II and noradrenaline in isolated small arteries from patients with cerebral autosomal dominant arteriopathy with subcortical infarcts and leukoencephalopathy (CADASIL). *Stroke, 35*, 853-858.

Institute of Medicine (2002). *Crossing the quality chasm: A new health system for the 21st century.* Washington, DC: Committee on Quality Healthcare in America, National Academy Press.

Kelsall, C.J., Chester, A.H., Amrani, M., & Singer D.R.J. (2005). C-type natriuretic peptide relaxes human coronary artery bypass grafts preconstricted by endothelin-1. *Ann Thorac Surg., 80*, 1347-1351.

Khong, T.K., & Singer D.R. (2002). Adverse drug reactions: Current issues and strategies for prevention and management. *Expert Opin Pharmacother, 3,* 1289-1300.

Klein, R. (2001). *The new politics of the NHS* (4th ed.). Harlow, Longman.

Kyu Kim, K., & Michelman, J.E. (1990). An examination of factors for the strategic use of information systems in the healthcare industry. *MIS Quarterly, 14*(2), 201-215.

Luftman, J. (2000). Assessing business IT alignment maturity. *Communications of the AIS, 4*(14), 1-51.

McNulty, T., & Ferlie, E. (2002). *Re-engineering healthcare: The complexities of organisational transformation*. Oxford: Oxford University Press.

McNulty, T., & Ferlie, E. (2004). Process transformation: Limitations to radical organisational change within public service. *Organisation Studies, 25*(8), 1389-1412.

Miles, M.B., & Huberman, A.M. (1994). *Qualitative data analysis*. Sage.

Missouris, C.G., & Swift, P.A., & Singer D.R.J. (2001). Cocaine use and acute left ventricular dysfunction. *Lancet, 357*, 1586.

Mohan, J. (2002). *Planning, markets and hospitals.* London: Routledge.

National Audit Office. (2003, November, 5). *Improving IT procurement*. Report by the Comptroller and Auditor General, HC 877 Session 2003-4. London: The Stationary Office.

National Audit Office. (2006a, June 16). *The National programme for IT in the NHS*. Report by the Comptroller and Auditor General, HC 1173 Session 2005-2006. London: The Stationary Office.

National Audit Office. (2006b, November 17). *Delivering successful IT-enabled business change.* Report by the Comptroller and Auditor General, HC 33-1 Session 2006-2007. London: The Stationary Office.

Nicolson, T.R.J., & Singer, D.R.G. (Eds.). (2004, 2006). Pocket prescriber, Hodder (1st ed.).

Pirmohamed, M. et al. (2004). Adverse drug reactions as cause of admission to hospital. *British Medical Journal, 329,* 15-19.

Pollock, A. (2005). *NHS plc: The privatisation of our healthcare*. London: Verso.

Puddy, V.F., Amirmansour, C., Williams, A.F., & Singer, D.R.J. (2002). Plasma brain natriuretic peptide as a predictor of haemodynamically significant patent ductus arteriosus in preterm infants. *Clinical Science, 103,* 75-77.

Puntmann, V.O., Hussain, M.B., Mayr, M., Xu, Q., & Singer, D.R.J. (2005, October). Role of oxidative stress in angiotensin-II mediated contraction of human conduit arteries in patients with cardiovascular disease. *Vascul Pharmacol., 43*(4), 277-282.

Scott, W.R., Ruef, M., Mendel, P.J., & Caronna, C.A. (2000). *Institutional change and healthcare organizations.* Chicago: University of Chicago Press.

Singh, N., Graves, J., Taylor, P., MacAllister, R.J., & Singer, D. (2002). Effects of a healthy diet and of acute and long-term vitamin C on vascular function in healthy older subjects. *Cardiovasc Research, 56*, 118-125.

Singer, D.R.J., & Singh, N. (2002). Left ventricular mass, arterial compliance and high risk of coronary heart disease in South Asians. *Int J Cardiol., 83,* 9-11.

Tyre, M.J., & Orlikowski, W.J. (1994). Windows of opportunity: Temporal patterns of technological adaptation in organizations. *Organization Science, 5*(1), 98-118.

Wanless, D. (2002, April). *Securing our future health: Taking a long-term view*. Final Report of an Independent Review of the long-term resource requirement for the NHS. London. Retrieved July 22, 2008, from www.hm-treasury.gov.uk/Consultations_and_Legislation

Weber, M. (1947). *The theory of social and economic organization*. New York: Free Press.

Willcocks, L., & Currie, W.L. (1997). Pursuing the re-engineering agenda in public administration. *Public Administration, 75*(4), 617-650.

Willcocks, L., & Lester, S. (1999). Information technology and organizational performance. In R.D. Galliers, D.E. Leidner, & B. Baker (Eds.), *Strategic information management*. Butterworth-Heinemann.

Winch, G.W., & Derrick, S. (2006). Flexible study processes in knotty system dynamics projects. *System Research and Behavioral Science, 23*(4), 497-507.

Winch, G.W., Derrick, S., Chandler, J., Badger, B., & Nokes, T. (2006). Exploring the training/service balance of senior house officer activities. *Medical Education, 40*(4), 355-362.

Winch, G.W., Joyce, P., & Green, R. (2006). A new construct for visualising and designing e-fulfilment systems for quality healthcare delivery [Special issue on sustainable quality services in the healthcare industry]. *The TQM Magazine, 18*(6), 638-651.

Wyatt, J.F. (1998). Four barriers to realising the information revolution in healthcare. In J. Lenaghan (Ed.), *Rethinking IT & health* (pp. 100-122). London: Institute for Public Policy Research.

Yin, R.K. (1994). *Case study research*. Sage. Retrieved July 22, 2008, from /wanless/consult/wanless_final.cfm

This work was previously published in Journal of Cases on Information Technology, Vol. 10, Issue 4, edited by M. Khosrow-Pour, pp. 1-16, copyright 2008 by IGI Publishing (an imprint of IGI Global).

Chapter 4.16

Developing a User Centered Model for Ubiquitous Healthcare System Implementation:

An Empirical Study

Jongtae Yu
Mississippi State University, USA

Chengqi Guo
Mississippi State University, USA

Mincheol Kim
Cheju National University, South Korea

ABSTRACT

In the advent of pervasive computing technologies, the ubiquitous healthcare information system, or u-health system, has emerged as an innovative avenue for many healthcare management issues. Drawing upon practices in healthcare industry and conceptual developments in information systems research, this article aims to explain the latent relationships amongst user-oriented factors that lead to individual's adoption of the new technology. Specifically, this study focuses on the introduction of chronic disease u-health system. Using the ordinary line square (OLS) regression analysis, we are able to discover the insights concerning which constructs affect service subscriber's behavioral intention of use. Based on the data collected from over 440 respondents, empirical evidences are presented to support that factors such as medical conditions, perceived need, consumer behavior, and effort expectancy significantly influence the formation of usage intention.

INTRODUCTION

Ubiquitous computing can be defined as the "contemplation of today's computers communicating each other through wireless network in actual activities of everyday life" (Weiser, 1993a; 1993b).

Some articulate such a concept as the embedded computers in walls, refrigerator, tables, and objects in the surrounding environment (Rhodes & Mase, 2006). In other words, the computer is expected to become a ubiquitous resource, much similar to the light with a switch and water with a tap. Two functionalities, computing tasks and telecommunications, are required to realize the features of ubiquitous computing such as localized information, localized control, and resource management (Weiser, 1993a; Rhodes & Mase, 2006). The evolving mobile technology has expanded the applicability of ubiquitous computing to areas including virtual reality, head mounted display (HMD), wearable computing, and smart office room (Weiser, 1993b).

An agile, responsive, and location-aware service delivery system is highly desired by the healthcare management business. Correspondingly, ubiquitous computing allows patients to receive prompt medical care anywhere (home, office, outdoor, or hospital) and any time (24 hours/7 days), thus improving the service quality and decreasing the risk of medical treatment failures. For example, a doctor can check the status of a patient in a real-time manner using the sensor which is installed in patient's home or attached to the patient's body. In case of emergency, the sensor can detect changes of the patient's health condition in the early stage and automatically contact the designated hospital to initiate treatment procedure. In summary, we define the u-health system as the use of ubiquitous computing technologies to support expeditious and personalized communications, activities, and transactions between a medical service provider and its various stakeholders. In the literature review section, Figure 3 describes the layout of the u-health system and its associated stakeholders.

Despite the strong potential of the technology, however, the studies of ubiquitous healthcare services are not widely conducted. Existing literature has focused mostly on pure technical concerns or system development process; whereas managerial issues and behavior perspectives of the u-health system application are largely overlooked. In this article, the authors discuss the issue of applying ubiquitous computing technology to healthcare management from end user's perspective. The main goal of this article is to identify and investigate the factors and their inter-relationships that affect end user's intention of adopting u-health system. For example, one critical factor is effort expectancy, which refers to the degree to which the user believes it is easy to use the technology. Theoretically, the effort expectancy is positively correlated with behavioral intention of use, namely, the easier the user finds to use the product, the more likely s/he will adopt it. A more thorough articulation of these factors can be found in the Research Model and Hypotheses section.

Realizing that the scope of healthcare discussion can be extremely broad, we focus our attention on chronic disease treatment in this research. A main question to be addressed is what factors influence end user's perception about the u-health system and how these factors are related with each other. Therefore, an investigation of people's subjective perception is warranted. The authors select South Korea as the place for data collection because first, people in South Korea have a high level of concern about health issues, especially chronic diseases. Largely due to the rapidly changing socio-economic structure, more than 16% of total population is reported to suffer from chronic diseases. According to a report by the Korean National Insurance Corporation (2007), South Korea is among one of the top countries that are mostly concerned with chronic diseases; second, South Korea has one of the highest mobile technology penetration rates in the world, thus providing a suitable environment for studying ubiquitous healthcare technology. In South Korea, more than 85% of Koreans use at least one cellular phone and subscribe wireless value added service (Shim, 2007).

Regarding the organization of this study, the authors first examine the current knowledge base in both medical research and supportive technology aspects. Such literature review process enables us to consolidate theoretical and practical findings so that a research model is developed to cater for our core research issue—understanding the perceptions of chronic disease patient towards u-health system. Next, we present the data analysis results that empirically validate the proposed hypotheses. At last, we conclude our findings and contributions.

LITERATURE REVIEW

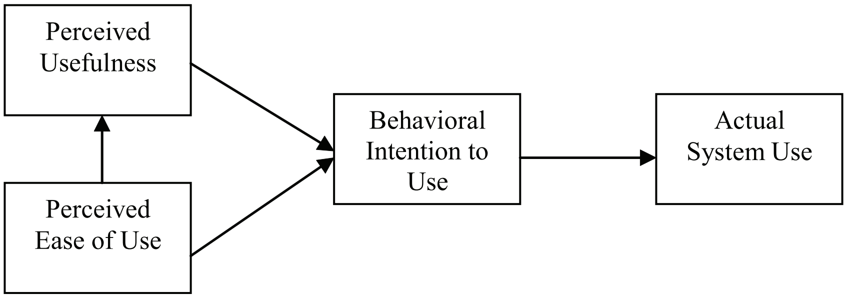
It is widely recognized that the IT innovation has historically and continually benefited healthcare business in numerous aspects. For instance, collaborative computer system allows healthcare workers to reengineer and streamline business processes within medical service life cycle by leveraging software and network applications. In the case of u-health system implementation, we need to consider both soft and hard factors. Soft factors are subtle factors containing people's experiences, feelings and perceptions; whereas hard factors refer to the instantiations of computing technology (e.g,. a HIPPA-compliant patient accounts management system). Following such idea, the purpose of reviewing previous literature is two-fold: to establish the scope of this study; to build preliminary ground work for utilizing earlier findings in the area of healthcare management to guide our research activities.

Prior Research in Healthcare Management Information Systems

The evolution of HMIS can be summarized as a transferring process from isolation to integration (Briggs, Nunamaker, & Sprague, 2005). Initially installed in stand alone PCs, HMIS took shape among segments of healthcare management process, such as drug inventory and account administration (Tan, 1995). Due to the soaring operational cost of healthcare and increasing need for cross-boundary collaboration (Bandyopadhyay & Schkade, 2000), a true HMIS was introduced and adopted by organizations including the Health Maintenance Organization (HMO). Information and communication technology provides healthcare industry with capabilities to perform tasks that are deemed impossible in the past. For instance, a medical center uses broadband video conferencing technology to enable a group of specialists to examine the patient, who is located in a far- distanced hospital.

Since technology adoption has been considered as one of the main driving forces behind the growth of healthcare expenditures (Barros, Pinto, & Machado, 1999), numerous studies have been done to investigate the factors influencing HMIS adoption on the organization's side (Wong & Legnini, 2000; Berta et al., 2005). These studies make contributions in terms of designing and validating cost-effective procedures that facilitate system adoption process and identifying envi-

Figure 1. The TAM model (Davis, 1989)



ronmental factors that influence the success of systems adoption. On the other hand, the authors found that extensive attention has been put on physicians' intention of using invested information technology (IT) products. However, further research is needed to investigate the role of the patient, who is the ultimate service subscriber, in the process of healthcare system implementation (Hu, Chau, Sheng, & Tam, 1999). Another viable lens for explaining subscriber side information system usage is the technology adoption model (TAM), which was formalized by F.D. Davis in 1989. Davis argued that the user's intention of use is essentially determined by two constructs: perceived usefulness (PU) and perceived ease of use (PEOU), as seen in Figure 1.

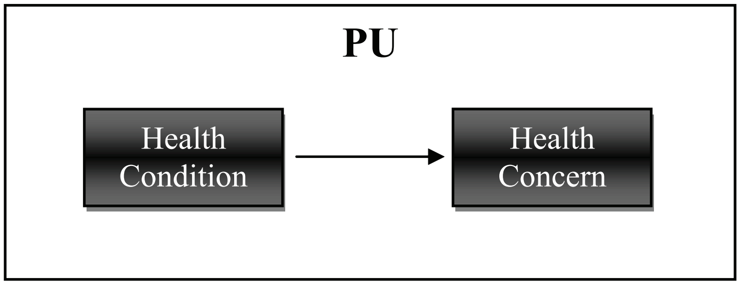
Parsimonious and generalizable notwithstanding, TAM becomes less robust in this research context because it fails to address some unique dimensions of u-health technology adoption. Therefore, we need modifications (e.g., broken down PU) that customize TAM constructs so as to accommodate the issue of chronic disease healthcare management. For instance, PU can be articulated as the formative relationship between health condition and health concern, as shown in Figure 2. The patient's awareness of his/her health condition leads to health concerns, which essentially form the evaluation of PU of suggested medical solutions. In this way, an example has been set up concerning how PU can be adjusted to apply technology acceptance theory under different research topics. A comprehensive discussion of research model construction is presented in the Research Model and Hypotheses section.

The U-Health System Concept and Targeted Problem Domain

Leveraging computing devices that are available yet invisible in the physical environment , u-health system is a built-in application combining technologies, methods, and procedures that aim to monitor, maintain, and improve individual's health condition (Park, 2003). One salient feature of u-health system is the anytime anywhere accessibility, which allows the real-time information of patient to be collected and then transmitted to medical organization for a cure or diagnosis (Yoo, 2006). With its surging penetration rate in global range, personal mobile device such as cellular phone offers an important platform on which the u-health system concept can be realized. The challenge, however, lies in the seamless integration between mobile technology and the existing data network infrastructure.

This study put a specific focus on the implementation of the u-health system in South Korea for chronic disease patients, whose number is increasing steadily and raises health concerns of the society. Treating chronic disease such as diabetes, tuberculosis, and anemia requires long-term treating efforts and care from both patient and medical center. In addition, effective communication between patients and medical service provider is critical in stabilizing patient's condition

Figure 2. Modifying PU (Davis, 1989)



(e.g., diabetes). Hence, the u-health system offers a promising solution that enhances information dissemination throughout the healthcare service delivery cycle. A visual description of a typical the u-health system implementation is presented in Figure 3. Using wired and wireless network, the u-health system has the following advantages (Korean National Insurance Corporation, 2007):

- Delivering a time-efficient medical service
- Automating communications among stakeholders
- Real-time detection of patient's conditions
- Easy portability of patient's historical medical records and prescriptions
- High level of accessibility and flexibility mitigating the effects of time and place constraints

In Figure 3, a sensor, which can be a patient's cellular phone or wearable computing device, measures the health status of the patient and transmits the information to u-health service provider, who maintains a large collection of patients' records in a database server. The patient's status is then forwarded to medical personnel in the hospital for diagnosis and possible treatment, which can be transmitted back to the patient over the same network.

RESEARCH MODEL AND HYPOTHESES

Many of the contemporary health problems, especially chronic diseases, are mostly related with life style changes such as smoking or unhealthy dietary pattern (McKeown, 1971; Riska, 1982). The medical research model that is based on individualistic-mechanistic notion of disease argues that an individual's willingness to improve his/her health status results in the changes of his/her behavior and thus promotes health status positively (Cohen & Cohen, 1978). Such willingness can be generated and motivated by the perceived personal health condition, namely, the medical concern. An individual who has a negative evaluation of his/her health condition is proactive to adopt healthcare service or activity that is believed to improve one's health condition (Lahiri & Xing, 2004). Further, health condition is considered a critical starting point in the healthcare utilization process (Windmeijer & Santos Silva, 1997). Therefore, it is assumed that a negatively perceived health condition leads to more medical service usage or activity to improve the health status.

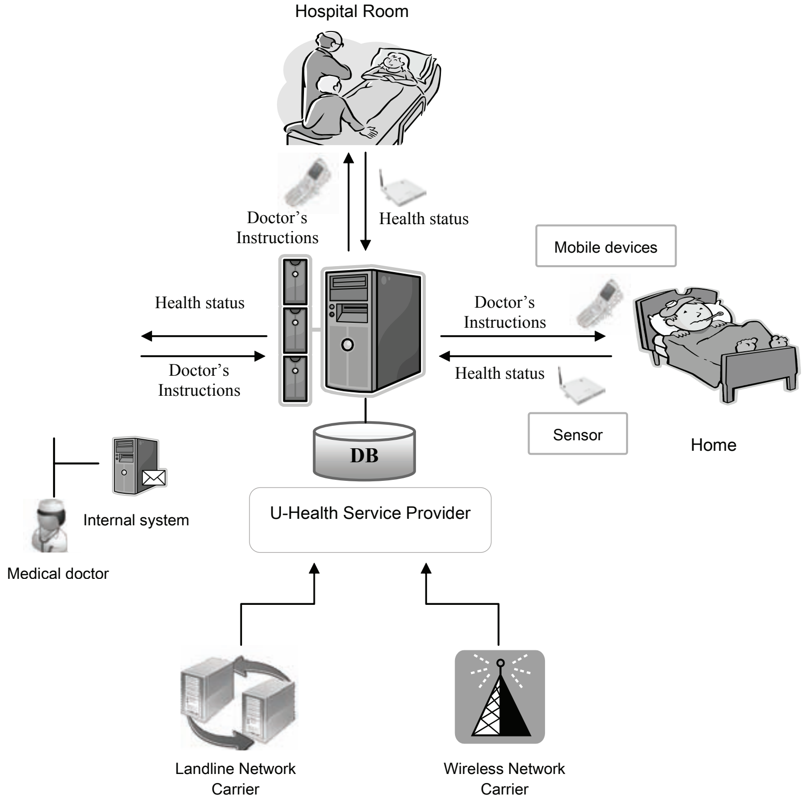
When people perceive health problems, they are likely to raise their health concerns about subsequent medical consequences. Such concern, in turn, can lead to certain activities including health information seeking, adherence to treatment, and interpretation of symptoms (Uskul & Hynie, 2007). Earlier studies have argued that the Internet has become the new alternative source of healthcare information (Eysenbach & Köhler, 2003; Madden, 2003; Morahan-Martin, 2004). Other research has suggested that patients diagnosed with chronic diseases appear to be active in seeking the medical information. Therefore, a high level of concern about health problem and consequence leads to more active medical service usage. Hence, it is important to specify and validate the mediating effect of medical concern, as shown in Figure 4, between medical condition and action taking.

Following the previous discussion, the authors contend that individuals who are actively involved with preventive or restorative healthcare measures are more likely to use the u-health service. Such argument can be further decomposed into the following hypotheses:

H1: *High level of medical concern leads to active medical activity.*

H2: *Perceived medical condition leads to active medical activity.*

Figure 3. The u-health system

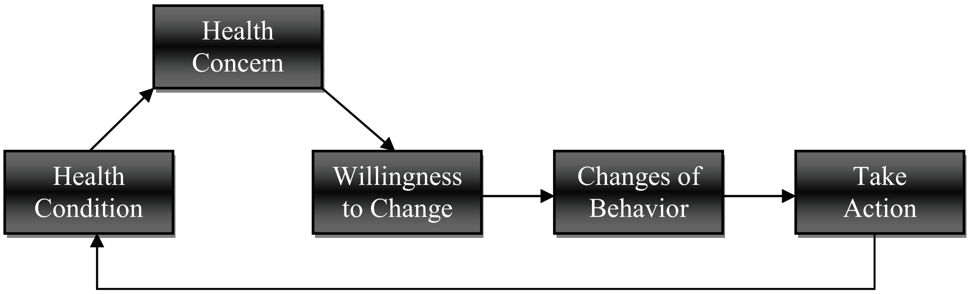


H3: *Perceived medical concern mediates the relationship between medical condition and medical activity.*

H4: *Active medical activity leads to behavioral intention of use.*

Specifying the relation between consumer needs and purchase intention has been a major research topic across various fields (Bhaskaran & Hardley, 2002; Odom, Kumar, & Saunders, 2002; Burke & Payton, 2006; Chae, Black, & Heitmeyer, 2006; Kervenoael, Soopramanien, Elms, & Hallsworth, 2006). The capability of identifying and satisfying the consumer's needs basically determines the success

Figure 4. Mediating effect of medical concern



of promoting a certain product or service (Lahiri & Xing, 2004). Several studies (e.g., Junginger et al., 2006; Zhang, Fang, & Olivia, 2007) have provided strong evidence indicating the effects of consumer's perceived need on the purchase intention. On the other hand, such need is positively correlated with perceived quality and perceived usefulness of the service or product. Moreover, users accept new technology when they expect certain performance improvement in completing tasks. If people believe the technology will be useful in increasing their job performance, they are more likely to adopt the technology (Davis, 1989; Venkatesh et al., 2003). Hence, we hypothesize that:

H5: *High level of perceived need for the u-health system leads to behavioral intention of use.*

It has been established in previous IS adoption literature that the behavioral intention of use is affected, although not exclusively, by effort expectancy, which is defined as the degree of ease associated with the use of the system (Venkatesh et al., 2003). The concept of effort expectancy is rooted in earlier constructs such as perceived ease of use in technology adoption model (TAM) (Davis, 1989) and perceived level of difficulty in theory of reasoned action (TRA) (Ajzen & Fishbein, 1975). In our research model, we articulate effort expectancy in two dimensions: experience and consumer behavior. Several studies have identified how significantly experience (e.g., learning) is related to job performance (Guido, 2007; Ngwenyama, Guergachi, & McLaren, 2007). These results strongly support the argument that experienced workers are more efficient and more productive in performing tasks than less experienced ones. Hence, it is inferred that experienced users of ubiquitous or mobile technology are more likely to use the medical service offered through

Figure 5. The Research Model

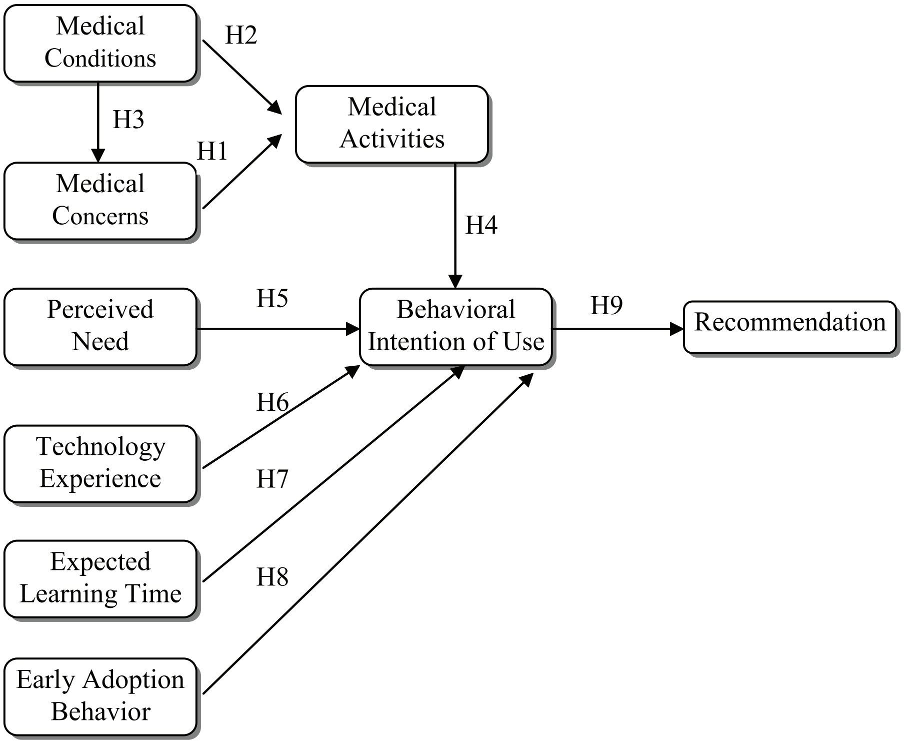


Table 1.The nine hypotheses

	Independent Variable	Dependent Variable	Description
H1	Medical Concerns	Medical Activities	High level of medical concern leads to active medical activity.
H2	Medical Conditions	Medical Activities	Perceived medical condition leads to active medical activity.
H3	Medical Conditions	Medical Concerns	Perceived medical concern mediates the relationship between medical condition and medical activity.
H4	Medical Activities	Behavioral Intention	Active medical activity leads to behavioral intention of use.
H5	Perceived Need	Behavioral Intention	High level of perceived need for u-health system leads to behavioral intention of use.
H6	Technology Experience	Behavioral Intention	High level of mobile technology experience leads to behavioral intention of use.
H7	Expected Learning Time	Behavioral Intention	Low level of expected time to learn how to use u-health system leads to behavioral intention of use.
H8	Early Adoption Behavior	Behavioral Intention	Early adopter behavior leads to behavioral intention of use.
H9	Behavioral Intention	Recommendation	High level of behavioral intention of use leads to recommendation.

the u-health system, namely, the less time a user needs to learn how to use u-health system indicates a lower level of adoption barrier.

Consumer behavior theory classifies the types of consumers according to how early they purchase the products. Innovators, or early adopters, are willing to take perceived risks to adopt newly introduced technology. So it is expected that an individual who follows the behavior of innovator would adopt the u-health service earlier than the follower or late adopter. Some researchers have identified certain correlation between the early adoption behavior and business success on the organizational level. For instance, Hendricks and his colleagues (2007) point out that early adopter firms report higher profitability improvements of ERP systems than late ERP adopter firms. Moreover, Smith (2006) suggests that large companies are inclined to be the early adopter of mobile commerce and thus reap the first mover benefits. To sum up, we hypothesized that:

H6: *High level of mobile technology experience leads to behavioral intention of use.*

H7: *Low level of expected time to learn how to use u-health system leads to behavioral intention of use.*

H8: *Early adopter behavior leads to behavioral intention of use.*

Finally, the recommendation construct is considered in our model because, for managers, it is critical to estimate the future purchase or repurchase of the services or products (Gupta & Stewart, 1996; Morgan & Rego, 2006). Hence, the hypothesis of the inter-relationship between behavioral intention of the u-health system use and customer recommendation is stated as the following:

H9: *High level of behavioral intention of use leads to recommendation.*

Based on the above hypotheses, we propose our research model in Figure 5. In addition, we summarize the previous hypotheses in Table 1.

RESEARCH METHODOLOGY

To test the hypotheses, the authors employ the ordinary line square (OLS) regression analysis to pinpoint predictor variables' contribution in explaining the variances of dependent variable—behavioral intention of use, which is also a mediator variable that describes how recommendation effects will occur. In academia, it has always been a fundamental dilemma for social researchers when attempting to maximize the three dimensions of research methodology: generalizability, precision, and realism. In other words, one cannot increase one of these three features without reducing the other one or two (McGrath, 1982). Therefore, it is up to researchers to justify their selection of research process that has the best goodness of fit with the research context. In this case, the authors determine to focus on the generalizability dimension mainly because the aim of this research is to obtain a finding that can be generalized to wider population, namely, chronic disease patients. Although a certain level of the in-depth knowledge is lost, it would essentially lead to another research project, such as a qualitative case study, that can make up for the deficiency.

As mentioned earlier, the research design of this study aims to account for usage intention formulation of u-health system that provides services to chronic patients. However, it is generally difficult to directly assess the quality of prescription service, especially in the case of chronic patient. The expertise of healthcare professional, the capability of healthcare system, and communication with the customer play respective roles in determining the service quality. The authors contend that it is not our top priority to validate strengths of u-health system in the aspect of service quality improvement, but to scrutinize the factors influencing the user's perception of adopting the system. To administrate the data collection process, a broad range of survey was distributed in South Korea, where there is a high level of concern about chronic disease. As a rule of thumb in social research, the satisfactory sample size is 200 effective responses at least. In this research, the authors were able to obtain effective surveys from 447 respondents and thus achieving a good sample size in order to warrant the significance of statistical findings. In terms of respondents' characteristics, most of feedbacks were collected from people who are aware of or understand chronic disease and have experience in using wireless computing technology.

Data Analysis and Results

In this section, the results are presented according to the following order: healthcare- related factors, perceived need, effort expectancy, and recommendation.

Healthcare Related Factors

As shown in Table 2, the medical concerns (H1) and medical conditions (H2) positively affect medical activities. In other words, individuals with a high level of medical concern, or poor medical condition, are more likely to be involved with medical activities such as taking medicine and regular exercising to maintain or to improve their health status.

To test the mediate effect, in which medical condition leads to medical activity through medical concern, the authors employ the four-step

Table 2. Test of the influence of medical concern and condition on medical activities

Model	Un-standardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	1.214	.204		5.949	.000
medical concern	.241	.037	.270	6.541	.000
medical condition	.225	.023	.399	9.670	.000

F=73.698, p=0.000, R^2=0.249.

approach proposed by Baron and Kenny (1986). The first step is to examine the direct effect of independent variable (medical condition) on dependent variable (medical activity). The second step is to test the relation between independent variable and mediate variable (medical concern). The third step is to conduct regression analysis focusing on the inter-relationship between mediate variable and dependent variable. The final step is to conduct regression analysis of the overall effects of independent variable and mediate variable on dependent variable. The mediate effect is proved to be significant when the effect of the coefficient in the first step is *not* significantly different from zero *and* the coefficient in the third step is significantly greater than zero. If both conditions are satisfied, a fully mediated model is said to be found (Frazier & Tix, 2004). In this study, Table 3 indicates that the effect of medical condition on the medical activity through the medical concern (H3) denotes partially instead of fully mediated relationship. The major reason is because the coefficient of medical condition is significantly different from zero while the coefficient of the medical concern is also significantly greater than zero. Hence, it is argued that medical concern partially mediates the formative relationship between perceived health condition and medical activity.

The results in Table 4 show that the effect of medical activities on the behavioral intention (H4) is not significant in this case. However, the scatter plot, as shown in Figure 6, provides an alternative explanation that the relationship between the two variables is not linear. In the plot, behavioral intention (Y-axis) appears to be significant in the left and right areas across the line of medical activities (X-axis). In the middle area of medical activities, however, the correlation is scattered and loose.

Table 3. Test of the influence of medical condition on medical concerns

Step	Model	Un-standardized Coefficients		T	Sig.
		B	Std. Error		
Step 1	Medical condition → medical activity	.237	.024	9.779	.000
Step 2	Medical condition → medical concern	.051	.030	1.700	.090
Step 3	Medical concern → medical activity	.270	.040	6.680	.000
Step 4	Medical condition & concern → medical activity	.225	.023	9.670	.000[a]
		.241	.037	6.541	.000[b]

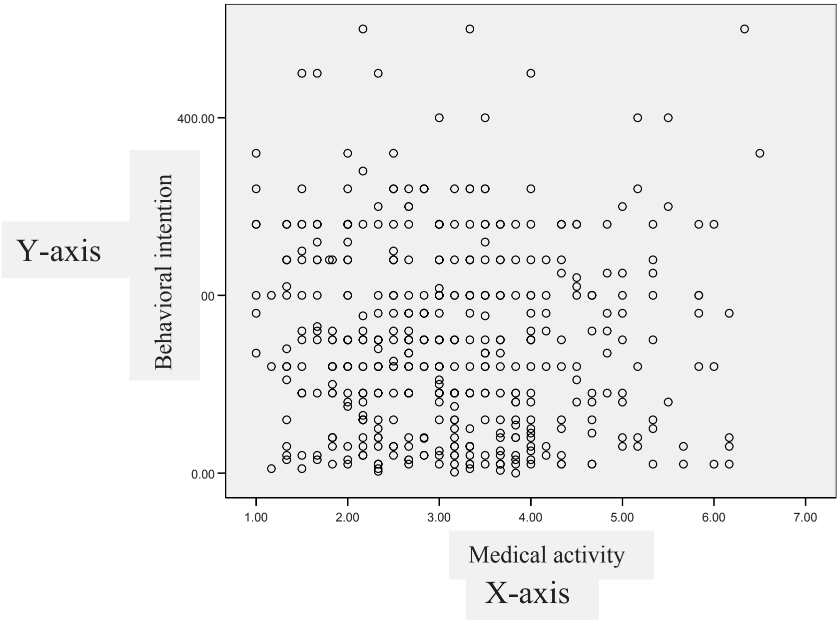
a-medical condition / b-medical concern.

Table 4. Test of the influence of medical activities on behavioral intention

Model	Un-standardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	156.926	14.136		11.101	.000
medical activities	-2.869	4.237	-.032	-.677	.499

F=.458, p=.499.

Figure 6. The scatter plot between medical activities and behavioral intention



Such u-shaped regression curve is subject to receiving two transformations in statistical analysis: logarithmic form and quadratic form. In this study, quadratic model is applied and the correlation between medical activities and behavioral intention is significant at LOS .05, as shown in Table 5 and Figure 7.

It can be inferred from previous discussion that individuals in two extreme groups are more prone to use u-health system. Those in the right extreme (high medical activity group) have higher concerns and poorer health condition than other groups. Such concerns and conditions would lead to the usage of innovative technology that might be helpful to improve their health status. On the other hand, the individuals in the left extreme (low medical activity group) do not give much attention to their health status due to several restrictions. For example, because of high work pressure, many employees have a difficult time arranging healthcare consulting service on a regular basis, which serves as a complementary reason for increasing cases of chronic diseases. Therefore, these people may realize the potential advantage of u-health system and thus believe that u-health system is able to eliminate the restrictions of accessing medical services. Individuals who are in the middle group may be satisfied with the current treatments for

Table 5. Test of the influence of medical activities on behavioral intention (Quadratic model)

Equation	Parameter Estimates		
	Constant	b1	b2
Quadratic	236.413	-55.900	7.737

F=3.889, p=0.021, R^2=0.017.

their health status management and find few benefits in seeking other solutions due to the economic lock-in effect.

Perceived Need

Referring back to the literature review, we have found a plethora of theoretical arguments validating and explaining the relationship between the customer's perceived need and purchase attention. Such argument is also verified in this research context. According to the statistical results shown in Table 6, the perceived need (H5) for u-health system positively affects behavioral intention. It strongly supports the fact that individuals having a high demand for u-health system are more likely to use the service than those who have lower need.

Effort Expectancy

In Table 7, the analysis of effort expectancy indicates that early adoption behavior (H8) and expected learning time (H7) for considering adoption are negatively connected with behavioral intention at the 0.05 level of significance. It is relatively easy

Figure 7. The scatter plot of quadratic estimation between medical activities and behavioral intention

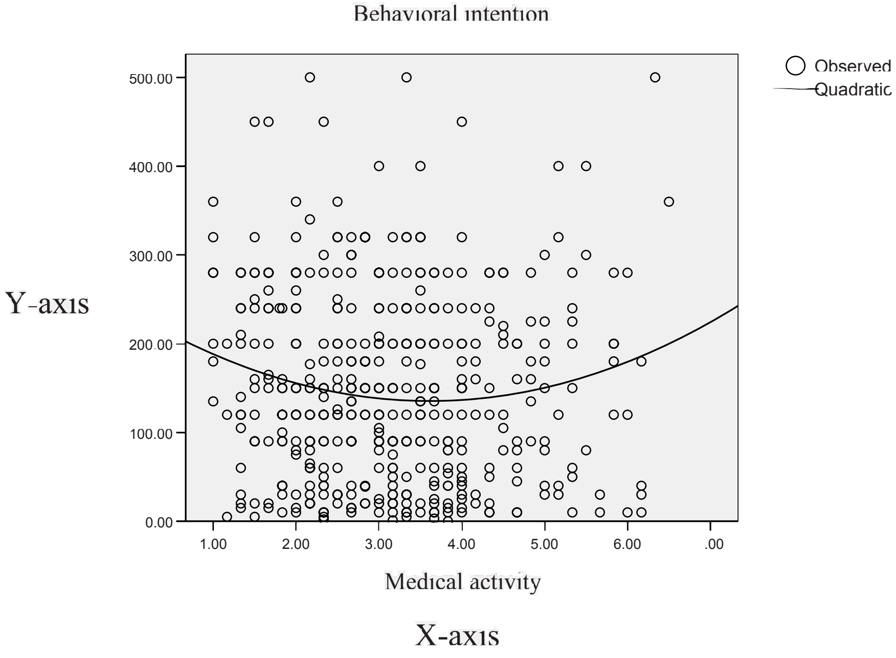


Table 6. Test of the influence of perceived need on behavioral intention

Model	Un-standardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	51.293	16.126		3.181	.002
Perceived Need	20.586	3.229	.323	6.375	.000

F=40.640, p=0.000, R^2=0.104.

to consider that the less learning time is needed to use the system, the more likely the behavioral intention of use can be formed. Whereas for H8, since we use a reverse scale, that is, 1 represents strong and 5 means weak, for measuring early adoption behavior, there is negative correlation between those two factors. In congruence with the theory, individuals who are early adopters are more likely to accept u-health service. However, experience of using mobile technology (H6) is not significant at the 0.05 level. It can be attributed to the high mobile technology penetration rate in South Korea. Since people are already skillful in using mobile device, there is lack of concern in technology experience that leads to behavioral intention of u-health system use.

Recommendations

According to the data analysis (shown in Table 8), higher behavioral intention leads to higher recommendation, which encourages the continuance of system use and reuse through customer recommendation after initial adoption behavior.

The results for all hypotheses testing are summarized in Table 9. An individual would not take action until s/he perceives his/her medical condition, which are supported in H1, H2 and H3. The impact of medical activities to behavioral intention of using medical product (e.g., u-health system) is non-linear. Tow groups of individuals, high medical activity group, those who have higher concerns and poorer health condition, and low medical activity group, those who do not give much attention to their health status due to some restrictions (e.g., tight working schedule), are estimated to have a high desire of adopting convenient healthcare services enabled by IT. The perceived need of individual leads to positive formation of behavioral intention of use. Whereas people will be reluctant in adopting the product if it takes too much efforts and the learning curve is too long, which leads to another inference

Table 7. Test of the influence of adoption behavior, experience, and expected time on behavioral intention

Model	Un-standardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	311.662	21.742		14.335	.000
Adoption behavior	-13.440	6.803	-.126	-1.976	.049
Experience	2.143	1.266	.100	1.693	.092
Expected time	-23.756	4.215	-.352	-5.637	.000

F=18.103, p=0.000, R^2=0.180.

Table 8. Test of the influence of behavioral intention on recommendation

Model	Un-standardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	.511	.035		14.498	.000
Behavioral Intention	.001	.000	.314	6.980	.000

F=48.718, p=0.05, R^2=0.099.

that the early adopters of new technology is estimated to have a lower barrier to embrace the new system. Once the behavioral intention is formed, the user is likely to recommend the product to others based on the previous positive experience obtained.

DISCUSSION AND CONCLUSION

The authors argue that consumer's intention of using the u-health system can be better understood if it is viewed through a multi-faceted framework. In this article, we draw upon literature from different paradigms including specific medical research and technology acceptance and use. The article's basic premise is that medical factors, perceived economic needs, and effort expectancy exert formative impacts on the consumer's behavioral intention. Such premise is then broken into a series of hypotheses in Table 9 extending the discussion to a further detailed level. By validating these assumptions, we are able to obtain more insights in terms of how key adoption factors interact with each other.

Table 9. Summary of Hypotheses Testing

	Independent Variable	Dependent Variable	Hypothesized Effect	Support
H1	Medical Concerns	Medical Activities	Positive	Yes[1]
H2	Medical Conditions	Medical Activities	Positive	Yes
H3	Medical Conditions	Medical Concerns	Positive	Yes (Partially)
H4	Medical Activities	Behavioral Intention	Positive	No (Non-linear)
H5	Perceived Need	Behavioral Intention	Positive	Yes
H6	Technology Experience	Behavioral Intention	Positive	No
H7	Expected Learning Time	Behavioral Intention	Negative	Yes
H8	Early Adoption Behavior	Behavioral Intention	Negative[2]	Yes
H9	Behavioral Intention	Recommendation	Positive	Yes

1. *The default level of significance for all hypotheses testing is .05.*
2. *Revere scales are used for the measurement.*

The statistical findings contend that a high level of health concern and perceived health condition positively lead to relevant medical activities including regular sport exercises and consulting with doctors. Although the data analysis does not support direct formative relationship between medical activities and actual u-health system adoption (e.g., people who visit doctors might not intend to use the u-health system), a further investigation on the data indicates that two groups of potential users—people who have a high level of health concerns and poor health condition and people who are unable to manage their health issues due to limitations such as severe work pressure—are more likely to use the system. Moreover, as many other studies have argued, the perceived need or perceived value of the system is found positively related with behavioral intention of use. In congruence with seminal theories including TAM, the study shows that individuals who are early adopters are more likely to accept u-health service since the expected learning cycle is short, or, the system is easy to use. The expected learning time is measured using reversed scale hence it has a negative relationship with the behavioral intention of use. Some of the limitations in this study lie in the measurements development and some insignificant statistical findings, which hinder us from better validating our proposal. Future efforts are required to shed light on designing and validating measures that would fill the voids in this study. Also, since no single research can maximize the three features of research process: generalizability, precision, and realism (McGrath, 1982), a different perspective can be obtained through a qualitative case study of u-health system or other innovative healthcare services.

REFERENCES

Ajzen, I., & Fishbein, M. (1973). Attitudinal and normative variables as predictors of specific behavior. *Journal of Personality and Social Psychology, 27*(1), 41-57.

Bandyopadhyay, K., & Schkade, L. (2000). Disaster recovery planning by HMOs: Theoretical insights. *Healthcare Management Review, 25*(2), 74-85.

Barros, P., Pinto, C., & Machado, A. (1999). A signaling theory of excessive technological adoption. *Healthcare Management Science, 2*(2), 117-125.

Berta, W., Teare, G., Gilbart, E., Soberman, G., Lemieux-Charles, L., Davis, D., & Rappol, S. (2005). The contingencies of organizational learning in long-term care: Factors that affect innovation adoption. *Healthcare Management Review, 30*(4), 282-292.

Bhaskaran, S., & Hardley, F. (2002). Buyer beliefs, attitudes and behaviour: Foods with therapeutic claims. *Journal of Consumer Marketing, 19*(7), 591-606.

Briggs, R., Nunamaker Jr., J., & Sprague Jr., R. (2005). Special issue: Crossing boundaries in information systems research. *Journal of Management Information Systems, 22*(4), 7-11.

Burke, R., & Payton, P. (2006). Measuring and managing shoppability: Ten principles to convert shoppers into buyers. *European Retail Digest, 50,* 66-78.

Chae, M., Black, C., & Heitmeyer, J. (2006), Pre-purchase and post-purchase satisfaction and fashion involvement of female tennis wear consumers. *International Journal of Consumer Studies, 30*(1), 25-33.

Cohen, C., & Cohen, E. (1978). Health education: Panacea, pernicious or pointless?. *The New England Journal of Medicine, 28,* 718-720.

Davis, F. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly, 13*(3), 319-340.

Eysenbach, G., & Köhler, C. (2003). What is the prevalence of health-related searches on the World

Wide Web? Qualitative and quantitative analysis of search engine queries on the Internet. *Proceedings of the AMIA Symposium,* 225-229.

Frazier, P., & Tix, A. (2004). Testing moderator and mediator effects in counseling psychology. *Journal of Counseling Psychology, 1*(51), 115-134.

Guido, F. (2007). The organizational l*earning* c*urve. European Journal of Operational Research, 177*(3), 1375-1384.

Gupta, K., & Stewart, D. (1996). Customer satisfaction and customer behavior: The differential role of brand and category expectations. *Marketing Letters, 7*(3), 249-263.

Hendricks, K., Singhal, V., & Stratman, J. (2007). The impact of enterprise systems on corporate performance: A study of ERP, SCM, and CRM system implementations. *Journal of Operations Management, 25*(1), 65-82.

Hu, P., Chau, P., Sheng, O., & Tam, K. (1999). Examining the technology acceptance model using physician acceptance of telemedicine technology. *Journal of Management Information Systems, 16*(20), 91-112.

Junginger, M., de Visser, E., Hjort-Gregersen, K., Koornneef, J., Raven, R., Faaij, A., & Turkenburg, W. (2006). Technological learning in bioenergy systems. *Energy Policy, 34*(18), 4024-4041.

Kervenoael, R., Soopramanien, D., Elms, J., & Hallsworth, A. (2006). Exploring value through integrated service solutions: The case of e-grocery shopping. *Managing Service Quality, 16*(2), 185-202.

Korean National Insurance Corporation. (2007). *Daily Report, Jan/29.*

Lahiri, K., & Xing, G. (2004). An econometric analysis of veterans' healthcare utilization using two-part models. *Empirical Economics, 29,* 431-449.

Lim, H., Widdows, R., & Jungkun, J. (2006). M-loyalty: Winning strategies for mobile carriers. *Journal of Consumer Marketing, 23*(4-5), 208-218.

Madden, M. (2003). America's online pursuits: The changing picture of who's online and what they do. Washington D.C.: Pew Internet and American Life Project, (www.pewinternet.org/reports/toc.asp?Report=106.).

McGrath, J. (1982). *Judgment calls in research*. Beverly Hills, CA: Sage Publications, Inc.

McKeown, T. (1971). A historical appraisal of the medical task. In: G. McLachlan & T. McKeown (Eds.), *Medical history and medical care* (pp. 29-50). London: Oxford University Press.

Morahan-Martin, J. (2004). How Internet users find, evaluate, and use online health information: A cross-cultural review. *CYBERPSYCHOLOGY and BEHAVIOR, 7*(5), 497-510.

Morgan N., & Rego, L. (2006). The value of different customer satisfaction and loyalty metrics in predicting business performance. *Marketing Science, 25*(5), 426-439.

Ngwenyama, O., Guergachi, A., & McLaren, T. (2007). Using the l*earning* c*urve* to maximize IT productivity: A decision analysis model for timing software upgrades. *International Journal of Production Economics, 105*(2), 524-535.

Odom, M., Kumar, A., & Saunders, L. (2002). Web assurance seals: How and why they influence c*onsumers'* decisions. *Journal of Information Systems, 16*(2), 231-250.

Park, K. (2003). Background to ubiquitous healthcare, No.272. Conference between Industry, Academic, Research Centers. Korea.

Rhodes, B. & Mase, K. (2006). Wearables in 2005. *IEEE Pervasive Computing, 5*(1), 92-95.

Riska, E. (1982). Health education and its ideological content. *Acta Sociologica, 25,* 41-46.

Smith, A. (2006). Exploring m-commerce in terms of viability, growth and challenges. *International Journal of Mobile Communications, 4*(6), 4.

Tan, J. (1995). *Health management information systems: Theories, methods, and applications*. Gaithersburg, MD: Aspen Publishers.

Uskul, A., & Hynie, M. (2007). Self-construal and concerns elicited by imagined and real health problems. *Journal of Applied Social Psychology*, *37*(9), 2156-2189.

Venkatesh V., Morris M., Davis G., & Davis F. (2003). User acceptance of information technology—toward to unified view. *MIS Quarterly, 27*(3), 425-478.

Weiser, M. (1993a). Hot topics: Ubiquitous computing. *IEEE Computer,* October.

Weiser, M. (1993b). Some computer science issues in ubiquitous computing. *Communication of the ACM, 36*(7), 75-84.

Windmeijer F., & Silva, J. (1997). Endogeneity in count data models: An application to demand for healthcare. *Journal of Applied Econometrics, 12,* 281-294.

Wong, H., & Legnini, M. (2000). The diffusion of decision support systems in healthcare: Are we there yet?. *Journal of Healthcare Management, 45*(4), 240-254.

Wong, H. (2007). Consumerism and q*uality* standards for subvented social s*ervices*: A case study of Hong Kong. *International Journal of Public Administration, 30*(4), 441-458.

Yoo, S. (2006). Ubiquitous health. *Industrial Health, Korea, 5,* 13-18.

Zhang, J., Fang, L., & Olivia, R. (2007). Online c*onsumer* search depth: Theories and new findings. *Journal of Management Information Systems, 23*(3), 71-95.

This work was previously published in International Journal of Healthcare Information Systems and Informatics, Vol. 3, Issue 3, edited by J. Tan, pp. 58-76, copyright 2008 by IGI Publishing (an imprint of IGI Global).

Chapter 4.17

Current Practices in Select Healthcare Systems

Venkat Sadanand
University of Saskatchewan, Canada

ABSTRACT

In this chapter, current practices of healthcare delivery in three economically advanced countries will be reviewed. Is healthcare delivery commensurate with economic prosperity? Countries with technological and economic advantages may be better poised to deliver healthcare efficiently. However, this is not the case in fact. The following review will show that medico-legal and technological prowess may not translate into a healthier life and better healthcare delivery. It will be argued that poor allocation of ample resources is tantamount to resource insufficiency. The chapter will cite anonymous but true cases of patients to illustrate the salient points.

DOI: 10.4018/978-1-60566-772-0.ch001

INTRODUCTION

In this chapter, current practices of healthcare delivery in three G8 countries will be reviewed. Does economic prosperity lead to a better quality of delivered healthcare? Countries with technological and economic advantages may seem to be better poised to deliver healthcare efficiently. However, this may not be the case in fact. The following review will show that medico-legal and technological prowess may not translate into a healthier life and better healthcare delivery. Distribution of wealth does not necessarily correlate with the distribution of health. It will be argued that poor allocation of ample resources is tantamount to resource insufficiency.

In the attempt to provide improved healthcare for its citizens, many of the G8 countries have tried everything in the spectrum from a publicly funded healthcare system to a fully private system. Common to all these are the intimidating waiting lists for doctors' appointments or surgeries. Some may argue that a waiting list is an inevitable by-product of an economically efficient healthcare system. Patients who are deemed to be surgical candidates are obviously quite ill and possibly in pain. If you ask such a patient if a waiting list is acceptable, the answer would be a resounding rejection of such a concept.

The issue at hand is more than an argument about what constitutes a welfare system. The concept of economic efficiency in healthcare is a red herring. To be efficient from an economic standpoint may not be the same as efficiency in the distribution of healthcare. One may argue that a competitive market resulting in economic efficiency may result in a distribution of wealth with people holding extremes of wealth or poverty. Inequities in health distribution may be a similar outcome of an economically efficient system. The United States of America is an example of this disparity in healthcare. There can be no such tradeoffs in healthcare. In an efficient healthcare system, one cannot accept a dichotomy with some people having ready access to healthcare and some having none. The existence of such a state of society is, admittedly, a failure of the healthcare system. Society must see to it that the last person who needs healthcare receives it.

Some may be quick to interpret this as an advocacy of socialism. In truth however, there is no such thing as socialism in healthcare. Socialism is an economic concept. Wealth distribution is an economic concept. But an equitable distribution of healthcare is as much a necessity as the distribution of oxygen. Everyone ages and every aging person is a potential healthcare consumer. Healthcare is a prime example of market failure. Therefore the allocation of healthcare by free markets is inherently inefficient. The reason a market for healthcare fails is due to (a) the existence of externalities discussed below and (b) the existence of transaction costs and asymmetric information. President Barrack Obama and Secretary of State Hillary Clinton have both strongly emphasized the philosophy that "every American has the right to affordable healthcare" during their 2008 presidential campaigns. Yet a waiting list is a denial of that essential service of healthcare.

In such a context what is a surgical or patient care waiting list? One may have a society where all its citizens have access to healthcare but are placed in a waiting list to see their doctor or to receive appropriate surgical intervention. How does this differ from a society where some have immediate treatment of their illnesses and some do not? The emergence and establishment of surgical waiting lists must therefore be considered a cost to society due to pain and suffering of those waiting patients. The impact on the patients' quality of life and society's productivity is obvious. In the written words of the Supreme Court of Canada Chief justice Beverly McLachlin in the 2005 *Chaoulli v. Quebec (Attorney General)* case, "Access to a waiting list is not access to healthcare."

Consider, for example, patient D.L. from Canada who has a brain tumor compressing on her optic nerve. She was virtually blind in one eye and was losing vision in the other. She was placed on a waiting list and it took several months for the surgery to decompress the tumor. On the day of the scheduled surgery, she was "bumped" and the surgery was cancelled due to unavailability of beds. One month later, her vision now worse, she was taken to surgery emergently. As another example, in the specialty of ophthalmology, the mean waiting time for cataract surgery in Canada was 17 weeks in 2005 (Conner-Spady, B.L., Sanmugasunderam, S., et al., 2005). Patients in the U.K. have had to endure long waiting lists for surgery, some as long as six to nine months (Martin, R., Sterne, J.A.C., Gunnel, D., et al., 2003). Even in the U.S. with a mostly private healthcare system, waiting lists are not uncommon (Hurst, J., & Siciliani, L., 2003).

How then do these waiting lists emerge? Can anything be done to improve such a system which tolerates the pain incurred by waiting patients in stark contradiction to its mission to care for the health and suffering of its citizens? In the Supreme Court of Canada judgment (Chaoulli v. Quebec, 2005) above, all justices of the Supreme Court agreed that such delays can affect the patient physically and psychologically and may cause irreparable harm.

This chapter will compare the healthcare systems of Canada, the United Kingdom and the United States of America. The purpose of this comparison is not only to understand the genesis of surgical waiting lists in economically advanced countries, but also to find solutions by increasing efficiencies in existing allocation of resources rather than additional capital investment. For example, it is seen in what follows that increasing capital expenditures or hospital capacity does not strongly correlate with improved healthcare status in the U.K. but it does in the U.S. This is possibly related to the way the healthcare system is financed.

CANADA

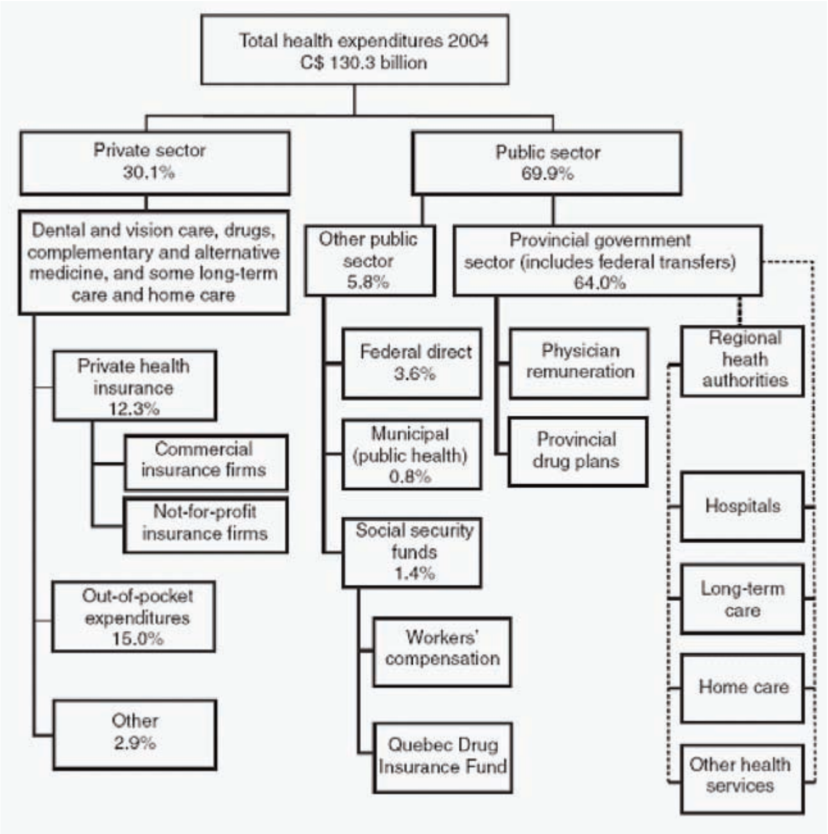
An attempt at universal healthcare was first legislated in Canada in the province of Saskatchewan in 1946. This eventually led to the Medical Care Act in 1966, which provided a framework for each province to offer a universal healthcare system. The success of this led to the Canada Health Act of 1984 and a commitment by the federal government to support the well-developed healthcare system predicated on the principles of universality, portability, comprehensiveness, public administration and accessibility (Lewis, S., Donaldson, C., et al., 2001). Thus, the government insures every Canadian and this insurance is portable anywhere in Canada. The Canada Health Act requires that every hospital and physician should be financed only by the government with no individual user charges. In addition, there cannot be any third party coverage for these services nor can a hospital or physician accept third party insurance for their services for Canadians. The fiduciary responsibility of healthcare delivery is relegated to individual provinces. However, there is a complex revenue sharing agreement between the federal government and the provinces that serves as a financial spigot, which can be turned off if individual provinces do not abide by the Act. This could potentially threaten the transfer of funds from the federal to the provincial government should a province choose to accept third party insurance or charge extra billings to patients.

Year after year the federal government sits with the provinces to renegotiate the transfer payment agreements. The little band-aid changes to the transfer agreements negotiated during these meetings did not do much to fundamentally alter the efficacy of healthcare delivery. Population demographics was changing with time and the healthcare budgets were falling behind unable to respond to these changes. Eventually, there was a stagnation in the real amount of spending for healthcare in the provinces leading to nation-wide reviews of the healthcare system. This led to a series of reforms, most notably, a decentralization of healthcare budgetary decision to regional health boards (Province of Alberta, 1994).

The key requirement in the Canada Health Act is that physician and hospital services be 100% publicly financed. But the provision of these services can be private. Doctors need not be government employees. Hospitals are non-profit corporations. However, there have been some recent developments in several provinces that have to be considered in assessing their impact on patient waiting lists. (Figure 1)

The Canada Health Act governs the financial conduct of hospitals and physicians. With an aging population, there has been an increase in the relative financial outlay for prescription drugs

Figure 1. Canada: Financing of health care, 2004 (Source: Chart data from CIHI (2004) Improving the health of Canadians. Ottawa, Canadian Institute for Health Information. Chart in Marchildon GP. Health Systems in Transition: Canada. Copenhagen, WHO Regional Office for Europe on behalf of the European Observatory on Health Systems and Policies, 2005.)



and community care. The latter is not under the purview of the Act. For example, in 1971, the median age in Canada was 26 and in 2001 it was 37.2. In addition, the percentage of people over 65 years of age is expected to grow from 8%in 1971 to 26.5% in 2051 (Statistics Canada, n.d.)

Second, the federal and provincial governments seem to have done little to respond to changing demographics and increasing demands on the healthcare system. The regionalization system appears to have divided the accountability for patient care between the provincial governments and the regional boards. Thus, if a patient in Saskatoon needs urgent medical or surgical care of a certain kind, the regional boards seem to have no moral responsibility to provide that and, in fact, may be better off sending the patient to another province or to the U.S for that care. Patient care costs for medical care received in another province are borne by the province, not by the regional board. The way the incentives work, regional boards may as well have more services rendered to patients from outside the province and thereby use their limited resources for their immediate needs. In the economics literature this is a classic problem of what is known as 'externalities.' The best examples of these inefficiencies are derived from the polluting factory. Consider a factory that produces computer hardware. Supposing the firm installs a production process by which the chemicals used in the process of etching circuit boards and microprocessors are washed away and deposited in a nearby flowing river. Or, for that matter, pollutants may be released underground and thereby pollute the water table. In either case, the cost of polluting the river or the water table is not borne by the factory. It is indeed borne by downstream fisherman or those who consume that water. Since those costs do not enter the balance sheet of the polluting company, its production decisions, which are guided by its costs, are completely blind to the enormous costs imposed on others. Such myopic decision-making by firms are rectified by taxing the firm for it's output so that the costs of cleaning up the river or water table is seen by the firm as a tax. This will enter its balance sheet and thereby affect its production decision. Such a process is called "internalization of costs". The costs of certain decisions taken by the health boards are not borne by the health boards but accrue to the governments and the patients. Excess use of carbon-based fuels and resulting high pollution levels is another example of externalities and wrong production decisions. In the context of Canadian healthcare and the recent regionalization, these externalities must be internalized. One possible approach to achieve this is by imposing an actual or implicit tax on the regional health boards for patient pain and suffering from waiting lists. The problem, however, with this approach is that health boards are not for-profit organizations and such taxes will do little to internalize the externalities.

The next approach to rectifying the problem of waiting lists is to view the situation from another perspective. The literature on Game Theory has looked into the problem of incentives in complex contracts under asymmetric information. One of the most popular theory is the principal-agent model. In these situations, one individual (the principal) contracts with another individual (the agent) to undertake a task whose outcome will affect the welfare of the principal and when the principal lacks information about the efforts or production process known only to the agent. In the context of Canadian healthcare, the Federal government is the principal who hands over a sum of money to the agent who is the provincial government who has to undertake the task of providing healthcare to its citizens. The Ministry of Health in the provincial government then pays its agent (the regional health boards) to deliver healthcare. So one has to examine the incentives to perform in a model where there is one principal-agent relationship (Federal Government – Provincial Government) and this, in turn, results in another principal-agent relationship (Provincial Government – Regional Health Board). The final output affects the welfare of the patients. The broader questions is: how can one structure incentives at all levels so that the healthcare is delivered with efficiency and patient welfare is maximized? This question and its solutions have been well-addressed by "Contract Theory". In their book on Economics, Organization and Management, Milgrom and Roberts (1992) develop the conditions for designing an efficient contract. One of the conditions is called the "informativeness principle". This states that any measure of performance that reveals information about the effort level chosen by the agent should be included in the compensation contract. Hence, waiting lists and underemployment of specialists are clearly monitored data. By including them in the Federal transfer of funds for healthcare, the two agents are given the proper incentives to reduce waiting times and hence patient suffering. Thus, if Federal transfer of funds are sensitive to patient waiting times and availability of specialists, then Provincial governments and regional health boards will find ways to reduce those waiting lists and provide an adequate supply of specialists for the patients. Short waiting lists should be rewarded with higher levels of funding while long waiting lists should trigger decreased funding. While this sounds counter-intuitive, the incentives it provides in a principal-agent setting will nevertheless achieve efficiency in healthcare delivery.

There is also the issue of strategic representation or misrepresentation by regional health boards with the current incentives. Larger waiting lists will provide sufficient rationale for the heath boards to request a budget increase. If the Provincial and Federal governments award such an increase, pursuit of higher budgets will result in increasing waiting lists and chronic shortage of specialists.

Finally, in some provinces, marginal privatization has developed. Day surgery clinics have sprouted that offer surgeries for which the patient does not require hospital admission.

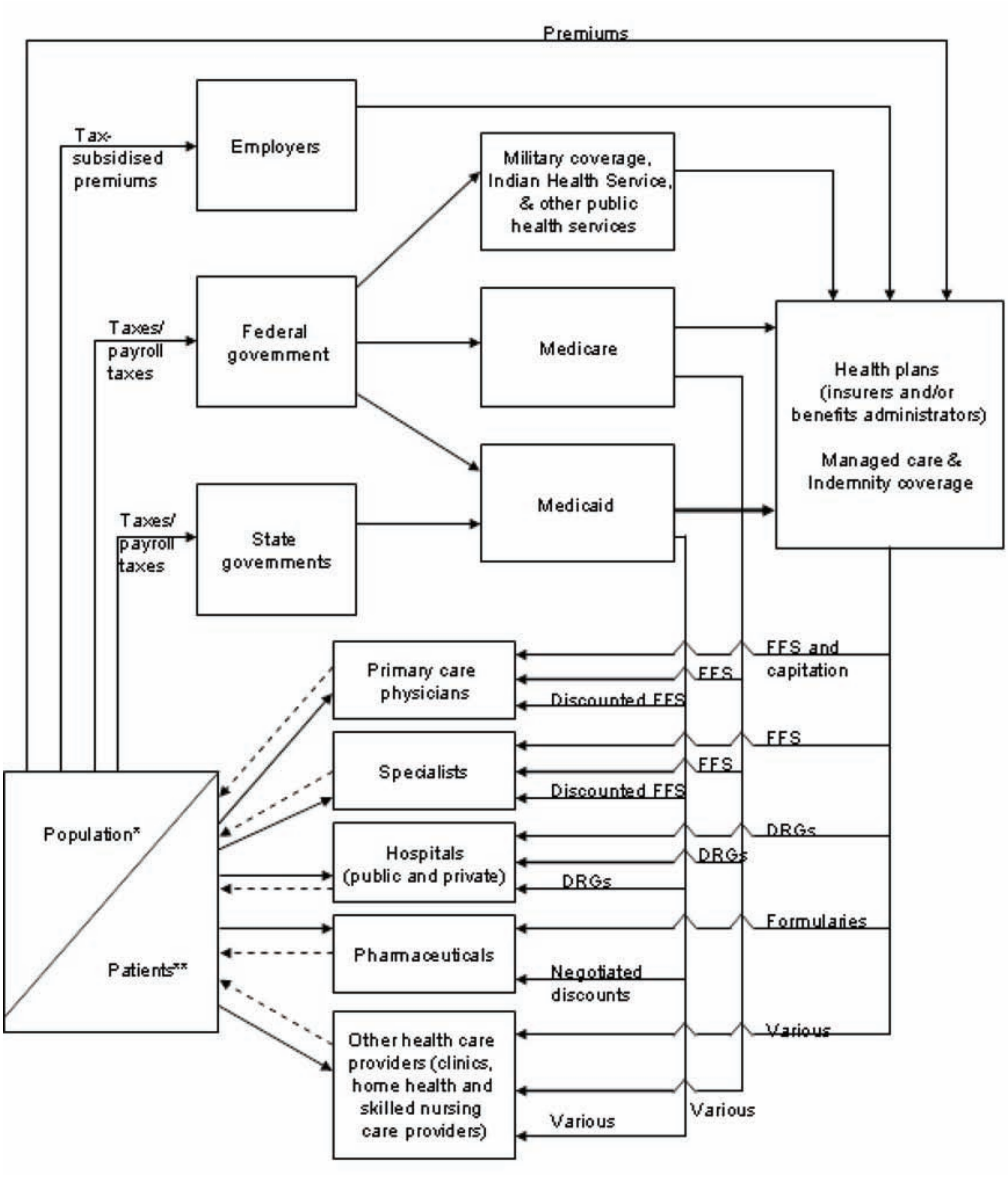
How then do these factors affect healthcare delivery in Canada? First, in contrast to a market driven healthcare system, a public healthcare system ignores the realities of demand and supply. Supply decisions are made with little concern for current or future demand. This leads to rationing and wait lists. Patients have to wait for diagnostic imaging, surgery, hospital emergency room and even access to a primary care physician (Esmail N., Hazel, M., & Walker, M.A., 2008). From the time a specialist decided to undertake treatment to the time the patient actually receives treatment is a waiting time during which all parties agree treatment is needed, but treatment is however not given. In the specialty of neurosurgery, for example, the 2008 waiting time from decision to treat to treatment is 19.4 weeks, which is one of the highest in any OECD country (Milgrom, P., & Roberts, J., 1992). Mean 2008 waiting time for an MRI scan was 9.4 weeks. Second, the availability of modern medical technology is restricted. For example, neuroendovascular techniques have evolved into a subspecialty in neurosurgery several years ago and most countries have nation-wide centers of excellence for these modalities of treatment for cerebral aneurysms. However, the province of Saskatchewan has yet (at the time of writing this book) to have a neuroendovascular facility, which is already the standard of care throughout the world. Third, the recent trend of new private day-surgery centers have eased the burden on surgical waiting lists and the government has so far looked the other way as these centers have clearly improved patient access to critical surgeries and physicians.

In summary, the Canadian healthcare system is founded on principles that are now ignored. Patients do not have timely access to healthcare and not having such access is, indeed, denial of healthcare. Suffering while on a surgical waiting list can only be appreciated by those who suffer, and least by those whose administrative decisions lead to waiting lists.

UNITED STATES OF AMERICA

In contrast to the Canadian healthcare system, the U.S. has adopted a market-based system. Private insurance companies cover a majority of individuals for their healthcare costs. Employers pay for the coverage. But employment is not a guarantee of health coverage. In 2005, nearly 15% of employees had no health insurance coverage from their employers (DeNavas-Walt, C.B.P., & Smith, J., 2007). In 2007, nearly 45 million Americans or about 16% of the population have no insurance coverage at all. Private insurance covered 68% of the population (DeNavas-Walt, C.B.P., & Smith, J., 2008). The insurance companies and the government depending upon the coverage held by the patients compensate physicians and hospitals. Most hospitals are private enterprises. Thus the purchase of medical equipment is viewed as an investment by the hospital, which reaps greater returns on the investment if more patients use the equipment. This is in contrast to Canada where new equipment is often viewed as a drain on a fixed budget. As a result of this availability of medical technology in the United States, it is currently one of the most advanced nations in the world in healthcare technologies. For example, in 1990, the number of MRI units per million population is 3.69 in the United States compared to 0.46

Figure 2. United States: Financing of health care, 2003 (Source: OCED Secretariat, 2003)



in Canada (DeNavas-Walt, C.B.P., & Smith, J., 2008). (Figure 2)

Despite market forces at work, patients in the United States do encounter waiting lists for surgeries, emergency medical care and physician appointments. Canada's rationing is supply based while the United States rations based on price. That is, those who cannot afford healthcare are doomed to a parallel inferior system where waiting lists and poor accessibility are the norm. In a market-based system, the allocation of resources is shifted in favor of those sectors where the marginal returns are higher. In 1986 the United States Congress passed an Act called EMTALA (Emergency Medical Treatment and Active Labor Act) requiring hospitals and ambulance services to provide care to anyone needing emergency treatment regardless of their ability to pay. Hence the uninsured patients crowd emergency rooms for routine ailments that are best managed in physician offices. This generates wait times for insured patients. The same price rationing consequences apply to surgical wait times. Although these times are much smaller than in Canada and the U.K. they nevertheless exist and represents a failure of a market based system.

A recent OECD study found that the major factors reducing waiting times for elective surgery are: higher number of acute care beds, higher surgical activity levels in hospitals, fee-for-service remuneration, a higher healthcare budget and a lack of fixed budgets for hospitals. Surprisingly, the study demonstrated that a younger population is not a factor in reducing waiting times. In a multivariate analysis in the same study it was found that the number of acute care beds and the number of physicians and specialists had the largest impact on waiting times (Fuchs, B.C., & Sokolovsky, J., 1990).

In summary, the United States does have waiting lists for elective surgeries, but the waiting times are an order of magnitude less than those in publicly funded systems. The humanitarian considerations for uninsured people, makes the system for insured people slightly inefficient. However, the principal (insurance company) – agent (doctors and hospitals) model in the United States is much closer to full efficiency than in Canada and the United Kingdom.

UNITED KINGDOM

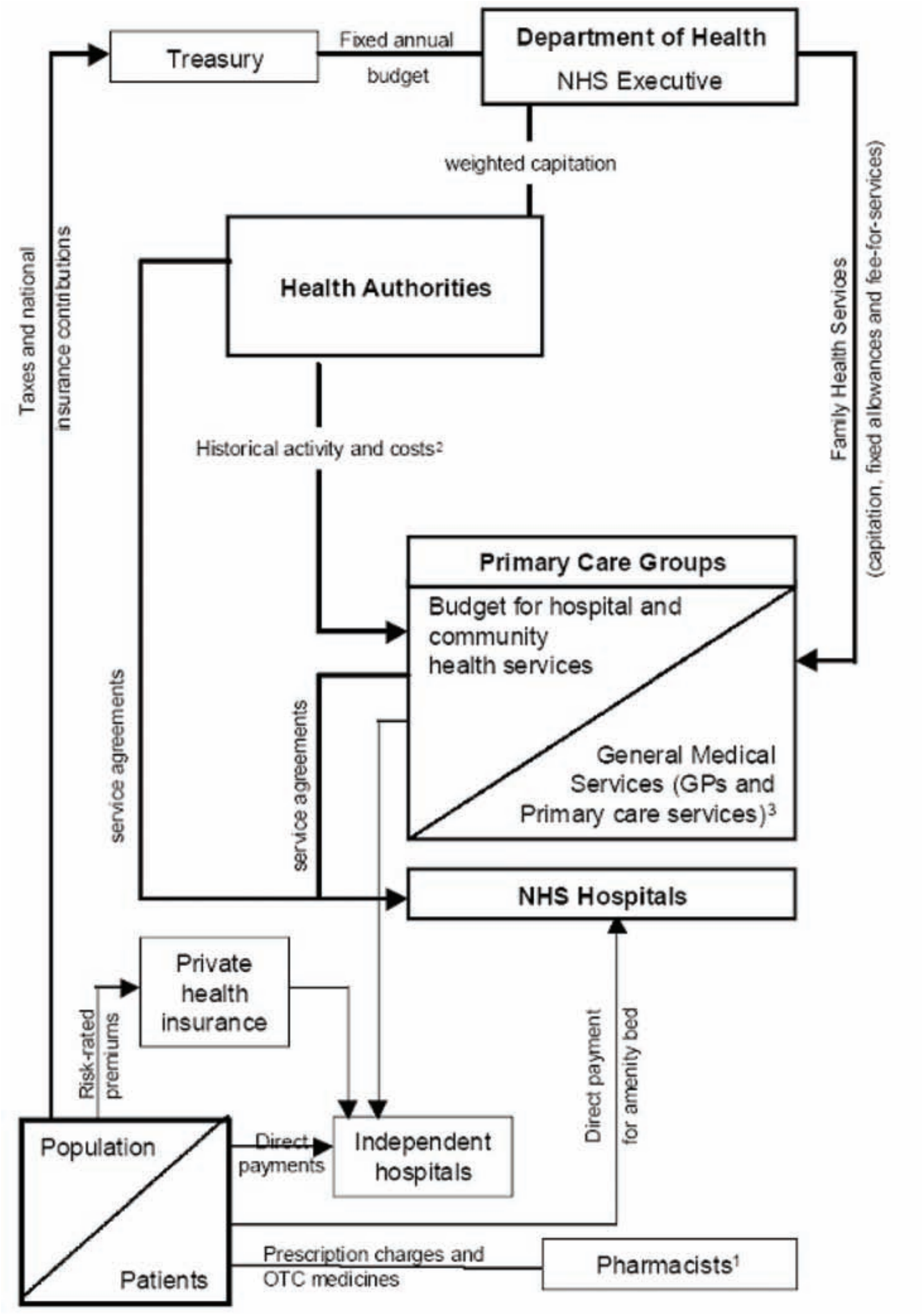
Healthcare in the United Kingdom works under a blend of public and private systems. The National Health Service (NHS) refers to four publicly funded healthcare systems in the U.K. with its components in England, Scotland, Wales and Northern Ireland. In addition, citizens may choose to purchase private medical insurance for hospital and doctor services. In 2001, 11.5% of the population held private medical insurance (Siciliani, L., & Hurst, J., 2003). Furthermore, 40% of adults with private medical insurance are in the top decile of income. As a percentage of total healthcare expenditure, public to private ratios were 83.3:16.7 (Laing, W., & Buisson, C., 2001). NHS does not cover all necessary medical treatment costs. The benefits are ill defined and its decisions are based on an analysis of costs and benefits of a particular medical technology, pharmaceutical or procedure. The National Institute for Clinical Excellence makes such recommendations. In some instances the health authorities may make rationing decisions. Drugs may be excluded because of poor therapeutic value or excessive costs. Employers mostly purchase private medical insurance provided by for-profit and non-profit organizations and most are group policies. NHS patients must have a referral from a GP to access secondary level care with specialists.

With poor hospital capacities and low per capita specialists figures, waiting times to see a specialist was on the average 13 weeks in 2001-2002 (Laing, W., & Buisson, C., 2001). NHS Trust hospitals had the longest waiting lists with between 52% and 83% of patients waiting longer than six months for elective surgery found in 25% of NHS hospitals (OECD Health Data, 2001). Interestingly, this study found that in contrast to the United States data, not much association was found between waiting times and hospital capacity and number of beds. Paradoxically increasing the number of specialists increased average waiting times suggesting that the supply of doctors induced demand. Individual level of employment, affluence and urgency of disease shortened waiting times. This mostly indicates the relative efficacy of the private medical insurance arm 40% of whose subscribers are in the top income decile as noted above. (Figure 3)

COMPARISONS

The three OECD countries discussed above have three different healthcare systems although many

Figure 3. United Kingdom: Financing of health care, 1999 (Source: Health Care Systems in Transition: United Kingdom, 1999. European Observatory on Health Care Systems)



would argue that the U.K. and Canadian systems are closer in principle to each other than to the United States. Recent OECD health data revels some interesting differences among these three countries (Martin, R., Sterne, J.A.C., Gunnel, D., et al., 2003).

Table 1 below, gives an estimate of waiting times for surgery in the United States compared to key OECD countries in 2001 (Mohan, R., Mirmirani, S., 2007).

The following comparisons of resource allocation in the three countries are from the OECD 2008 health data. (Table 2)

Table 1.

Percentage of Patients Waiting > 4 months for Elective Surgery in 2001	
United States	5
Australia	23
Canada	27
New Zealand	26
United kingdom	38

An Example

Given an understanding of the heathcare systems in the three countries, this section will consider as an example the generation of waiting lists in one of the provinces in Canada. We will specifically consider two kinds of surgical waiting lists: waiting lists by the specialist to see the patient after referral by a GP and patient waiting lists after a decision is made to undertake surgery.

Consider the first waiting list. Family physicians or GPs send a referral letter to the specialist. The specialist then places the patient on a clinic waiting list. This waiting list is generated due to the limited hospital and outpatient facility resources as well as the limited number of specialists that the health boards have decided to recruit. Thus, a specialist can only run a fixed number of clinics per week. The number of clinics is independent of patient demand for referrals. There may be days when the specialist has time to see patients but the hospital and outpatient facilities do not have the resources to allow the specialist to see patients as the same resources are shared by several specialists. In one of the specialties, for example, the clinic waiting list is between 150-250 patients waiting to be seen. Patients scheduled to see a specialist may be pushed back due to a more urgent referral. This combination of triage and limited resources can render a waiting list long and increase patient dissatisfaction with the healthcare system. It also impedes timely care of patients who are suffering. Some patients wait for over a year to get to see their specialist.

Consider the second waiting list. This is divided into two parts: those patients who are placed on "the board" and those who are on an elective waiting list. The "board" is for emergency surgeries that are constrained by limited resources. When the day's scheduled surgeries are completed, the patients on the board get their turns. Due to

Table 2.

Countries	**#CT Scanners Per 1000 Pop.**	**#MRI Scanners Per 1000 Pop.**	**Health Expenditure % GDP**	**Practicing Physicians Per 1000 Pop.**	**Male Life Expectancy at Birth**	**%Public Asking for Complete Rebuild of System**
Canada	12	6.2	9.8	2.1	78	12
United States	33.9	26.5	15.2	3.7	75.2	34
United Kingdom	7.8	5.6	8	2.9	77.1	15

limited resources again, only one or in rare cases two operating rooms are allowed to run to clear the board. Board surgeries can fall under three categories: E1, E2 and E3. An E3 surgery has to be called within 24 hours. An E2 surgery has to be called within 8 hours of booking and an E1 has to be called within 1 hour of booking. In practice though an E3 can have patients waiting several days for their surgeries and, in some instances, patients have walked out of the hospital in frustration against medical advice. In addition, an E3 surgery cannot be started after midnight. An E2 surgery can only be started after the day's cases are done and an E1 case can "bump" a scheduled elective surgery usually from the same surgical specialty. A patient may join the board as an emergency arrival at the Emergency Room. That patient may be a new patient, a patient not on the scheduled waiting list or one who is already on the scheduled waiting list and his condition has deteriorated.

The second part of the second waiting list is the patients who are placed on a scheduled waiting list for elective surgery. This list is generated by the degree of urgency of the patient's ailment requiring surgery. Patients on this waiting list are called on a specific date to come for surgery. However, there is a chance that on the day of their scheduled surgery, they may be refused surgery because of limited resources on that day. They would they go back on the scheduled waiting list and once again, wait their turn. It is easy to see that the system has been patched up with disjoint solutions that disregard patient suffering while waiting and inappropriate use of limited resources.

The keys to the inefficiency in the system are the limitation of resources that is blind to demand and the sharing of these limited resources by all the surgical specialists. A surgeon may be given, for instance, 3 or 4 operating days per month. Thus, if he has 70 patients waiting for surgery, some of the patients would have to wait for 6-8 months provided none of the scheduled patients is "bumped" by non-availability of resources on the day of surgery or none is "bumped" by a more emergent patient who entered the system through the emergency room.

CONCLUSION

The analysis above suggests that surgical waiting times are generated from a lack of addressing the mechanisms underlying the generation of waiting lists. Statistical studies done in each of the three countries in this chapter appear to show different independent factors affecting waiting times. Specifically, in Canada, limited number of hospital beds, limited number of specialists, limited operating times, limited medical technologies and a system operates under economic externalities can all contribute to long waiting lists and increased patient suffering. In comparing the three countries and their healthcare systems, the issues are not the relative superiority of one system versus the others. It is the degree to which each country lacks the proper incentives to achieve efficiency within its system. The issue therefore is the inadequacy of ad hoc incentives in a system without a formal modeling-based understanding of the healthcare delivery. One cannot blame a given system for the inefficiencies generated by inappropriate or inadequate contracts and incentives.

REFERENCES

Chaoulli v. Quebec (Attorney General) (2005). 2005 SCC 35. 1 S.C.R. 791, Para 123, Docket 29272, Supreme Court of Canada.

Conner-Spady, B. L., & Sanmugasunderam, S. (2005). Patient and physician perspectives of maximum acceptable waiting times for cataract surgery. *Canadian Journal of Ophthalmology*, *40*, 439–447.

DeNavas-Walt, C.B.P., & Smith, J. (2007, August). *Income, poverty, and health insurance coverage in the United States: 2006*. U.S. Census Bureau.

DeNavas-Walt, C.B.P., & Smith, J. (2008, August). *Income, poverty, and health insurance coverage in the United States: 2007*. U.S. Census Bureau.

Esmail, N., Hazel, M., & Walker, M. A. (2008). *Waiting your turn: Hospital waiting lists in Canada* (18th ed.). Fraser Institute.

Fuchs, B.C., & Sokolovsky, J. (1990, February). *The Canadian health care system, CRS Report for Congress.* Congressional Research Service: Library of Congress.

Health Data, O. E. C. D. (2001). *A comparative analysis of 30 countries CD-ROM.* Paris: OECD and CREDES.

Hurst, J., & Siciliani, L. (2003). *Tackling Excessive Waiting Times for Elective Surgery: A Comparison of Policies in Twelve OECD Countries.*

Laing, W., & Buisson, C. (2001). *Private Medical Insurance: UK market sector report 2001*. London: Laing & Buisson.

Lewis, S., & Donaldson, C. (2001). The future of healthcare in Canada. *BMJ (Clinical Research Ed.)*, *323*, 926–929. doi:10.1136/bmj.323.7318.926

Martin, R., Sterne, J. A. C., & Gunnel, D. (2003, January). NHS waiting lists and evidence of national or local failure: analysis of health service data. *BMJ (Clinical Research Ed.)*, *326*, 188. doi:10.1136/bmj.326.7382.188

Martin, R. M., & Sterne, J. A. C. (2003). NHS waiting lists and evidence of national or local failure: analysis of health service data. *BMJ (Clinical Research Ed.)*, *326*, 188–192. doi:10.1136/bmj.326.7382.188

Milgrom, P., & Roberts, J. (1992). *Economics, Organization and Management.* Englewood Cliffs, NJ: Prentice Hall.

Mohan, R., Mirmirani, S. (2007, December). *An assessment of OECD health care system using panel data analysis*.

Province of Alberta. (1994). *Regional health authorities act.* Edmonton: Queen's Printer for Alberta.

Siciliani, L., & Hurst, J. (2003). *Explaining waiting times variations for elective surgery across OECD countries.*

Statistics Canada, Estimates of Population, Canada, the Provinces and Territories (Persons), CANSIM Table No. 051-0001, Ottawa.

This work was previously published in Multi-Agent Systems for Healthcare Simulation and Modeling: Applications for System Improvement, edited by R. Paranjape; A. Sadanand, pp. 1-12, copyright 2010 by Medical Information Science Reference (an imprint of IGI Global).

Chapter 4.18

Computerised Decision Support for Women's Health Informatics

David Parry
Auckland University of Technology, New Zealand

ABSTRACT

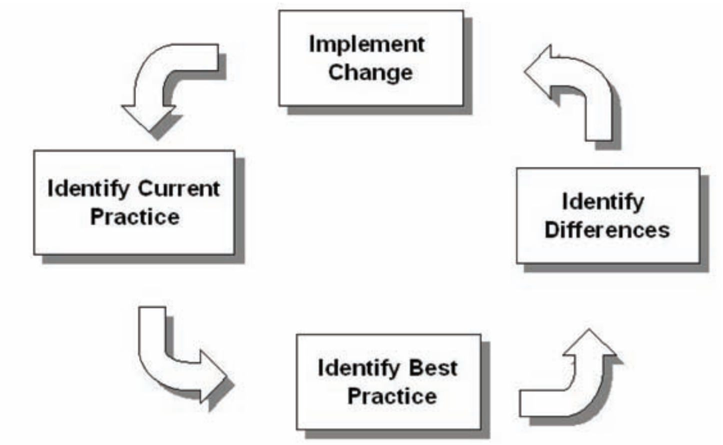
Decision analysis techniques attempt to utilize mathematical data about outcomes and preferences to help people make optimal decisions. The increasing uses of computerized records and powerful computers have made these techniques much more accessible and usable. The partnership between women and clinicians can be enhanced by sharing information, knowledge, and the decision making process in this way. Other techniques for assisting with decision making, such as learning from data via neural networks or other machine learning approaches may offer increased value. Rules learned from such approaches may allow the development of expert systems that actually take over some of the decision making role, although such systems are not yet in widespread use.

DOI: 10.4018/978-1-60566-078-3.ch015

INTRODUCTION

Decision analysis involves formally identifying the important aspects of making decisions in terms of the required information, the process followed, and the outcomes expected. Of course, people make decisions all the time without going through this process, so decision analysis is often reserved for situations where the decisions are particularly difficult because there is no good precedent or the decision maker is uncertain, the consequences of making the wrong decision are serious or because the decision making process needs to be particularly explicit and verifiable. As with all informatics activities, computer support is helpful, but not a complete replacement for clinical judgement, or a remedy for poor knowledge of the area.

Figure 1. The audit cycle



Computational intelligence involves the use of computers to make decisions themselves, in conjunction with humans, or independently.

Formalising decision making processes allows for a reflection on the decision-making process, and the sharing of this process with others such as colleagues, patients or researchers. The audit of behaviour is linked to the use of evidence–based practice (Rosenberg & Donald, 1995). As part of evidence based practice, clinicians are seen to need to justify their actions in the light of scientific research. Briefly, evidence based practice requires the following stages:

- Identification of a clinical problem
- A systematic search for evidence
- Assessment of the evidence in a structured way
- Synthesis of the evidence
- Decision on what is "best practice"

The best practice thus identified becomes the second part of the audit cycle (Figure 1). Decision analysis involves the incorporation of data from good sources of evidence, such as clinical trials in order to identify best practice. This best practice may involve a quite complex process of decision making that depends on many factors, and it may be that decisions need to be segmented in terms of whether they apply to individual cases, groups of patients or whole populations.

CLINICAL DECISION MAKING

Decision analysis is intended to both model and improve decision-making. The techniques used have a number of similarities but the importance of different aspects of the decision changes with the size of the group being affected. In general, as the groups affected get larger, the distribution of values for parameters are easier to predict, while as groups get smaller then the variation between individuals becomes more important. Dowie made an important point in a 1996 paper (Dowie, 1996) that the decision making process needs to incorporate evidence, cost effectiveness and preferences of the people involved. The use of evidence of clinical benefit, although it is necessary for the choice of action, is not always sufficient to make the decision obvious.

Decision Making for One Patient

Classically, clinical decision making concerns the actions taken to improve the health of one patient. This is at the heart of the clinicians role and has been expressed in the form of the Hippocratic Oath "*To practice and prescribe to the best of* *my ability for the good of my patients, and to try to avoid harming them.* "(Anonymous, 2007). In the case of decisions affecting a single patient, it is obviously important to know what the patient herself regards as an acceptable outcome. The acceptability or otherwise of an outcome is known as its "utility" in decision analysis terms. It is important to realise that these utilities can vary to quite a large degree. For example work described in (J. Thornton & R. Lilford, 1989; J. G. Thornton & R. J. Lilford, 1989) has shown that there is a very wide variation in the risk that women are prepared to accept, and that this is not simply a matter of lack of information, or an immediate emotional response. Thus, blanket policies for decision making may not reflect the patient's wishes, and reflects back on the importance of patient preference. This is not surprising if one accepts that healthcare is another part of life where autonomy and personal choice are important, just as for example the choice of whether to have a baby in the first place !

This problem cannot be solved simply by providing information – what is an acceptable risk to one person may not be to another. Indeed even within the professional body, there are wide variations in what the professional would perceive to be the best approach to a particular situation. Studies examining obstetricians attitude to decision –making in childbirth- for example whether a caesarean section is appropriate have show wide variations in preference. (Land, Parry, Rane, & Wilson, 2001).

A practical issue arises in that individuals react differently to therapy and have unique combinations of pre-existing conditions, genetic makeup and physiological response.

Decision Making for a Group of Patients

Complexity arises in treating pregnant women where there is more than one individual involved in the outcome. A detailed discussion of the ethics involved is out of the scope of this chapter but one should realise that there may be potential conflicts between the optimum outcomes for mothers, babies, twins and even siblings in the case of "saviour" embryos (Brownsword, 2004).

Decision Making for Population Health

When the focus changes to the population, then the emphasis changes from individual benefits and utilities, to the wider common good. However, strict utilitarian approaches are not acceptable in most cases, so individual rights, and general principles such as equity need to be taken into consideration. On the positive side, variation between individuals will tend to become less important when deciding on policies for populations, although the identification of subgroups may be important. Example of this sort of decision making may include screening for cervical cancer, and provision of HPV vaccination within a population(Jones et al., 2007)

DECISION ANALYSIS

Pubmed defines decision analysis as: "Mathematical or statistical procedures used as aids in making a decision. They are frequently used in medical decision-making."

Decision analysis techniques attempt to bridge the gap between knowledge and information – that is by somehow representing the knowledge that is available, they allow information to be used to inform decision making. In terms of the use of computers, the continuum ranges from an effectively paper-based approach, such as clinical algorithms, to computer –supported decision making, as may be seen in a decision analysis spreadsheet, to a fully automatic artificial intelligence system.

Sources of Information for Decision Making

Some decisions are relatively easy to support with even limited information. For example, early trials of penicillin-based antibiotics for peritonitis in the 1940's showed that only those patients given the drug survived. Fortunately, most decisions are not as stark as this, but in order to make use of decision analysis techniques, there are some important parameters to consider. Firstly, the information must be reliable and apply to this particular patient group. Thus it is important to have correct reference data for predicted growth charts depending on the ethnic background of the patient, such statistics are described in chapter 14. It is also very important to have the best possible evidence, and this has been made easier by the growth of evidence-based medicine (Rosenberg & Donald, 1995), and in particular the availability of systematic reviews. The Cochrane Collaboration Database on pregnancy and childbirth was one of the earliest libraries of systematic reviews available (Cochrane Collaboration, 1997), and has continued to grow as part of the wider Cochrane library. For many of the techniques such as statistical decision analysis and Bayesian methods, data on the prevalence or likelihood of certain conditions are important and these can be discovered form some of the sources described in the statistical measures chapter. For knowledge discovery techniques, comprehensive databases, which may be derived from electronic health records (see the chapter on the electronic health record), may be needed, these are particularly useful when multiple factors are included in the outcome calculation, or to gain an understanding of the expected outcome in local conditions.

When people make decisions without any decision support tools, it is also helpful if the available evidence and information is collated and available, and electronic sources such as the web are increasingly valuable for this purpose (see Chapter XIII). This can be especially useful in the case of rare conditions or unusual combinations of factors, where there may be no compelling evidence from good clinical trials.

Bayesian Methods

The reverend Thomas Bayes had his essay on probability published posthumously (Bayes, 1764). Bayesian methods involve trying to quantify the likelihood of a particular event occurring given what has happened before. This differs from classical statistics which deals with the frequency of observed events. In simple terms a Bayesian approach allows you to suggest how likely a diagnosis is given data about how often the diagnosis occurs in the population you are studying and the results of any diagnostic tests, given the sensitivity and specificity of them.

In addition, modern Bayesian approaches often include the use of utility values. In order to select a recommended course of action, the chance of something happening and the desirability of that outcome are combined. This is a very common human activity, and usually a simple multiplication is performed to produce a utility score (desirability*likelihood). It is important to note that the desirability of an outcome may vary hugely between and within populations, which supports the work of Dowie (Dowie, 1996). There has been extensive debate about the validity of Bayesian approaches to decision-making, with a number of authors making the point that the prior odds of an event may not be widely available, and that the different means of reporting trials of diagnostic tests can lead to confusion and incorrect estimates(Cooper, 1992; Harris, 1981)

One of the most important things that Bayesian approaches make plain is the importance of the prior likelihood of any condition. This is particularly helpful in the situation where

If A is an event that you are trying to detect and B is the result of a test. P(A) represents the prior probability of a particular event, and P(B) the prior probability of getting the result then:

$$P(A \mid B) = \frac{P(B \mid A)P(A)}{P(B)}$$

Where P(B|A) is the probability of getting the result B given the condition A, and P(A|B) is the probability that the patient has the condition A given the result B. This allows the accuracy of the test, in terms of true positive and false positive, of the test to be included in the calculation, along with the general prevalence. So for example, imagine the situation where there is a test such as Foetal Fibronectin (FF) for preterm labor. Assuming that the probability of having preterm labor in this population is .1, and the probability of getting a true positive result is 0.99 and the probability of a false positive result is .01 then the probability of a positive result when the patient actually has preterm labour is given by (0.99*0.1)/((0.99*0.1)+(0.01*0.9))=0.917. so that around 92% of the time, a positive test means that the patient is having preterm labor. Note that this calculation is sensitive to the base rate, or prior probability of having preterm labor, if this was halved (ie it was .05)then the calculation would be:

(0.99*0.05)/((0.99*0.05)+(0.01*0.95))=0.84 or 84%. Effectively Bayes theorem says in this case that the less common the condition, the less likely a positive result is likely to be true.

Bayesian networks (Heckerman & Wellman, 1995) are extensions of the Bayesian approach where the prior probability of a certain node being in a certain state is dependent on the posterior probability of nodes that lead to that state – a chain of causation.

Decision Trees

Decision trees are useful for mapping the data recorded in studies into potential outcomes. They have been used for deciding on the management of ectopic pregnancies (J. Elson et al., 2004). They can also be derived from data and may allow easier understanding of the processes involved. While they can be derived as part of the Knowledge Discovery process (see the section below) they can also be created by people directly from observations.

The fictional example shown below (Figure 2) concerns a hypothetical patient who is at 36 weeks gestation with pre-eclampsiapre-eclampsia. Induction of Labour (IOL) is suggested as being helpful, in this circumstance, but it may cause an increase in the chance of less- desired outcomes, such as emergency Lower segment caesarean section (LSCS). Utility values for different outcomes can be included in order to try to make the "best decision". In the example the utility value for each outcome is multiplied by the probability of each outcome. The overall result is that IOL has a utility of:

(0.1*0+0.2*0.25+0.3*0.5+0.2*1)=0.4,

but not inducing has a utility of

(0.2*0+0.2*0.25+0.3*0.5+0.4*1)=0.6,

so the non-IOL approach is preferred.

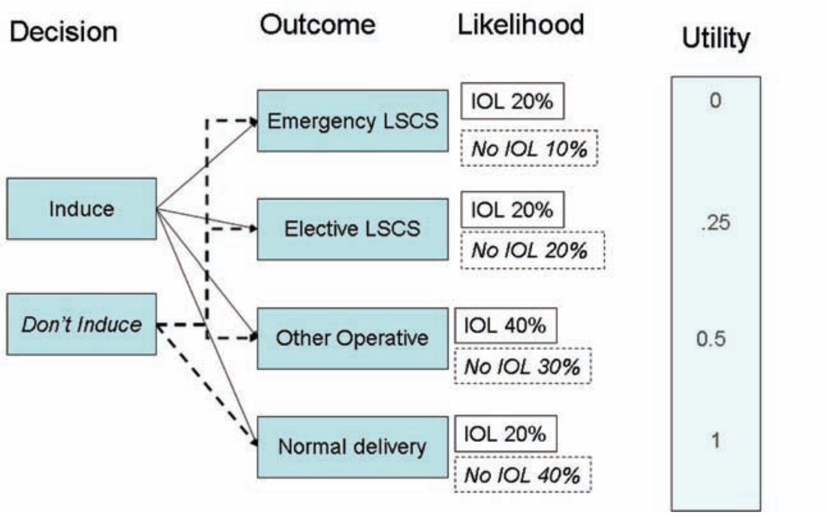
Sensitivity analysis can also be performed on these models, with the probability of each outcome being changed. More complex multi-stage trees can also be devised.

Decision Support Systems

Decision support systems (DSS), also known as decision aids, cover a wide range of approaches, as their name suggests the emphasis is on helping to make decisions, rather than removing the decision making process from the control of clinicians and patients.

A recent study (Montgomery et al., 2007) used a decision analysis tool to assist pregnant women in making a decision in the context of vaginal

Figure 2. Decision tree



birth after caesarean section (VBAC). VBAC is a particularly interesting area of study because there is no universally accepted approach, and the consequences of a simple decision rule –"all women who have had a caesarean section will have another one" leads to unwanted consequences for the healthcare system – a rise in the caesarean section rate and consequent costs– and harm to the women – the morbidity associated with a caesarean section. In VBAC there are essentially 3 possible outcomes –

1. Vaginal birth – lowest risk of morbidity to mother, but some possibility of requirement to go to 3.
2. Planned caesarean-
3. Emergency caesarean – highest risk of morbidity for mother

The tool used was effectively a decision tree, each women was asked how much she preferred each outcome on a scale of 0-100. After she had done this the program combined this information with the prior odds of each outcome to produce a decision tree, which was then printed out.. This study showed a small but significant increase in vaginal birth in the group that used the tool. Interestingly this effect was not seen when comparing patients who were given information only to help them make the decision. The degree of uncertainty in decision making measured by a decision conflict scale among the women also decreased when they used the DSS tool. However this level was even lower amongst the "information only" group. An accompanying editorial (Lauer & Betran, 2007) makes the point that this DSS is designed to allow the preferences to be made before the possible outcomes are known. It also acknowledges that this approach may be more successful than exhortation in reducing Caesarean section rates.

ARTIFICIAL INTELLIGENCE AND DECISION SUPPORT

Artificial Intelligence (AI) has been defined as "The study and implementation of techniques and methods for designing computer systems to perform functions normally associated with human intelligence, such as understanding language, learning, reasoning, problem solving," (U.S. National Library of Medicine, 2001). Some authors detect a difference between artificial intelligence as a way of mimicking human decisions, and as a way of studying them. More succinctly it can be thought of way of using computers to turn data into decisions.

Different techniques are covered by the use of the term AI – some involve discovering knowledge and some involve using existing or derived knowledge for decision-making.

KNOWLEDGE DISCOVERY FROM DATABASES (KDD)

KDD is also known as machine learning and involves the use of data that has been collected to understand the causes and outcomes of events. There are some broad categories of knowledge discovery (Fayyad, Piatetsky-Shapiro, & Smyth, 1996); classification, regression, clustering, summarisation, dependency modelling and change and deviation. The conversion from data to knowledge is at the heart of intelligence, and hence artificial intelligence. The interested reader is encouraged to experiment with freely available machine learning tools – one of the most well known is "WEKA" (Witten & Frank, 2005) available from the University of Waikato New Zealand (http://www.cs.waikato.ac.nz/ml/weka/). One particularly well known method of knowledge discovery is the use of artificial neural networks, but decision trees and Bayesian networks as well as more traditional statistical methods have their place.

Neural Network Techniques

Artificial Neural networks (ANN) attempt to model decision making on the processes existing in the brain of humans or animals. They have a perhaps surprisingly long history of development and use with early work beginning in the 1950's and 196o's. An excellent review of the history can be found in (Widrow, Widrow, & Lehr, 1990). Simply, ANN use one or more layers of "neurons" represented in a computer with connections between them (Figure 3).When a neuron is activated – i.e. the input values correspond to a particular value or range of values, then it "fires". The next layer then examines the input from the connections – which are assigned different weights -and this may then cause another layer to be stimulated, or an output to be produced. ANN are often used for learning the relationship between inputs and outputs, and can represent very complex relationships, more so than linear regression etc. They are also able to "learn" behaviour. This can be done in a number of ways, but essentially, it involves using a "training set" of data, where both the inputs and desired outputs are known, as each set of inputs as placed into the system the weights of the connections, number of connections and sometimes number of neurons are adjusted in order to create the desired outputs, using some appropriate adjustment scheme. The success of this process is then measured by using a "testing set" of data where the desired output is known but the network is not changed.

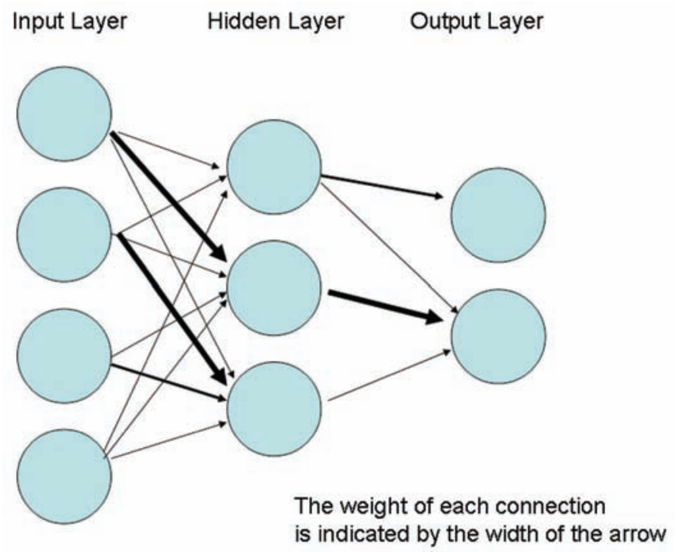
Various approaches such as accuracy of classification, a confusion matrix, sensitivity and/or specificity are then calculated. One of the issues to consider when training such a network is the danger of "overtraining" that is the situation where the network becomes extremely good at modelling the dataset used for training, but this dataset is not representative of the general case.

Classifiers – these are systems that use data about a person or condition to make a decision as to which class they belong – e.g. their diagnosis. These are usually learning systems that should get better as examples are presented to them.

If the classes are unknown – for example the outcome of the patients is not yet determined then similar techniques called *clustering* algorithms are used. Examples of classifiers are neural networks, decision trees such as C4.5and statistical methods.

Evolutionary computation methods such as genetic algorithms(Pena-Reyes & Sipper, 2000) and particle swarm optimisation (Kennedy, Kennedy, & Eberhart, 1995) can be thought of as systems

Figure 3. Example of a neural network



that attempt to model different solutions to the problem of linking input to output and choose the one that is best. In technical terms this is called traversing the solution space; essentially these techniques use different methods to find functions that best give the expected outputs from the known inputs.

Generally KDD systems act on data to produce knowledge, that is they induce rules. The opposite approach, using existing knowledge to deduce outcomes is also used, in particular in the form of the expert system.

EXPERT SYSTEMS AND KNOWLEDGE BASED APPROACHES

These systems attempt to encode expert knowledge about an area as a set of rules in a knowledge base. An Expert System is: 'a computer program that represents and reasons with knowledge of some specialist subject with a view to solving problems or giving advice' (Chard & Schreiner, 1990) (p. 185). Expert Systems have had chequered history in medicine, with work starting in the early 1960's. A number of systems such as MYCIN (a system for selecting anti microbial drugs) and INTERNIST (a general internal medicine diagnosis program) were produced in the 1970's and work has continued using this and similar models. Work up to the mid '80s was reviewed by Shortliffe (Shortliffe, 1997) and de Vries (de Vries & Robbe, P.F., 1985). Medicine is an attractive target for expert systems because there is a great deal of information available on how clinicians make decisions, and it seems reasonable to view diagnosis and treatment as the application of rules. Clinical expertise is expensive, the consequences of mistakes are serious and there are many situations where such expertise is not readily available in human form. Examples of the latter include systems developed for diagnosing the acute abdomen for use on ships (Grigorenko, Zaiats, Kleshchev, Lifshits, & Samsonov, 1989). However, because of the potential risks and the complexities of the problems involved most medical expert systems have been used as decision support rather than decision making systems e.g. (Sittig, Gardner, Pace, Morris, & Beck, 1989). In fact the practical systems have mostly been advisory, and linked to databases of medical records such as the HELP system (Haug, Gardner, & Tate, 1994) to flag unusual or undesirable events. The only major systems that have 'closed the loop' i.e. act autonomously, are those in electronic pacemakers and especially implantable defibrillators which decide on very simple rules whether to attempt to cardiovert the patient, but this is really more in the domain of signal processing than artificial intelligence (Reid et al., 1983). An explanation of why expert systems are not in general use is given in (Shortliffe, 1997) and (Berg, 1994) and many other authors. Because it is rare for systems in the medical domain to be given complete authority for decision making, the term *intelligent decision support systems* has been introduced. Although many evaluations have been performed, very few of these have had the rigour expected for the assessment of other medical developments. Interestingly, the study by Johnston (Johnston, Langton, Haynes, & Mathieu, 1994) found that the well-conducted studies they collected showed that decision support systems did generally provide benefits in terms of patient outcome.

Applications in Women's Health

Women's Health Informatics is a particularly interesting area for the application of AI techniques for the following reasons:

- Large amounts of data are routinely collected, particularly in the Maternity domain, and there is some agreement about what is collected and what outcomes are important, so that data can be compared over long series and between centres.
- Screening programmes – especially cervical cancer screening- have been in place for a long time and audit of these programmes has produced a large amount of data, along with the requirement to examine large numbers of images(see chapter 11).
- In maternity, decisions are often made under uncertainty – so support for decision making from AI techniques is attractive (see chapter 10)

However, there remain formidable obstacles to use, including the fact that each woman is different, and many variables are open to interpretation, such as severity of pre-eclampsiapre-eclampsia.

SYSTEMS IN ACTION

Decision Support for Obstetrical Interventions

Induction of Labour can be a difficult decision to make, because of the lack of definitive evidence of the best course of action in a particular case. It is difficult to study because:

- Indications are formulated in a vague way (i.e. severe pre-eclampsiapre-eclampsia, rather than blood pressure (BP)>140/90)
- Published indications may not reflect actual practice.
- The indications for IOL are not completely agreed between experts - or even consistently applied by individual experts. For example, Figure 2 shows the rate at which 3 clinicians perform IOL for post-dates at 40, 41 or 42 weeks. In theory, if each clinician was consistent and the number of weeks gestation was the only criteria being considered, all post-dates induction would be performed at the same gestation.

IOL decision making is also important because of the potential risk and cost of the procedure. IOL has been associated with higher rates of other interventions and with greater reported pain during delivery and use of analgesia (E. C. Parry, Parry, & Pattison, 1999). There is no doubt that IOL is a valuable procedure that can improve outcomes for mother and baby in the correct circumstances as systematic reviews by (The Cochrane Collaboration, 1997) have shown. It is of concern if it is under used as well as over-used. With rates of IOL rising to over 25% in some centres, small changes in the IOL rate affect large numbers of women. A more philosophical problem is that pregnancy and birth are a natural process and are being reclaimed from "medicalization" by women. If unnecessary IOL's are being performed, or even if the reasons cannot be clearly explained then women will not tolerate it.

IOL is an interesting problem to study because the problem is similar to a lot of medical decisions made under uncertainty. However it has the advantage over many medical decision-making problems that the parameters involved are generally agreed, the domain is relatively small, and there has been a large amount of work done to study the effect of different decision making schemes

Finally, the greatest problem confronting the study of the decision making process in IOL is the fact that each mother and baby is different, and the outcome if the other course of action was followed will never be known. Happily, the rate of foetal deaths and complications is very low and the safety of IOL is very high so it is impossible to tell from epidemiological, retrospective or even reasonably-sized prospective study such as reported by Hannah (Hannah et al., 1996) evidence whether the correct number of IOL's is being performed. In essence, any IOL strategy used in current 1st world practice is as good as any other for preventing bad outcomes. The title of a paper "Induction of Labour, not how but why" (O'Connor, 1994), sums up this paradox. In a similar context, it has been calculated (Grant, 1994) that 200 unnecessary Caesarean sections are performed for every life-saving one. Similarly, the IOL debate is not about reducing bad outcomes; it is about reducing the rate of unnecessary IOL's.

There has been a fair amount of work to try and simulate the decision making process in Obstetrics. This can be seen as the first step in trying to support or even automate the decisions. Neural networks have been used to try and model the decision making process using historical data (MacDowell et al., 2001) and simulated patients have been presented to obstetricians in order to try an ascertain what information they use (D. T. Parry, Yeap, & Pattison, 1998). Machine learning tools have been used to try and predict the likelihood of preterm birth (Woolery & Grzymala-Busse, 1995).

Machine learning and other types of knowledge discovery require large datasets, and future electronic records and datasets may begin to provide this sort of resource.

REMINDER SYSTEMS

There is another category of decision support tools that fall between the fully automatic, and the fully manual. Reminder or alert systems sit within an electronic health record and allow deviations from expected practice, or failure to follow protocols to be highlighted. Systems such as PRODIGY and other guideline-based approaches can integrate with the clinical record and alert clinicians during clinical episodes(Peleg, Tu, Bury, Ciccarese, & al., 2003).

DISCUSSION

There has been relatively little use of Artificial intelligence in clinical practise in women's health. This reflects the generally small impact that Artificial intelligence techniques have had in supporting the general decision making in medicine. However the picture is not all gloom for a number of reasons. Special purpose data-interpretion systems such as CTG expert systems and Cervical smear analysis tools (see chapters 10 and 11) have become more popular and effective, and embedded into diagnostic systems. However, general models designed to predict outcome or support decision-making are not widely used. This is partly because of their dependency on exact figures that may pot be available, (Harris, 1981), and partly because of their dependence on data being available in computerised form.

However a recent review (Kawamoto, Houlihan, Balas, & Lobach, 2005), has demonstrated that systems that fit into clinical workflow, are available in clinical settings, give recommendations and require justification for non-compliance with their recommendations, are likely to produce an improvement in clinical outcomes.

The increasing development of appropriate protocols, and the implementation of them within clinical systems is likely to assist in this process. With the rise of internet-based tools it is likely that such protocols may become increasingly easy to produce and maintain(D. T. Parry, Parry, Chebi, Dorji, & Stone, 2008 (in press)), especially in an open-source environment. The central relationship between clinician and woman must, however, be preserved and these developments represent an aid, rather than a replacement for clinical judgement.

FUTURE RESEARCH DIRECTIONS

Decision-making remains a key task for health professionals and it is unreasonable to expect them to meekly hand it over to machines. However, decision analysis and intelligent decision support tools offer a wide range of potential benefits to professionals and patients. Undoubtedly this area has suffered from a perception that it is dry and mathematical, and too hard to understand. It is heartening to see more efforts made to make such systems usable, and useful. Many of the most used systems are effectively hidden from the user, embedded within electronic health record or measurement systems. This follows a trend that has seen decision support tools incorporated into commercial database management systems, and particularly placed on the web.

This area is a potentially very rewarding one for clinical workers as they can help improve the care of many future patients by allowing their knowledge and experience to be reused.

REFERENCES

Anonymous. (2007, 3rd October 2007). *Wikipedia - Hippocratic Oath*. Retrieved 16th October 2007, 2007, from http://en.wikipedia.org/wiki/Hippocratic_Oath

Bayes, T. (1764). Essay Towards Solving a Problem in the Doctrine of Chances *Philosophical Transactions of the Royal Society of London*.

Berg, M. (1994). Modeling Medical Work: On some Problems of Expert Systems in Medicine. *SIGBIO Newsletter of the ACM*, 2-6.

Brownsword, R. (2004). Reproductive Opportunities and Regulatory Challenges. *The Modern Law Review*, *67*(2), 304–321. doi:10.1111/j.1468-2230.2004.00488.x

Chard, T., & Schreiner, A. (1990). Expert systems in obstetrics and gynaecology. Review. Baillieres.Clinical.Obstetrics.&.*Gynaecology.*, *4*, 815–840.

Cochrane Collaboration. (1997). Cochrane Pregnancy and Childbirth Database (Version III) [CD-Rom]. Oxford,UK: Update Software.

Cooper, M. (1992). Should Physicians be Bayesian Agents? *Theoretical Medicine*, *13*, 349–361. doi:10.1007/BF02126701

de Vries, P. H., & Robbe, P. F. (1985). An Overview of Medical Expert Systems. *Methods of Information in Medicine*, *24*, 57–64.

Dowie, J. (1996). 'Evidence-based', 'cost-effective' and 'preference-driven' medicine: decision analysis based medical decision making is the pre-requisite. *Journal of Health Services Research & Policy*, *1*(2), 104–113.

Elson, J., Tailor, A., Banerjee, S., Salim, R., Hillaby, K., & Jurkovic, D. (2004). Expectant management of tubal ectopic pregnancy: prediction of successful outcome using decision tree analysis. *Ultrasound in Obstetrics & Gynecology*, *23*(6), 552–556. doi:10.1002/uog.1061

Fayyad, U., Piatetsky-Shapiro, G., & Smyth, P. (1996). From Data Mining to Knowledge Discovery in Databases. *AI Magazine*, (Fall): 37–53.

Grant, J. M. (1994). Induction of labour confers benefits in prolonged pregnancy. *British Journal of Obstetrics and Gynaecology*, *101*(2), 99–102.

Grigorenko, G. F., Zaiats, G. A., Kleshchev, A. S., Lifshits, A., & Samsonov, V. V. (1989). The outlook for introducing the Konsul'tant-2 expert medical system on board ships. *Voenno-Meditsinskii Zhurnal*, (2): 49–50.

Hannah, M. E., Ohlsson, A., Farine, D., Hewson, S. A., Hodnett, E. D., & Myhr, T. L. (1996). Induction of labor compared with expectant management for prelabor rupture of the membranes at term. *N. Eng. Med. J.*, *334*(16), 1005–1010. doi:10.1056/NEJM199604183341601

Harris, J. M. (1981). The hazards of bedside Bayes. *Journal of the American Medical Association*, *246*(22), 2602–2605. doi:10.1001/jama.246.22.2602

Haug, P. J., Gardner, R. M., & Tate, K. E. (1994). Decision Support in Medicine: Examples from the HELP System. *Computers and Biomedical Research, an International Journal*, *27*, 396–418. doi:10.1006/cbmr.1994.1030

Heckerman, D., & Wellman, M. P. (1995). Bayesian Networks. *Communications of the ACM*, *38*(3), 27–30. doi:10.1145/203330.203336

Johnston, M. E., Langton, K. B., Haynes, R. B., & Mathieu, A. (1994). Effects of computer-based clinical decision support systems on clinician performance and patient outcome. A critical appraisal of research. *Annals of Internal Medicine*, *120*(2), 135–142.

Jones, R. W., Coughlan, E., Reid, J. S., Sykes, P., Watson, P. D., & Cook, C. (2007). Human papilloma virus vaccines and their role in cancer prevention. *Journal of the New Zealand Medical Association*, *120*(1266), U2829.

Kawamoto, K., Houlihan, C. A., Balas, E. A., & Lobach, D. F. (2005). Improving clinical practice using clinical decision support systems: A systematic review of trials to identify features critical to success. *BMJ (Clinical Research Ed.)*, *330*(7494), 765. doi:10.1136/bmj.38398.500764.8F

Kennedy, J., Kennedy, J., & Eberhart, R. (1995). *Particle swarm optimization Particle swarm optimization.* Paper presented at the Neural Networks, 1995. Proceedings IEEE International Conference

Land, R., Parry, E., Rane, A., & Wilson, D. (2001). Personal preferences of obstetricians towards childbirth. *Australian and New Zealand Journal of Obstetrics and Gynaecology*, *41*(3), 249–252. doi:10.1111/j.1479-828X.2001.tb01224.x

Lauer, J. A., & Betran, A. P. (2007). Decision aids for women with a previous caesarean section. *BMJ (Clinical Research Ed.)*, *334*(7607), 1281–1282. doi:10.1136/bmj.39247.535532.80

MacDowell, M., Somoza, E., Rothe, K., Frye, R., Brady, K., & Bocklet, A. (2001). Understanding Birthing Mode Decision Making Using Artificial Neural Networks. *Medical Decision Making*, *21*(6), 433–443.

Montgomery, A. A., Emmett, C. L., Fahey, T., Jones, C., Ricketts, I., & Patel, R. R. (2007). Two decision aids for mode of delivery among women with previous caesarean section: randomised controlled trial. *BMJ (Clinical Research Ed.)*, *334*(7607), 1305. doi:10.1136/bmj.39217.671019.55

O'Connor, R. A. (1994). Induction of labour - not how but why? *British Journal of Hospital Medicine*, *52*(11), 559–563.

Parry, D. T., Parry, E. C., Chebi, A., Dorji, P., & Stone, P. (2008. (in press). Open source software – a key component of E-Health in Developing nations. *International Journal of Healthcare Information Systems and Informatics*.

Parry, D. T., Yeap, W. K., & Pattison, N. (1998). Using Rough Sets to study expert behaviour in induction of labour. *Australian Journal of Intelligent Information Processing Systems*, *5*(3), 219–225.

Parry, E. C., Parry, D. T., & Pattison, N. (1999). Induction of labour for post-term pregnancy: an observational study. *Australian and New Zealand Journal of Obstetrics and Gynaecology*, *38*(3), 275–279. doi:10.1111/j.1479-828X.1998.tb03065.x

Peleg, M., Tu, S., Bury, J., & Ciccarese, P., & al., e. (2003). Comparing computer-interpretable guideline models: A case-study approach. Journal of the American Medical Informatics Association 52. *Journal of the American Medical Informatics Association*, *10*(1), 52–69. doi:10.1197/jamia.M1135

Pena-Reyes, C. A., & Sipper, M. (2000). Evolutionary computation in medicine: An overview. *Artificial Intelligence in Medicine*, *19*(1), 1–23. doi:10.1016/S0933-3657(99)00047-0

Reid, P. R., Mirowski, M., Mower, M. M., Platia, E. V., Griffith, L. S., & Watkins, L. Jr (1983). Clinical evaluation of the internal automatic cardioverter- defibrillator in survivors of sudden cardiac death. *The American Journal of Cardiology*, *51*(10), 1608–1613. doi:10.1016/0002-9149(83)90195-9

Rosenberg, W., & Donald, A. (1995). Evidence based medicine: an approach to clinical problem-solving. *British Medical Journal*, *310*, 1122–1126.

Shortliffe, E. H. (1997). Computer Programs to Support Clinical Decision Making. *Journal of the American Medical Association*, *258*(1), 61–66. doi:10.1001/jama.258.1.61

Sittig, D. F., Gardner, R. M., Pace, N. L., Morris, A. H., & Beck, E. (1989). Computerized management of patient care in a complex, controlled clinical trial in the intensive care unit. *Computer Methods and Programs in Biomedicine*, *30*(2-3), 77–84. doi:10.1016/0169-2607(89)90060-6

The Cochrane Collaboration. (1997). Cochrane Pregnancy and Childbirth Database (Version III) [CD-Rom]. Oxford,UK: Update Software.

Thornton, J., & Lilford, R. (1989). The caesarean section decision: patients' choices are not determined by immediate emotional reactions. *J.Obs. Gyn.*, *9*, 283–288.

Thornton, J. G., & Lilford, R. J. (1989). Basic reference gambles recommended for utility assessment. *American Journal of Obstetrics and Gynecology*, *161*(1), 256–257.

U.S. National Library of Medicine. (2001, 15 November 2001). *Medical Subject* Headings. Retrieved 11 January, 2002, from http://www.nlm.nih.gov/mesh/

Widrow, B., Widrow, B., & Lehr, M. A. (1990). 30 years of adaptive neural networks: perceptron, Madaline, and backpropagation 30 years of adaptive neural networks: perceptron, Madaline, and backpropagation. *Proceedings of the IEEE*, *78*(9), 1415–1442. doi:10.1109/5.58323

Witten, I., & Frank, E. (2005). *Data Mining: Practical machine learning tools and techniques* (2 ed.). San Francisco: Morgan Kaufmann.

Woolery, L. K., & Grzymala-Busse, J. (1995). Machine learning for development of an expert system to predict premature birth. *Biomedical Sciences Instrumentation*, *31*, 29–34.

ADDITIONAL READING

Shortliffe, E., & Cimino, J. (Eds.). (2006). *Biomedical Informatics: Computer Applications in Health Care and Biomedicine (Health Informatics)* (Third ed.): Springer. Journal - Artificial Intelligence in Medicine

This work was previously published in Medical Informatics in Obstetrics and Gynecology, edited by D. Parry; E. Parry, pp. 302-314, copyright 2009 by Medical Information Science Reference (an imprint of IGI Global).

Chapter 4.19

Exploiting Process Thinking in Health Care

Teemu Paavola
LifeIT Plc, Finland

ABSTRACT

In Finland, a project designed to modernize processes and reduce the waiting list for joint replacement surgery has recently been completed. The new surgery arrangements for artificial joint patients were monitored for a period of 1 year. The new arrangements involved relocating the anaesthesia phase outside the operating theatre. The reorganization of the patient care process for joint replacement surgery succeeded in achieving a 50% increase in operations. While conventional operations can often be pushed up a notch with state-of-the-art technology, for example, this article supports the argument that process thinking can be exploited effectively to support new ways of work and improve productivity in health care. Paying enough attention to this at the planning stage can be vital to the success of new IT system implementation.

INTRODUCTION

The Act on Specialized Medical Care concerning the maximum times to arrange treatment, which came into force in Finland in March 2005, has made many health care units look at the arrangement of the services they produce in a new light. Particular attention is fixed on the legal obligation concerning the waiting times between treatment decisions and treatment measures, which is to be no more than 6 months. The need to increase the number of operations has become a matter of current debate particularly in orthopaedics, where the length of queues has become unlawfully long at several hospitals in Finland. Improvements in controlling the queues have previously been achieved by the more efficient handling of referrals (Harno, Paavola, Carlson, & Vikinkoski, 2000), but with orthopaedics this was felt to be ineffective (Harno, Arajarvi, Paavola, Carlson, & Arnala, 2001). In special operative areas, making use of all the development potential available within the traditional treatment chains should be explored as a permanent remedy, after first-aid obtained in the form of outsourced services.

The literature on both IT and process development is quite unanimous in its belief that both are necessary for achieving more efficient operation and a productivity increase. Therefore an IT system project is often a change project by nature, which can make it challenging particularly in the field of health care (Berg, 2001; Littlejohns, Wyatt, & Garvican, 2003), where resistance to change is virtually a characteristic of the profession (Weick & Sutcliffe, 2003).

This article illustrates a case where process thinking and process development tools were exploited to support new ways of work and improve productivity in health care. In Finland, Seinäjoki Central Hospital implemented a project to revise processes in order to reduce queues in surgery, particularly artificial-joint surgery. The project was part of the ProViisikko project of the Hospital District of South Ostrobothnia and Finnish Funding Agency for Technology and Innovation. The project in question was originally classified as an IT project which also incorporated process development. Over the course of the project, however, the balance between the two components shifted, and there was no time to incorporate the new IT system before the changes were implemented. This article describes the results of the experiment for the benefit of, for example, other operation units that are taking a close look at their operations and of developers and management in health care as support for decision-making. Parts of the study have been published in Finnish language (Jokipii, Kalliovalkama, & Paavola, 2006).

LITERATURE REVIEW

The term "process thinking" refers to a number of management theories that have been used by industry in its quest for better operating processes over the last few decades. In many of these, the use of IT also has a significant role. Indeed, IT has become more important in a number of areas, including health care; yet process thinking has not always been employed.

The populations of Europe and the Americas are ageing quickly. The health care system is struggling with the combination of rising demand and escalating costs in specialist medical care, while at the same time, there is strong support for reduced public-sector health care spending but firm rejection of any cuts in service levels. If the two targets are to become reality simultaneously, the methods enabling them to be achieved should be chosen on the basis of how deep the cuts should be.

Cosmetic improvements would be fairly painless: for example, Total Quality Management (Crosby, 1979; Deming, 1991) would result in long-term improvements in operating processes as a more efficient use of resources would bring gradual savings. Some scholars have, however, likened some quality management theories to a rain dance (Schaffer & Thomson, 1992). In their view they look good, sound good and allow those involved to feel good, while at the same time they may have no influence on the rain itself. There are also other management theories in the field of process thinking.

According to the time-based management approach, all development should focus on process lead-time (Stalk & Hout, 1990). In such an approach all other positive aspects, improved quality, cost savings and customer satisfaction will follow automatically. However, development measures do not need to mean squeezing more out of the stages intended to boost the value of the treatment process. In fact, industrial companies have been able to find larger savings in the way they use the time that brings no added value, which, after all, accounts for more than 95% of the total (Stalk & Hout, 1990).

In contrast to total quality management, which emphasizes continuous development, business process reengineering (BPR) proposes a radical revision of the business process. The aim is to start from scratch without the burden of old operating approaches (Oliver, 1993; Hammer & Champy, 1993). The reengineering starts with a definition of the desired end result. This will form the basis for the planning of the new process functions and sequences. The aim is to maximize value-adding functions and to get rid of all operations not adding to the value. Extensive use of the information technology is often used as the means for achieving the desired results.

Effecting the operational changes required by BPR has been somewhat problematic. Resistance to change, which is inherent in human nature, and the fact that reengineering is often a zero-sum game, make the implementation of the change process more difficult (Buchanan, 1997). Besides, reengineering thinking emerged just as the recession of the early 90s began to bite, and was often used as a justification for drastic job cuts. In fact, for a while BPR was almost likened to the Black Death in the industrial sector. Since then it has lost some of its reputation and has evolved from a much-feared consulting tool into a set of practical measures. The theory, though somewhat worn-out, is still useful, as it underlines the importance of the information technology in performance improvement. Great potential for applying the theory and information technology can be found in sectors that for ages have relied on well-entrenched operating models, such as health care (Evans, Hwang, & Nagarajan, 1997).

The importance of IT for productivity in different organizations has been discussed for decades. The discussion led by Straussmann (1990) and Brynjolfsson (1993) has particularly focused on explaining what is known as the IT Productivity Paradox. Although Brynjolfsson (1993) and Brynjolfsson and Hitt (1996) later declared that the problem had disappeared by 1991, not all researchers have agreed, and interest in explaining the phenomenon remains high, so much so that Texas-based reseachers Anderson, Banker, and Ravindran (2003) proposed a new IT Productivity Paradox to replace the original. They observed a growth in the market worth of businesses after Y2K investments leading up to the turn of the millennium. These investments were made for replacing systems already in use, yet they still resulted in significant increases in productivity. Anderson et al. (2003) proposed this as a new, inverse phenomenon to be explained, calling it the New Productivity Paradox. According to their theory, the weak IT impact on productivity especially immediately after the turn of the millennium (2000-2002) can be attributed to companies simply not investing enough in IT, in direct contradiction to the IT Productivity Paradox.

Lee and Menon (2000) argue that hospitals that are characterized by high technical efficiency are no more productive than hospitals characterized counterwise. In fact, in the hospitals studied IT capital seemed to have a negative correlation to productivity. They explain this by the fact that although hospital's processes may have been efficient, resource allocation and budgeting between various categories of capital and labor had not been efficient. Devaraj and Kohli (2000) believe that the effect of IT on performance can been seen only after a time lag and cannot necessarily be observed in cross-sectional or snapshot data analyses. With data collected from eight hospitals, their study indicates support for the impact of technology contingent on BPR practiced by hospitals.

STARTING POINTS FOR CHANGE AND EXPERIMENT

Seinäjoki Central Hospital wanted to reorganize the operations for artificial-joint patients so that three operations could be performed in the same operating room in the course of a normal day's work instead of two. The introduction of a new IT system was also planned as part of the project. The experimental period lasted from November 2004 to November 2005.

The revision of the treatment process utilized process thinking and process development tools. Of these, the Theory of Constraints (Goldratt, 1990) was thought the best applicable for examining the process for treating artificial-joint patients. The point in this approach is to identify those stages in the process that dictate the maximum current throughput. By allocating additional resources and development action to these bottlenecks, the throughput can be improved without needing to interfere in the other stages of the process. The main change for increasing the usage of the operating room capacity was transferring the anaesthetic stage from the operating room to separate induction facilities. Experiments on this had been reported earlier in medical journals (Hanss et al., 2005; Sandberg et al., 2005; Torkki et al., 2005).

In the new arrangement, the anaesthetic stage was transferred outside the operating room. At the same time, one anaesthesia nurse was added to the operating team, working both in the operating room and in anaesthetic. Another anaesthetic nurse took the next patient in good time to the recovery room or to the operating room's induction facilities to be anaesthetized. As soon as the operating room was cleaned after the previous operation, the next patient could be prepared for surgery. The next patient was brought to the operating room already anaesthetized and in the correct position for the operation.

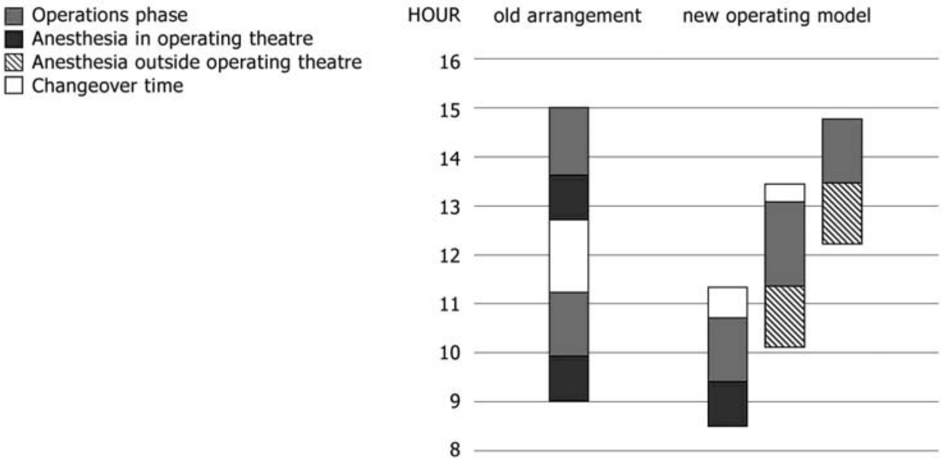
The duties of the orthopaedist that were not part of the operations or preparation for them were scheduled outside the operation days. Thus, the surgeon whose turn it was to operate was able to focus exclusively on the work in the operating room. At the beginning of the experimental period, the same orthopaedist operated for 1 week at a time, but this practice had to be changed so that the operation days were rotated among different practitioners. At the beginning of 2005, there were five orthopaedists working at Seinäjoki Central Hospital.

MATERIAL, METHODS AND RESULTS

In Finland, every year about 6,800 artificial joint operations are carried out on the hip and some 7,200 on the knee, and there are more than 1,700 instances of further surgery. These operations are performed in almost 70 hospitals, but the minimum number of 200 operations recommended by the Ministry of Social Affairs and Health is only exceeded in 25 units. Every year the Hospital District of South Ostrobothnia performs between 550 and 600 artificial-joint operations.

In the study, quantitative material was collected from the operating days in the experimental period on which three artificial-joint operations were

Figure 1. The old arrangement and the new operating model for artificial joint surgery



carried out (147 patients); because of the small number of orthopaedists, there were 2-3 of these days in a week. Comparative material consisted of the days on which two artificial-joint operations were carried out between January 1 and June 30, 2004 (54 patients).

The time when patients were in the operating room and changeover times were recorded in the operation database. The time-monitoring material consisted of the times when the operating room was in use. The median time that patients were in the operating room and the median changeover time, when there is no patient in the operating room, were used for comparison purposes.

Qualitative material was collected through interviews during the experimental period and by means of a work-satisfaction questionnaire carried out among doctors and nurses a year after the experiment started.

The new operating model made it possible to carry out three operations during a normal working day (see Figure 1). The orthopaedists examined the patients during a preoperative visit or on the day preceding the operation. The first patient of the morning was in the operating room in time, and the operation started on time at 8.30 a.m. The anaesthetization stages for the second and third patients, which were carried out staggered with the operation, took slightly longer than if carried out in the operating room.

As it was possible to separate some of the steps previously carried out in the operating room and have them done outside, the hospital succeeded in increasing the throughput of the process by 50%, even though the usage capacity of the operating room remained almost the same.

Adding a fourth nurse to the operating team (now 2 in anaesthetization and 2 in the operation) made it possible to shorten the changeover times considerably: the average time was reduced from 54 minutes to 13 minutes. This was because the team was able to take coffee and meal breaks in turn. One of the operation nurses was able to help the orthopaedist as necessary.

In the three-operation model, anaesthetizing the second or third patient of the day in separate facilities reduced the time the patient was in the operating room by 20 minutes (149 minutes vs. 129 minutes).

According to the questionnaire, 50% or more of the doctors who took part in the experiment felt that the meaningfulness of their work and work motivation had increased and thought that the three-operation experiment should become a permanent fixture. The nursing staff felt that minimizing the idle waiting improves the atmosphere and increases work motivation to some extent. The doctors felt the new operating model improves the meaningfulness of the work and work motivation more than the nursing staff did.

DISCUSSION

The usage capacity of the operating room is generally considered to be the bottleneck in the operation process. This generalization leads easily to a practice where outsourced services or increasing the number of a hospital's own operating rooms are seen as the only options for increasing output. From our experiences the throughput of the process for artificial-joint operations can be increased while the usage capacity of the operating room remains the same or even decreases. Focusing the operations on one operating room proved to be effective.

An increase in the throughput of the operation process was sought without increasing the workload of the staff. The hospital succeeded in doing this by firstly dealing with idle waiting. Targeting greater efficiency here and a simultaneous improvement in the throughput required development in several areas, for example, adding one nurse to the operating team, a bigger work contribution from the hospital attendant in preparing patients, preparing the anaesthetic in a new way and changing the orthopaedist's work schedule. The justification for adding one nurse was that in the revised staggered operation stage, there was also one patient more.

It was not possible to anticipate all the effects of the change. In order to ensure that things went smoothly, specialist experienced doctors acted as anaesthetists and orthopaedists during the experimental period, but at the same time the arrangement narrowed the opportunities for training specializing doctors. Furthermore, not enough preparation was made for the increase in the number of operations at all stages of the treatment process. At times, the growth in the throughput caused congestion on the ward and especially in further treatment at health centres.

In financial terms, the transfer to the practice of three operations was worthwhile. The resources for arranging three operations were obtained principally by utilizing the fixed costs of the hospital more efficiently. In alternative cost accounting comparing the additional cost caused by a hospital's own activities with the cost of an artificial-joint operation acquired from the private sector or another provider (minus the costs of the prosthesis, materials and cost of the treatment days) shows a difference of some USD 4,000 between the hospital's own work and outsourcing with regard to the added third primary operation per day. Because of the limited number of orthopaedists, however, it was not possible in the experimental period to run "flat out" five days a week.

Fifteen complete operations a week would be enough to meet the need for artificial-joint surgery in the entire hospital district, and the revised treatment process would generate annual savings of between USD 700,000 and USD 800,000 for the Hospital District of South Ostrobothnia, even taking into account the additional recruitment required. Savings come from cutting back on services purchased from private hospitals, as the hospital itself can now perform a larger percentage of the joint replacement surgery required.

Although planned as part of the project, the introduction of the new IT system did not take place during the present change project. The reason for this was that the software was not complete when the project was launched. Nevertheless, the IT system appears to have played a noteworthy role in the launching of the project because key players whose commitment was essential to the successful implementation of the change were motivated by the eventual benefits of the IT system to support the project. The IT system was intended to work as a tool for monitoring patients in rehabilitation and to make it easier to organize follow-up visits in a timely fashion and based on actual needs. The new IT system would further reduce the workload at the hospital by making it possible to carry out postoperative patient monitoring at local health centers rather than at the hospital outpatient clinic.

CONCLUSION

This article presents a succesful reorganization of the care process for an artificial joint patient. The project by a middle sized Finnish hospital offers an encouraging example of a way to exploit process thinking and process development tools in health care. Seinäjoki Central Hospital succeeded in obtaining a 50% increase in flow-through in the process for treating artificial-joint patients with the transfer of the anaesthesia stage outside the operating room in the reorganization. For every two joint replacement operations previously conducted, there were now three operations performed in the same theatre and in a normal working day. In the longer term, the arrangement would mean that in Finland the entire country's need for artificial joint surgery, about 15,600 operations per annum, could be dealt with in 30 operating rooms. This could considerably streamline the publicly-financed health care system in Finland, as these operations are currently performed in almost 70 hospitals.

The introduction of the new patient care process demonstrated that the operating theatre capacity was not causing a bottleneck, but that it was the orthopaedic surgeons brought in at the various intervals who formed the key resource. The reorganized care process for patients requiring joint replacement surgery should produce annual cost savings of USD 700,000 to USD 800,000 for the Seinäjoki Central Hospital. Following the experience gained in the project, the Seinäjoki Central Hospital has decided to adopt the project model on a permanent basis. A similar reorganization is also possible in other hospital districts. This observation, however, should only be applied to orthopaedic joint replacement surgery.

An interesting detail in this change project was that the role of the IT system itself was completely marginal. All kinds of justifications for investing in IT systems can be given, from economic calculations to managerial intuition (Paavola, 2007), but in the change project described in this article, IT seemed to act only as a catalyst. Perhaps the project could not have been successfully implemented to the extent it was had not an IT component, which "always requires changes in the operational process," been included. This observation of IT acting as a catalyst for performance enhancement and hence improved productivity deserves further study. It would be worth exploring to what extent indirect impact should be considered in making IT investments alongside direct effects, and how this phenomenon could be studied. Are there cases where IT investment was motivated as leverage for achieving a particular change in the operating environment, even though the same impact on productivity could have been achieved without IT investment?

ACKNOWLEDGMENT

The author would like to thank Pekka Jokipii, MD and Kari Kalliovalkama, MD for their contribution to this study. This project was partly funded by the Finnish Funding Agency for Technology and Innovation.

REFERENCES

Anderson, M., Banker, R., & Ravindran, S. (2003). The new productivity paradox. *Communications of the ACM, 46*(3), 91-94.

Berg, M. (2001). Implementing information systems in health care organizations: Myths and challenges. *International Journal of Medical Informatics, 64*(2/3), 143-156.

Brynjolfsson, E. (1993). The productivity paradox of information technology. *Communications of the ACM, 36*(12), 67-77.

Brynjolfsson, E., & Hitt, L. (1996). Paradox lost? Firm level evidence on the returns to information systems spending. *Management Science, 42*(4), 541-558.

Buchanan, D. (1997). The limitations and opportunities of business process re-engineering in a politicized organizational climate. *Human Relations, 50*, 51-72.

Crosby, P. B. (1979). *Quality is free*. New York: McGraw-Hill.

Deming, W. E. (1991). *Out of crisis*. Cambridge, MA: Cambribge University Press.

Devaraj, S., & Kohli, R. (2000). Information technology payoff in the health care industry: A longitudinal study. *Journal of Management Information Systems, 16*(4), 41-67.

Evans, J., Hwang, Y., & Nagarajan, N. (1997). Cost reduction and process reengineering in hospitals. *Journal of Cost Management, 11*(3), 20-27.

Goldratt, E. M. (1990). *Theory of constrains*. Croton-on-Hudson, NY: North River Press.

Hammer, M., & Champy, J. (1993). *Reengineering the corporation—a manifesto for business revolution*. New York: Harper Business.

Hanss, R., Buttgereit, B., Tonner, P. H., Bein, B., Schleppers, A., Steinfath, M., et al. (2005).

Overlapping induction of anesthesia: An analysis of benefits and costs. *Anesthesiology, 103*(2), 391-400.

Harno, K., Arajärvi, E., Paavola, T., Carlson, C., & Arnala, I. (2001). Clinical effectiveness and cost analysis of patient referral by videoconferencing in orthopaedics. *Journal of Telemedicine and Telecare, 7*(4), 219-225.

Harno, K., Paavola, T., Carlson, C., & Viikinkoski, P. (2000). Patient referral by telemedicine: Effectiveness and cost analysis of an intranet system. *Journal of Telemedicine and Telecare, 6*(6), 320-329.

Jokipii, P., Kalliovalkama, K., & Paavola, T. (2006). Tekonivelpotilaan hoitoprosessin uudistaminen. *Suomen Lääkärilehti (Finnish Medical Journal), 61*(14), 1626-1627.

Lee, B., & Menon, N. (2000). Information technology value through different normative lenses. *Journal of Management Information Systems, 16*(4), 99-119.

Littlejohns, P., Wyatt, J., & Garvican, L. (2003). Evaluating computerised health information systems: Hard lessons still to be learnt. *British Medical Journal, 326*, 860-863.

Oliver, J. (1993, August). Shocking to the core. *Management Today*, 18-22.

Paavola, T. (2007). Justifying IT system investments. *International Journal of Healthcare Technology and Management, 8*(1/2), 97-106.

Sandberg, W. S., Daily, B., Egan, M., Stahl, J. E., Goldman, J. M., Wiklund R. A., & Rattner, D. (2005). Deliberate perioperative systems design improves operating room throughput. *Anesthesiology, 103*(2), 406-418.

Schaffer, R., & Thomson, H. (1992). Successful change programs begin with results. *Harward Business Review, 22*(1), 80-89.

Stalk, G., & Hout, T. (1990). *Competing against time—how time-based competition is reshaping global markets*. New York: The Free Press.

Strassmann, P. (1990). *The business value of computers*. New Canaan, CT: The Information Economic Press.

Torkki, P. M., Marjamaa, R. A., Torkki, M. I., Kallio, P. E., & Kirvela, O. A. (2005). Use of anesthesia induction rooms can increase the number of urgent orthopedic cases completed within 7 hours. *Anesthesiology, 103*(2), 401-405.

Weick, K., & Sutcliffe, K. (2003). Hospitals as cultures of entrapment. *California Management Review, 45*(2), 73-84.

This work was previously published in International Journal of Healthcare Information Systems and Informatics, Vol. 3, Issue 2, edited by J. Tan, pp. 12-20, copyright 2008 by IGI Publishing (an imprint of IGI Global).

Section V

Organizational and Social Implications

This section includes a wide range of research pertaining to the social and organizational impact of health information systems around the world. Chapters included in this section analyze preparing healthcare organizations for IT adoption, demographic difference in telehealth outcomes, physician characteristics and electronic medical records, and patient perspectives and roles in creating health records and recording health data. The inquiries and methods presented in this section offer insight into the implications of health information systems at both a personal and organizational level, while also emphasizing potential areas of study within the discipline.

Chapter 5.1

Organizational Factors:
Their Role in Health Informatics Implementation

Michelle Brear
University of New South Wales, Australia

INTRODUCTION

The influence of organizational factors on the success of informatics interventions in healthcare has been clearly demonstrated. This health specific research, informed by a larger body of evidence emerging from interdisciplinary organizational, psychological and sociological research, has confirmed the view that organizational factors can be the decisive factor in the success of an intervention (Lorenzi *et al*, 1997).

However it remains rare for organizational factors to be explicitly addressed in the implementation process. As such their contribution to the success or failure of informatics applications is not properly understood. This has implications for future interventions. Applications which were not utilized or did not perform adequately in a particular setting may be dismissed, while other, less appropriate systems may be adopted because organizational factors influenced their success. Explicit study of the role of organizational factors on the implementation of health informatics interventions is necessary to develop an understanding of their influence in the healthcare context.

Healthcare organizations tend to be highly task oriented, labor intensive and dependent on interdisciplinary teamwork, so the influence of organizational factors within them may differ considerably from the business settings in which they have traditionally been studied (Chau, 2001). Health organisations are also increasingly under-resourced due to the global downturn in government social spending, health sector privatization and aging populations.

DOI: 10.4018/978-1-60566-078-3.ch016

It is these characteristics which necessitate rapid uptake of informatics applications, capable of automating aspects of healthcare provision and reducing labor intensity (Coiera, 2004).

From a technical perspective, rapid and fundamental transformation of the healthcare sector through informatics is achievable. However, without a clear understanding of, and ability to manage organizational factors it is unlikely that informatics applications will realize their potential in the health sector. This short review provides an overview of the key organizational factors influencing the success of informatics interventions. It begins by positioning informatics interventions in the broader context of organizational change, before discussing the current understanding of selected factors.

INFORMATICS IMPLEMENTATION AS ORGANIZATIONAL CHANGE

Implementing informatics applications is essentially “a politically textured process of organizational change” (Berg, 1999, p87), aimed at achieving user acceptance and utilization of informatics applications. Organizational change requires people to be aware of a need for change, identify a particular course through which the change can occur and take actions to make it happen (Lorenzi, 2004). Resistance to change occurs if users are not aware of the need for change, not convinced of the course of action set out or unable to carry out the necessary action. It is the users, not the technology that should be the centre of the change process, as the decision to utilise the system is ultimately theirs (Berg, 1999).

Even the best-designed and well-intentioned informatics interventions are likely to lead to productivity losses in the early stages and create major changes (Lorenzi, 2004). Timely and effective training of users can reduce the disruption, however is not enough to ensure success as even a correctly used system can have far reaching effects. Informaticians taking a ‘socio-technical’ approach, view the application as one component of a complex system, the health organisation, whose introduction will disrupt other components of the system (e.g. patients and clinicians). They advocate design approaches which aim to create technology which ‘fits’ within the complex system (Kaplan, 2001).

The multi-disciplinary nature of health sector organisations makes finding the correct ‘fit’ challenging (Kaplan, 2001). A range of professionals with different needs, expectations and work norms, are likely to use an application and each will expect it to ‘fit’ with their work practice. When an application does not fit resistance will increase. This is often due to valid concerns about increased workload or ability to care for patients (Timmons, 2003). When systems do not ‘fit’, the best way to overcome resistance is to change them. However when they are essentially effective, resistance can be overcome by changing people’s opinions or work norms. Organizational culture and social networks, from which many of these norms and opinions arise, need to be understood and managed.

ORGANIZATIONAL CULTURE

Organizational culture is the set of shared norms and values and tacit rules within which members of an organisation function (Lorenzi & Riley, 2000). “Every culture supports a political and social values system” (Lorenzi, 1997, p85) which will influence the reaction to an informatics application. Healthcare settings often involve a professional hierarchy between doctors and nurses, are characterized by high levels of informal and disruptive communication and place value on clinician/patient relationships and patient care.

It is necessary to identify and target the aspects of organizational culture presenting opportunities for and barriers to success when changing the organisation through an informatics intervention.

Managing change requires mediating the influence of culture on events, rather than necessarily aiming to change it (Demeester, 1999). Where organizational culture and informatics applications appear incompatible, adaptation of the application should be considered.

If it is not possible to modify the system, success is dependent on changing the organizational culture to make it compatible. Cultural change directly targeted at the strongly held values of users, may only increase resistance. If the organisational culture supports a belief that informatics applications undermine good clinician/patient relationships, attempting to convince clinicians that good relationships with their patients are not important is unlikely to be a successful strategy for winning acceptance of the application. However it may be possible, through an educational process, to convince clinicians that informatics applications do not necessarily undermine good relationships and in the right conditions can even enhance them. Users may already be convinced of the need to change some aspects of organizational culture which do not threaten the values they are most passionate about. The structure of an organisation and work patterns and roles of individuals within it are influential and may be appropriate areas to encourage change.

Organizational Structure

The structure of an organisation will affect the way in which decisions are made, the type of leadership which emerges and the way resistance is dealt with in the implementation process. 'Flatter' organizational structures tend to encourage the sharing of ideas, emergence of innovation and broader involvement in decision-making (Leonard *et al*, 2004). In these types of organisations management tends to adopt a collaborative approach, working alongside, listening to and involving those working on the ground, rather than making decisions on their behalf and communicating orders. Management is supportive, approachable and accountable and shows dedication to continuous learning (Zimmerman, 1993). These types of organisations are more likely to include practicing clinicians in formal decision-making bodies such as management committees. They are also more likely to recognize, encourage and legitimize the role of grass roots leaders with clinical credibility and presence and have a commitment to involving informatics users in the implementation process.

User involvement throughout the process "leads to increased user acceptance and use by encouraging realistic expectations, facilitating the user's system ownership, decreasing resistance to change, and committing users to the system" (Lorenzi, 1997, p86). It also allows better definition of problems and solutions, from the user's perspective and develops a better understanding amongst users of the application (Lorenzi, 1997). Involving users in the design and implementation of a system is more likely to result in applications suited to the current work patterns of the intended users.

Work Patterns and Roles of Clinicians

Any informatics application must be compatible with the current work practices and values of the organisation (Greenhalgh, 2004; Kaplan, 2001; Lorenzi & Riley, 2000). Compatibility will differ between organisations and cultures so applications require the capacity to be tailored to the needs of individual organisations. Take an electronic prescribing system for example. In one hospital it may be used to enter prescription orders during ward rounds via a laptop computer however a different hospital (or even another ward within that hospital) may find it more appropriate to install the system on a computer terminal at the nurses stations so that orders can be entered retrospectively. Bearing in mind the necessity to consider the unique context of individual organisations, it is possible to make some generalizations regarding the work patterns and roles of clinicians to broadly inform the design of informatics interventions.

Doctors have traditionally worked with a high degree of professional autonomy and status (Gagnon, 2003). Applications perceived to undermine their autonomy and status as professionals or "subvert the art of medical practice" (Kaplan, 2001, p4) are more likely to meet with resistance. In a qualitative study examining factors influencing adoption of a CDSS involving automatic clinical reminders, Rousseau et al (2004) found clinicians favored on-demand evidence systems to automatically generated reminders. The latter were perceived to be intrusive, often inapplicable and not particularly useful for making patient management decisions.

Clinicians tend to be patient focused, require an ability to maintain control of patient care and make decisions specific to individuals which computers are not capable of. They must be convinced that applications will not jeopardize their ability to care for patients (Timmons, 2003). Overly prescriptive systems, or those which attempt to take on the uniquely human quality of thinking, are unlikely to be successful. Rouseau et al (2004) noted inapplicable reminders were a barrier to effective use and found that practitioners formed a habit of ignoring all reminders. In a study of adherence to electronic HIV treatment reminders, Patterson *et al* (2004) found the inapplicability of reminders to many patients' specific situations, and the time taken to document why the reminders were not adhered to, were significant barriers to effective system use.

All applications will create some change to normal work patterns and roles. That is essentially what their implementation is intended to do (Berg & Toussaint, 2003). Users need to be realistically informed of and prepared for changes to normal work practice. It is inevitable that users will expect some future benefit from adapting their behaviors and realistic communication of the likely benefits, particularly if they are indirect or not clearly visible, should form an integral part of the communication strategy.

Communication

Communication binds individuals together and is integral to the implementation process. Without effective communication it is impossible to lead, learn, make decisions, prepare individuals for an intervention or use it effectively (Zimmerman, 1993). Lack of communication, or ineffective communication which lacks trust, can negatively influence the uptake of a technology (Ash, 1997). There is no 'magic formula' for effective communication, however there are some key principles which should be applied to enhance the effectiveness of communication.

Communication must be timely. People require time to digest information and prepare for changes (Tilley & Chambers, 2004). However they also forget. Users who are trained to use a system months before its implementation may not remember how to use it when it finally arrives. Information must also be communicated at an appropriate time. Disrupting a lunch break or patient care, may not be the most appropriate way to inform users about a new application.

Communication must be sincere and truthful. Users must be offered an honest and realistic assessment of the potential negative consequences and expected benefits of an application. For example if an electronic medical record application is introduced, it may be realistic to expect its use to be more time consuming in the initial stages while users master the system. However in time, its ability to provide comprehensive patient information at the click of a button may save time and provide better quality information. It is also important to acknowledge unexpected benefits and problems if they occur.

Sources of communication have an immense impact on the perceived message, its credibility and influence (Kaplan, 2001). A manufacturer's leaflet declaring the new system easy to use is unlikely to carry much weight with users, however a respected clinical peer conveying this information may be quite influential.

It is essential the communication be recognized as multi-dimensional, rather than a one-way channel from management to users. Mechanisms for receiving feedback must be created and where it is not forthcoming, should be actively elicited from users. Magrabi *et al* (2004) incorporated two mechanisms for feedback into an online DSS. Users could volunteer feedback at any time, however it was also actively elicited by randomly prompting users. Once received, feedback should be acted upon to adapt the application to meet user needs (Greenhalgh, 2004). For example, in response to clinician feedback, the patterns of automatically generated reminders in a clinical decision support system (CDSS) was altered to limit the number of reminders perceived by clinicians to be inapplicable. Communication through informal structures (e.g. gossiping in the tea room) is inevitable and ability to manage it directly, limited. However the less effective formal communication mechanisms are, the more likely it is that communication will take place through informal channels in the social network.

SOCIAL NETWORKS

A social network consists of the individuals, groups and organizations with whom, and patterns of communication by which individuals in an organisation interact. It is through social networks that organizational culture and behaviors are reinforced and adapted (Lorenzi, 1997). The culture represented within a social network can be influential. For example, Gagnon *et al* (2003) found that physicians who perceived social and professional responsibility to adopt telemedicine applications [from others in their social network] had a stronger intention to do so. The culture represented in each individual's social network will differ, and each individual within will interact and be influenced differently.

To properly understand a social network it is necessary to examine the interactions, not the individuals. Frequency of interaction is important but should not be viewed in isolation from the style of communication (e.g. formal or informal), type of communication (e.g. synchronous or asynchronous) the strength of ties between the participants in an interaction and power relations involved (Katz et al, 2004). When implementing an informatics application, interactions which occur in clinical teams and with respected opinion leaders, are particularly influential in relation to individuals decisions to utilise applications.

Effective Teamwork

The clinical team has been identified as the organizational unit most influential in the diffusion of innovation (Gosling *et al*, 2003). Well functioning teams facilitate effective communication, encourage continuous learning and offer a trusting environment in which ideas and issues can be raised. Through these interactions, teams develop shared visions and common goals which support the introduction of new innovations to fulfill these goals. As work in health organisations is highly dependent on teamwork and it is teams, not individuals, which must adopt informatics applications, well functioning teams are a prerequisite for successful informatics implementation (Goldstein *et al*, 2004).

In organisations where well functioning teams do not exist, an informatics intervention may be an opportunity to develop teams, by uniting individuals around a shared vision and common goals which the application can fulfill. Doctors and nurses take on different roles and responsibilities in the process of caring for patients so a shared vision may not be immediately apparent. However both groups ultimately work towards the goal of providing optimal patient care, so incorporating an application into a vision of improved patient care may be a way to unite users.

Consideration should also be given to the size and composition of teams. Teams of more than 15 tend to fragment into sub-teams, while very small teams have a tendency to become cliquish, so ideally they should consist of 10-15 members (Gosling *et al*, 2003). The work environment may largely dictate a team's composition. In healthcare settings teams are usually multidisciplinary. Individuals however, are more likely to create ties with those they perceive to be similar, so identifying similarities amongst multidisciplinary teams is pertinent (Katz *et al*, 2004). Identifying and utilizing the influence of respected clinicians within the team can also be useful.

Clinical Champions and Opinion Leaders

Respected clinicians with influence amongst their peers, who support the intervention play an important role in convincing others of an application's worth, as do those who oppose the intervention. They are commonly referred to as clinical champions or opinion leaders. As the name 'champions' tends to imply a positive influence and does not necessarily imply the champion has influence amongst peers (Lolock *et al*, 2001), 'opinion leader' will be used in this paper.

Opinion leaders are individuals with the ability to influence others in the social network, who make a major personal commitment to diffusing information about an informatics application (Lorenzi & Riley, 2000). Such diffusion may have a negative or positive influence, and can discourage or encourage the adoption of the application. For example Ash (1997) identified the presence of 'champions' as a significant factor in the diffusion of email in academic health science centres. Conversely Timmons (2003) discusses a "strong and articulate" ward sister whose resistance to using an electronic system in the ward was successful in preventing its implementation. It is not unusual to have both negative and positive opinion leaders within a network.

Whatever their persuasion they tend to be charismatic individuals with good interpersonal relationships based on trust and understanding. They act through clinical conviction, generally outside of the formal structures, and give applications credibility at a local level. Their role is essentially informal, and, on the proviso their colleagues respect them, they tend to be self-appointed (Lolock, 2001). The role is largely dependent on personal motivation and conviction and therefore difficult to formalize. The potential alienating effect of being an opinion leader means that those without sufficient commitment are likely to be reluctant to take on such a role (Lolock, 2001)

Despite a general consensus that successful interventions are more likely when champions are present, there is a lack of understanding about exactly what it is they do, the circumstances in which they will be influential and how best to describe them. As with each of the factors mentioned here, opinion leaders are one small component of a large and complex system (the health organisation) and it is difficult to isolate their effect. There is also considerable evidence to suggest that other factors, in particular the suitability of the application, influence the emergence of opinion leaders. As with all the factors mentioned here, further research is needed to identify how opinion leaders influence and how the 'champions' amongst them can be encouraged.

CONCLUSION

There is a general recognition that numerous organizational factors will influence the success of an informatics intervention. This is supported by a body of evidence from multi-disciplinary and health specific research. In particular research has noted the influence of: organizational culture and social networks. Organisational culture, the shared norms and values within which members of an organisation function influences the organization's structure and patterns of communication. Social networks, the individuals and groups with whom one interacts and the interactions which occur between them, are the social space in which teams are formed and work and individuals are influenced, particularly by those individuals known as opinion leaders or clinical champions. Organizational factors are highly inter-related and the exact nature and contribution of each to the success of an intervention is not clear. A health specific understanding and recognition of these factors is necessary if informatics applications are to reach their potential in healthcare settings.

ACKNOWLEDGMENT

This work was previously published in Handbook of Research on Informatics in Healthcare and Biomedicine, edited by A. Lazakidou, pp. 410-418, copyright 2006 by Information Science Reference, formerly known as Idea Group Reference (an imprint of IGI Global).

REFERENCES

Berg, M. (1999). Patient care information systems and health care work: a sociotechnical approach. *International Journal of Medical Informatics*, *55*, 87–101. doi:10.1016/S1386-5056(99)00011-8

Berg, M., & Toussaint, P. (2003). The Mantra of Modeling and the Forgotten Powers of Paper: A Sociotechnical View on the Development of Process-oriented ICT in Health Care. *International Journal of Medical Informatics*, *69*, 223–234. doi:10.1016/S1386-5056(02)00178-8

Chau, P. Y. K., & Hu, P. J.-H. (2002). Investigating Healthcare Professionals' Decisions to Accept Telemedicine Technology: an Empirical Test of Competing Theories. *Information & Management*, *39*, 297–311. doi:10.1016/S0378-7206(01)00098-2

Coiera, E. (2004). Four Rules for the Reinvention of Healthcare. *British Medical Journal*, *328*, 1197–1199. doi:10.1136/bmj.328.7449.1197

Demeester, M. (1999). Cultural Aspects of Information Technology Implementation. *International Journal of Medical Informatics*, *56*, 25–41. doi:10.1016/S1386-5056(99)00036-2

Gagnon, M.-P., Godin, G., Gagne, C., Fortin, J.-P., Lamothe, L., Reinharz, D., & Cloutier, A. (2003). An Adaption of the Theory of interpersonal Behaviour to the Study fo Telemedicine Adoption by Physicians. *International Journal of Medical Informatics*, *71*, 103–115. doi:10.1016/S1386-5056(03)00094-7

Goldstein, M.K. Coleman, R.W. Tu, S.W. Shankar, R.D. O'Connor, M.J. Musen, M.A. Martins, S.B. Lavori, P.W. Shilipak, M.G. Oddone, E. Advani, A. A. Gholami, P. & Hoffman, B.B. (2004). Translating Research into Practice: Organisational Issues in Implementing Automated Decision Support for Hypertension in Three Medical Centers. *Journal of the American Medical Informatics Association*, *11*(5), 368–376. doi:10.1197/jamia.M1534

Gosling, A. S., Westbrook, J. I., & Braithwaite, J. (2003). Clinical Team Functioning and IT Innovation: A Study of the Diffusion of a Point-of Care Online Evidence System. *Journal of the American Medical Informatics Association*, *10*(3), 244–251. doi:10.1197/jamia.M1285

Greenhalgh, T., Robert, G., MacFarlane, F., Bate, P., & Kyriakidou, O. (2004). Diffusion of Innovations in Service Organisations: Systematic Review and Recommendations. *The Milbank Quarterly*, *82*(4), 581–629. doi:10.1111/j.0887-378X.2004.00325.x

Kaplan, B. (2001). Evaluating informatics applications- some alternative approaches: theory, social interactionism, and call for methodological pluralism. *International Journal of Medical Informatics*, *64*, 39–56. doi:10.1016/S1386-5056(01)00184-8

Katz, N., Lazer, D., Arrow, H., & Contractor, N. (2004). Network Theory and Small Groups. *Small Group Research*, *35*(3), 307–332. doi:10.1177/1046496404264941

Leonard, M., Graham, S., & Bonacum, D. (2004). The Human Factor: The Critical Importance of Effective Teamwork and Communication in Providing Safe Care . *Quality & Safety in Health Care*, *13*(Suppl 1), i85–i90. doi:10.1136/qshc.2004.010033

Lolock, L., Dopson, S., Chambers, D., & Gabbay, J. (2001). Understanding the role of opinion leaders in improving clinical effectiveness. *Social Science & Medicine*, *53*, 745–757. doi:10.1016/S0277-9536(00)00387-7

Lorenzi, N. M. (2004). Beyond the Gadgets: Non-technological barriers to information systems need to be overcome. *British Medical Journal*, *328*, 1146–1147. doi:10.1136/bmj.328.7449.1146

Lorenzi, N. M., & Riley, R. T. (2000). Managing Change: An Overview. *Journal of the American Medical Informatics Association*, *7*(2), 116–124.

Lorenzi, N. M., Riley, R. T., Blythe, A. J. C., Southon, G., & Dixon, B. J. (1997). Antecedents of the People and Organizational Aspects of Medical Informatics: Review of the Literature. *Journal of the American Medical Informatics Association*, *4*(2), 79–93.

Magrabi, F. Westbrook, J.I. Coiera, E. W. & Gosling, A.S. (2004). Clinicians' Assessments of the Usefulness of Online Evidence to Answer Clinical Questions. Proceedings of the 11th World Congress on Medical Informatics, 297-300.

Patterson, E. S., Nguyen, A. D., Halloran, J. P., & Asch, S. M. (2004). Human Factors Barriers to the Effective Use of Ten HIV Clinical Reminders. *Journal of the American Informatics Association*, *11*(1), 50–59. doi:10.1197/jamia.M1364

Rousseau, N., McColl, E., Newton, J., Grimshaw, J., & Eccles, M. (2003). Practice-based, Longitudinal, Qualitative Interview Study of Computerised Evidence Based Guidelines in Primary Care. *British Medical Journal*, *326*, 314–321. doi:10.1136/bmj.326.7384.314

Tilley, S., & Chambers, M. (2004). The process of implementing evidence-based practice- the curates egg. *Journal of Psychiatric and Mental Health Nursing*, *11*, 117–119. doi:10.1111/j.1365-2850.2004.00685.x

Timmons, S. (2003). Nurses Resisting Information Technology. *Nursing Inquiry*, *10*(4), 257–269. doi:10.1046/j.1440-1800.2003.00177.x

Zimmerman, J. E., Shortell, S. M., Rousseau, D. M., Duffy, J., Gillies, R. R., & Knaus, W. A. (1993). Improving Intensive Care: Observations based on organisational case studies in nine intensive care units: A prospective multicenter study. *Critical Care Medicine*, *21*(10), 1143–1451.

KEY TERMS

Clinical Champion: Clinical Champions are opinion leaders who 'champion' or encourage the uptake of an application.

Opinion Leader: An opinion leaders is an individual, respected amongst their peers who acts out of clinical conviction to influence the opinions of others vis-à-vis an informatics application.

Organisational Culture: Organisational culture is the set of shared norms and values and tacit rules within which members of an organisation function.

Organisational Factors: In an informatics context, organisational factors are factors relating to the culture and functioning of an organisation which, negatively or positively, influence its ability to adapt to an informatics intervention.

Social Network: A social network consists of the individuals, groups and organisations with whom an individual interacts, and the interactions which take place between the individual and other components of their social network.

Socio-technical Approach: A socio-technical approach is one which views informatics applications as part of the broader social and political context within which they are implemented.

Teamwork: The co-operative effort of a small group to achieve a specified outcome.

This work was previously published in Medical Informatics in Obstetrics and Gynecology, edited by D. Parry; E. Parry, pp. 315-322, copyright 2009 by Information Science Reference (an imprint of IGI Global).

Chapter 5.2

Changing Healthcare Institutions with Large Information Technology Projects

Matthew W. Guah
Erasmus University Rotterdam, The Netherlands

ABSTRACT

This article reviews the development of institutional theory in direct relations to historical changes within the UK's National Health Service (NHS) with an eye to contributing to the theoretical specification of healthcare information processes. This is done partly by extending certain paradigms (see Meyer & Rowan, 1991; Powell & DiMaggio, 1991; Tolbert & Zucker, 1994) through a proposed model of causes and consequences of variations in levels of institutionalisation in the healthcare industry. It reports findings from a 5-year study on the NHS implementation of the largest civil ISs worldwide at an estimated cost of $10 billion over a 10-year period. The theoretical basis for analysis is developed, using concepts drawn from neo-institutionalism, realisation of business value, and organisational logic, as well as mixed empirical results about the lack of IT investments value in the NHS. The findings suggest that large scale, IT change imposed upon a highly institutionalised healthcare industry is fraught with difficulty mainly because culturally embedded norms, values, and behavioural patterns serve to impede centrally imposed initiatives to automate clinical working practices. It concludes with a discussion about the nature of evaluation procedures in relation to the process of institutionalising IS in healthcare.

INTRODUCTION

An historical overview of IT projects in the UK's National Health Service (NHS) during the last six decades is presented here with the intention to both clarify the links between institutional theory and previous traditions of sociological work on organisational structure. The initial exposition of this theory by works of established institutionalists (Meyer & Rowan, 1991; Scott, Ruef, Mendel, &

Caronna, 2000; Tolbert & Zucker, 1994) focuses on the ways of challenging dominant theoretical and empirical traditions in organisational research. While this article clarifies some ambiguity and elaborates on the logical and empirical implications of a phenomenologically based version of institutional theory, the primary aims are to clarify the independent theoretical contributions of institutional theory to analyses of the NHS and to develop this theoretical perspective further in order to enhance its use in empirical research in other healthcare environments (internationally and globally).

Markus (1983) claims that interaction theory draws together three principal strands of resistance: (1) internal factors, (2) technical problems, and (3) political context. This theory has been highly influential in IS strategy and other social sciences generally since Markus first developed the ideas over two decades ago. The focus here (see Table 1) is on how interaction theory offers a new way of looking at IS implementation in the healthcare industry.

Much has been researched in the last few decades about the major lack of a coherent implementation strategy for IS (Sambamurthy & Zmud, 1994) in the healthcare industry (Stevens, Schade, Chalk, & Slevin, 1993; Vogel, 2003). Most of such claims have been levelled against an apparent "productivity paradox" with respect to investments in healthcare management (in general) and IS (in particular). The Wanless report (2002) and Committee on Quality Health Care in America assessment report by Institute of Management (2002)—both national government's mandated investigations into the UK and USA national healthcare systems respectfully—among others, have failed to find a convincing body of evidence that investment in healthcare IS is associated with increased output (refuting the productivity paradox), but not with healthcare value as measured by patient satisfaction.

WHAT IS INSTITUTIONALISM?

Institutionalism is continuously being used to mean different things by researchers of political science, economics, and sociology. Lowndes (1996, p. 182) presents institutionalism as informal codes of behaviour, written contracts, and complex organisations with four elements:

- A middle-level concept. Institutions are devised by individuals and therefore constrain individuals' actions. Institutions here are seen as part of the broad social fabric and medium for individuals' day-to-day decisions and other activities. DiMaggio and Powell (1994) argue that institutions shape human actions, imposing constraints while providing opportunities for individuals.

Table 1. Implementation theory: Usage, fitness, relationship and sufficiency

Authors	**IS Implementation**	**Theory Description**
Lucas, 1993	Appropriate use of IS	Process theory explaining appropriate IS use Variance theory linking use with business value
Grabowski & Lee, 1993	Strategic fitness of IS	Process-type relationship between strategic fit and performance of IS
Markus, 1983	Relationship of IS assets	How IS investment do or do not become IS assets How IS assets do or do not yield improved organisational performance
Sambamurthy & Zmud, 1994	Insufficient to produce impacts	Process model connecting raw material inputs to outputs Variance theory of IS management competencies and IS impacts Variance theory linking impacts and business value

- Having formal and informal aspects. Lowndes (1996) views institutions to involve formal rules or laws, which allows informal norms and customs to be practiced. That is because some institutions are not consciously designed nor neatly specified, yet part of habitual actions by its members. Such institutions may be expressed in organisational form and relate to the processes within.
- Having legitimacy. Legitimacy in institutions goes beyond the preferences of individual actors. Such preferences are valued in them and go beyond their immediate purpose and outputs.
- Showing stability over time. Lowndes (1996) views institutions as gaining their legitimacy due to their relative stability over time, and their links with a "sense of place."

New institutionalists generally view institutions to have "the humanly devised constraints that shape human interaction" (North, 1990, p. 3) what March and Olsen, (1989) refer to as "rules of the game" (p. 162) that organisations and individuals are constantly expected to play the game. Another stand taken by new institutionalists sees informal institutions (tradition, custom, culture, and habit) are embedded in culture and conventions defined as behaviour structuring rules (March & Olsen, 1989; North, 1990). New institutionalists stress embodied values and power relations of institutions together with interaction between individuals and institutions (Lowndes, 1996). They attempt to distinguish between informal institutional rules and personal habits. Such distinction forms the basis for the definition of institution in this research where informal conventions and their impact upon the NHS and its partners are being explored.

Research Methodology

The research study began in 2001, with the initial interest of conducting an exploratory-descriptive study in 10 NHS hospitals to explore why, "historically, the NHS has not used or developed IT as a strategic asset in delivering and managing healthcare" (Department of Health [DoH], 2000). Intensive literature review unveiled few longitudinal studies, which systematically and rigorously examined how IT systems were introduced and changed over time. There were very limited studies that examined inter-organisational relationships between different constituents in the adoption and diffusion of IT systems (NHS directorship, hospital management systems, or IT suppliers and patients). Not only were most of these studies descriptive and lacked a historical dimension, they presented IS in healthcare as largely theoretical with most contributions reporting the findings of a specific IT project implementation using simple success and failure criteria—Scott et al. (2000) being among the most significant contributions.

Using such a relevant and wide-ranging backdrop this research study recognised that it was important to extend the empirical enquiry for two reasons: (1) exploratory-descriptive case studies on a single organisation (or one hospital) would not elicit in-depth and rich data to develop any meaningful analysis and conclusions on how IT was being deployed and managed; and (2) the introduction of a large scale, IT-enabled change program needed to be researched at the wider societal, organisational field and individual levels, covering an extended period of time, to understand the processes of institutionalisation (Tolbert & Zucker, 1994). The research study was therefore designed to capture the myriad of views and opinions about the national program over a 5-year period to build a rich picture of such processes underpinning large scale IT change.

Three methods of data collection were adopted: (1) a range of academic, government, and industry studies on the healthcare sector were

Table 2. Numbers of interviews conducted

Categories of Interviewees	Year 1		Year 2		Year 3	
	Contacts Made	Persons Interviewed	Contacts Made	Persons Interviewed	Contacts Made	Persons Interviewed
NHS Information Authority	32	5	30	10	10	15
Major IT Service Providers	90	56	60	45	17	12
Primary Care Trusts Admin	15	5	25	12	22	12
Secondary Care Trust Admin	0	0	9	3	7	4
Local NHS IT Managers	15	6	20	11	60	42
Medical Consultants	3	1	8	4	9	6
Nurses & Junior Doctors	13	3	15	3	11	4
Healthcare Researchers	35	20	20	8	10	7
Total Interviews		105		96		102

assembled—both UK and healthcare services in other countries. The materials proved invaluable for understanding the societal, economic, political, cultural, and technical differences in healthcare nationally and internationally; (2) participation in trade fairs, conferences, workshops, and exhibitions on healthcare—focusing on general or more specific healthcare activities. These events also generated many useful research contacts that proved invaluable for targeting interviews. (3) A semi-structured interview (see Table 2) schedule was used to enable interviewees to expand on their answers. While most interviews lasted for about 90 minutes, a limited number lasted just under an hour, with nearly all interviews being tape recorded and subsequently transcribed. Respondents were later contacted with feedback from the interviews and, where necessary, errors were corrected. This method of data collection was critical for allowing interviewees to raise additional themes, issues, and concerns that they felt were important to the research study. As a result of the political contention of some of the interview content, some interviewees asked that names of individuals and hospitals be anonymous.

After the initial 6 months of interviews, the scope of the study had to be extended, as it was important to elicit data and information from a wider range of respondents engaged in the implementation of the national program. These included IT service providers bidding for public sector IT contracts and doctors in general practices around the country. Most IT service providers offered critical insights into the political and procurement processes within the NHS and public sector more generally (Guah & Currie, 2004). General practitioners, on the other hand, offered useful insights about the communication channels underpinning the institutional processes underpinning the national program. Given the range of constituents involved, the resulting data were evaluated and interview schedules refined, ensuring questionnaires be more closely targeted to the professional and personal situation of the individual, as generic questions were less meaningful. The final questionnaire—consisting of

15 questions—was ultimately divided into the following major themes:

- ***Vision*** **for the national program:** overall vision and how it was compatible with individual hospital objectives.
- ***Strategy*** **for the national program:** Who was engaged with and how the strategy was being communicated within different organisations.
- ***Implementation*** **of the national program:** What professional, managerial, and technical skills or capabilities were needed to implement various elements of the national program.
- ***Value delivery*** **for the national program:** The main risks identified by each hospital and how past IT failure could be avoided, as well as looking at the cost/benefit choices and issues for each organisation.
- ***Risk\analysis*** **for the national program:** The value being derived from the national program.

The aim was to get the perspectives of a number of different informants using structured interviewing, by building up intensive longitudinal cases which would, nevertheless, be amenable to statistical analysis. In this method, differences of perception of informants become part of the data, not an inconvenience to be explained away in the search for some objective truth.

DATA ANALYSIS

Content analysis was used to surface themes in the interview data that reflected participants' understandings related to systems implementation. The approach suggested by Weber (1990) was used to code the interview data. A set of codes used to classify the data was developed, based on concepts from the research literature and augmented with major additional concepts discovered by the researchers during the coding. We used a content analysis form where each sentence from the interview transcripts was assigned one or more codes. Each data element was coded with an assessment of the level of agreement in code assignments, involving a certain degree of recoding of data sources. As this was the first study that uses content analysis about modelling of system implementation in the NHS, a certain degree of recoding was considered acceptable.

Table 3 contains a list of the most frequently cited attributes and benefits of the system implementation model. The audiotapes were fully transcribed and individual hospital and service provider summaries were produced before conducting a content analysis of each transcript. After a complete review of all summaries, issues describing IS implementation strategies by iterative examination were identified. Certain themes emerged, which were explored using the competing values framework as an interpretive framework where appropriate (see Table 3). The

Table 3. Frequently described implementation attributes and benefits

Implementation Attributes			Implementation Benefits		
Item	**Count**	**% of Cat**	**Item**	**Count**	**% of Cat**
Applications work together	40	13	Improved data accuracy/reliability	61	20
Data sharing	173	57	Lower costs of support, maintenance	212	70
Common database	127	42	Greater efficiency and productivity	167	55
Real-time processing	106	35	New or increased functionality	106	35
Record once, use everywhere	121	40	Better management, decisions, analysis	136	45

trustworthiness of such analysis has been assessed by triangulation between data sources and exploring any differences in the researcher' interpretations during a couple of follow-up meetings with selected interviewees.

During the period of the field study, there was a continuing, vigorous, informal debate within NHS Information Authority as to the merits of establishing a fault proof IS implementation framework in healthcare, particular for the NHS, during this period of healthcare reform. Benefits in terms of improved quality, greater structure, and more discipline were widely accepted.

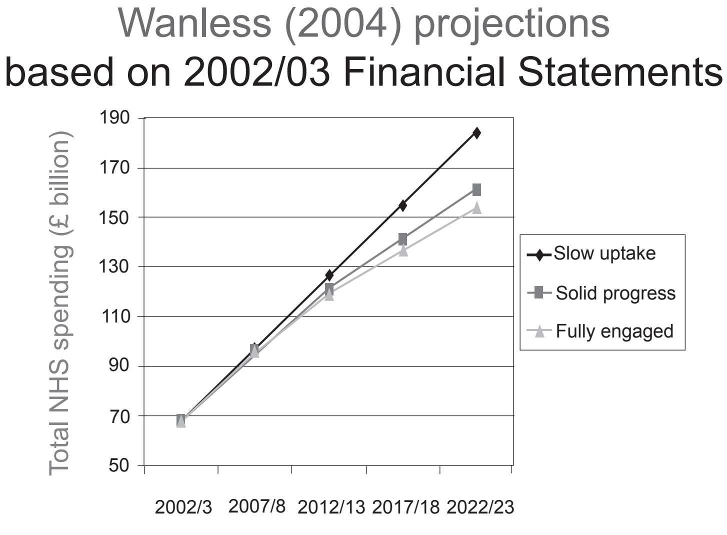
THE NHS CASE STUDY

The NHS is the institution responsible for all healthcare and services in the UK with the goal of undertaking this responsibility at no costs to the public, at the point of delivery. The NHS was created in 1948 by a parliamentary art of the UK government of Mr. Howard Wilson, after a national healthcare review by Mr. Black immediately after World War II. While the NHS operating environment has changed radically within the last six decades, only a few periods of strategic importance to the objective of this article will be revisited by the author.

The period from late 1980s to early 1990s brought in the advent of competitive bidding bringing long-term increase costs to the management of the NHS, as well as a feeling of internal market within the NHS. By the mid-1990s, management of IS in the NHS was division based. Divisions were spread across several sites and medical functions were centrally controlled. Computing services and IS development projects were beginning to be contracted to external private businesses, and staff at the NHS were beginning to feel disgruntled and unappreciated. The increasing influence of global communications, Internet, and other new technologies demanded a response from the NHS.

In the late 1990s the government increasingly recognised the opportunity to use IT to improve the delivery of service within the NHS. After a series of reviews of NHS IT service delivery, a more integrated and seamless IT organisation was recommended (DoH, 2000; Wanless, 2002). The NHS Information Authority embarked on the Integrated Care Report Service (ICRS) project

Figure 1. NHS projected expenditures over two decades (Wanless, 2004)



to provide, among other services, a nationwide electronic patient database. The result was a document called "Information for Health" that specified the need for the complete automation and integration of various patient information databases in the country (DoH, 2000). The system was commissioned to selected IS service providers at a combined price of $10 billion.

In spite of its vision—to transformation IT—the NHS has a history of introducing large-scale IT development projects that have not been overall successes, with some suggesting failure rates of between 60 to 80% (Brown, 2001). Though the UK public sector spent around $3.5 billion annually on IT, the failure of major IT-enabled projects were characterised by delay, overspending, poor performance, and abandonment (National Audit Office [NAO], 2004, p. 3). At the political level, it is argued that "better IT is needed in the NHS because the demand for high-quality healthcare continues to rise and the care now provided is much more complex, both technically and organizationally" (Connecting for Health, 2004, p. 7). About $250 million is spent on management and administration in the NHS, a controversial figure, as many believe more doctors and nurses should be recruited (see Figure 1).

THEORETICAL ANALYSIS OF THE CASE

The NHS case study illustrates the dynamic nature of a national healthcare IS implementation, set within the context of a rapidly changing organisation. As with all large IT-enabled programs, the success or otherwise of the strategic plan is in its implementation (Doolin, 2004; Hendy, Reeves, Fulop, Huchings, & Masseria, 2005; Herzlinger, 1989). The lessons of IT costs versus medical decision making are well documented in the literature and involve the lack of alignment between the business and IT strategy (Luftman, 2000); a lack of ownership and leadership of the IT project among senior decision makers (Brown, 2001); poor risk assessment skills (Heathfield, Pitty, & Hanka, 1998); over-scoping of the functional and technical specification leading to IT projects becoming over-budget and late (NAO, 2004); poor communication between program/project managers and potential users of the system (Guah & Currie, 2005); inadequate resources to deliver/implement IT systems (Currie & Guah, 2006).

The empirical research found that issues of project risk were at the forefront of the minds of clinicians, general practitioners (GPs), hospital managers, and IT staff. Formal project management methods and tools were perceived as offering only part of the solution to mitigate the considerable risks from introducing the national program. The fragmentation was not just about the diversity of IT systems within the NHS, but also about the political geographical, social, organisational, and financial complexity of delivering healthcare.

The overriding view was for the national program to become an integrated IS across and beyond the NHS. The threats to achieving this were perceived by many clinicians to fall within the control of politicians and IT service providers rather than from NHS staff. Project risk mitigation was a complicated issue, compounded by the political and ideological considerations, such as the public-private partnership funding initiative (PFI), which facilitated the increasing use of private sector firms. While the NHS is often characterised as a top-down bureaucracy (Mohan, 2002), past achievements in IT development and implementation had often been initiated at a decentralised (hospital, departmental, unit) level. Although this was now discouraged by the centrist approach of the national program, staff participating in the research expressed concerns that any failures associated with IT project implementation may be labelled *staff resistance* rather than the shortcomings of external constituents, such as politicians, management consultants, or IT suppliers.

The success or failure of IS is inextricably linked with the dynamics of the organisation within which they exist. Miranda and Saunders (2002) have demonstrated the complex interaction of technical, social, cultural, and political elements that result in a failed IS. Equally, IS success depends on more than technical competence. The cultural and political environment of the NHS is difficult to study as it depends not only on the tangible organisational structure but also on the tacit knowledge and the perceptions of the participants (Guah & Currie, 2005). This is in addition to the cultural and political environment of an organisation that is not static but rather in a state of constant flux and dynamic change.

Institutionalism of IS in the NHS is concerned with processes of cultural persistence and change of healthcare processes. The survival of an organisation depends as much on conforming to societal norms of acceptable practice as to achieving high levels of production efficiency and effectiveness (Covaleski, Dirsmith, & Michelman, 1993). Prior work has shown that an organisation's formal structure, policies, and procedures serve to demonstrate conformity with the institutionalised rules and requirements of external constituents (DiMaggio & Powell, 1983; Meyer & Rowan, 1991). In light of these concerns healthcare in the UK showed that the national program was intended to play a high profile role within the heavily institutionalised environment of hospitals (Scott et al., 2000).

The UK healthcare system is infused with institutional logics emanating from various sectors across the organisational field. Healthcare is politically contentious where societal level logics developed by government are embedded into policies and procedures that cascade down to organisations where they are interpreted by various stakeholders including clinicians, managers, administrators, and patients. How these logics are interpreted varies according to the degree to which they affect changes to the perceived or real material resource environment of the institutional actors. The vision for the national program was infused with the institutional logics more commonly associated with the private sector, as an innovation that would contribute to greater productivity, efficiency, cost control, and customer satisfaction in healthcare delivery. Paradoxically, this externally directed institutional logic served to under represent and simplify the vast complexities and contradictions in how it was perceived, and reacted to, by those affected by government-led IT-enabled changed. Within the NHS, staff were increasingly sceptical about the merits of private sector logics, such as the PFI initiative, as their values, norms, and goals invariably placed financial considerations secondary to choices about patient care.

The proliferation of new entrants into the healthcare organisational field was a consequence of changing government policies over six decades. During this era of professional dominance, healthcare workers, particularly clinicians, enjoyed a level of freedom to define and structure their working practices. This extended to choices about the types of technology adopted and diffused across the NHS. As a new era emerged in the 1970s, which embraced managerialism as a way to enhance efficiency and performance, the European healthcare system was increasingly inundated with various managerial fads and panaceas, like BPR and change management (Herzlinger, 1989). An outcome of such interventions was that isomorphic structures across the NHS were increasingly threatened, as NHS managers were keen to demonstrate "best practice" examples through the adoption of the latest management ideas. Implicit in this logic was that NHS organisations that had not embraced "new ideas" ran the risk of being labeled as "against modernisation" or, at worst, "failing institutions."

Moving from an era of managerialism to one which increasingly advocates the use of "market mechanisms" to regulate and monitor healthcare services, efforts to differentiate NHS organisations still needs to be intensified further. The political rhetoric surrounding the right of patients to "choose" between one provider and the next is not likely to be based upon anything more than a crude assessment of the number of "stars" awarded a primary care trust (PCT), with those holding a low number becoming labeled as offering a less than adequate quality of service to patients. This will further fragment the organisational field of healthcare as the status of individual NHS organisations becomes increasingly differentiated on the basis of current and future evaluation criteria to measure performance. The topic of performance measurement was highly contentious, however, as respondents offering both a clinical and technical perspective believed that the emphasis upon target-setting was carefully designed to absolve politicians from responsibility by accentuating the role and accountability of professional groups.

The concepts of the organisational field, institutional logics, and governance systems are central to our understanding of how the healthcare system adopts and adapts to changes in the material-resource environment and the beliefs, rules, and ideas that comprise the value system. How and why these eras have emerged underpins our investigation into the UK NHS and facilitates our understanding of the nature and scope of large-scale change programs, and the extent to which they signal an institutional change within healthcare.

The institutional logics and governance systems must therefore be understood to explain why this type of change has occurred. In our investigation, we are concerned to apply our theoretical framework to help us understand how a large–scale, nation-wide technical change program is being adopted and diffused throughout the healthcare system and, more specifically, the changes in the organisational field, institutional logics, and governance systems that serve to encourage or inhibit such change.

TOWARDS BETTER VALUE IN HEALTHCARE DECISION MAKING

The national program is intended to help the situation healthcare managers presently face—with almost no say over the crucial factors which most managers anywhere else in the Western world and in other industries need to have in order to be effective (Wanless, 2004). The situation was brought about by a mixture of a quasi-medieval system and a control approach to managing patient data. Unlike other industries (i.e., banking and airline industries) where decision making leads to a good outcome, requires adaptation, and matching of the process to the individual customer, the healthcare industry may not necessarily provide a gold standard for a process that guarantees good outcomes for patients (Grabowski & Lee, 1993; Martin, 2003).

The previous is partly a result of humans being biological creatures and biological systems are inherently variable. As individuals we all have our own copies of genetic material—these materials mutate and evolve randomly. Because of the variability, the number of formulas and data points required to document each instantiation of a biological system constantly increases by several folds. Consequently, the number of conditions that need to be handled by uniform data standards is much greater than that required by standards for simpler physical, production or materials handling systems, however large or geographically widespread they may be. It takes into consideration that the patient's state of health is the result of the complex interaction between his/her unique genetics makeup, brain capacity, environment, and habits. Thus explaining why some individuals may be able to carry on fairly normal activities despite severe loss of 80% of their pulmonary capacity, others may be disabled by minor arthritis. Careful reproduction of a healthcare process that results in a good outcome for the former may not help the later.

Such scenarios dictate that the delivery of healthcare is not only unique in variety but also in the range of services and products. This explains why healthcare services are not typically chosen by the patient but by a more professional and knowledgeable representative (although these medics are increasingly being influenced by the pharmaceutical companies and/or government (Stevens et al., 1993). This shows just how the healthcare industry is different from others in the Western economy because the market in most industries is driven by the customer.

Health industry requirements are also exceptionally demanding in a number of areas. Most notable are the implications of violations of personal privacy while involving all those who need to know; dual responsibility for personal and public health; the complexity and expansion of the knowledge base and terminology; the high risk to the providers' livelihood combined with pressures to make critical decisions continuously and rapidly; and poorly defined outcomes. All of this is in the context of a "guild system" of responsibility, accountability, and power (Markus, 1983; Vogel, 2003). The healthcare industry also has to support personal and moral values, which in themselves are very complex. The judgments taken about personal attitudes to risk and potential benefit on interventions are all driven by our unique physical and mental makeup and local context—though our values are constantly changing over time.

The implementation of the national program demonstrates how healthcare services are perhaps the most complex large-scale business of UK's economy. More variability and uncertainty at the point of service, as to causality, processes, and to the outcome of that investment exists in healthcare delivery than in any other public sector. With such "variability and uncertainty" in the healthcare business, it is not surprising that identifying and measuring, let alone valuing, a financial return on investment (ROI) from computers in healthcare presents special challenges.

Value is a much broader concept than "benefits" as it implies the additional gain from one investment as opposed to another (Lucas, 1993; Sambamurthy & Zmud, 1994). The national program, like other IT projects, can generate value in many ways. As well as creating quality and process improvements, data from the system has utility that is much more subjective than that of any other resource (Guah & Currie, 2004). While data may be viewed as a commodity, asset, or resource, information is derived from the qualitative use of data and involves value judgments.

A number of the difficulties in "measuring" the national program's potential value the patients are that (Currie & Guah, 2006; Hendy et al., 2005):

- many infrastructure investments cannot be cost justified on an ROI basis;
- some of its sob-systems are being implemented to change difficult-to-measure NHS staff actions;
- many parts may be strategic systems, thus, eluding measurement;
- much of the new investment does not take into account the prior costs;
- efficiency (doing things right) is easier to measure than effectiveness (doing the right things); and
- since effectiveness (doing the right things) and innovation (doing new things) can not be readily quantified in terms of traditional outputs, improvements are not usually reflected in economic efficiency statistics.

While the effectiveness of a healthcare delivery process can be defined as "the extent to which a desirable outcome is achieved in a timely manner," the efficiency of healthcare delivery process could also be defined as "the extent to which healthcare delivery process is completed with the minimal consumption of resources." Consider the rather complex process of diagnosing and treating certain categories of patients in the NHS, most healthcare delivery processes can be effective (the patient achieves a full recovery and returns to his/her normal activities within 3 months) but relatively inefficient (say the patient had a 15-day inpatient stay, extensive ambulatory services, and consumed $300,000 in healthcare resources). The healthcare delivery process also can be ineffective (the patient has minimal subsequent capacity and never returns to his/her normal activities) but efficient (if the patient had a 3-day inpatient stay, a short post discharge ambulatory regimen, and consumed only $5,000 in healthcare resources). This demonstrates the need for healthcare managers to further strive for high effectiveness in combination with high efficiency and at the lowest possible costs.

Most components of the national program are intended for use in the NHS primarily to capture and manipulate data for improved—both clinical and administrative—decision making. Majeed (2003) suggests that part of the value anticipated from the national program derives from improvements in the effectiveness of the clinical decision-making process. It should enable physicians and nurses to make better, quicker decisions through mechanisms such as online access to evidence-based results for designated disease conditions, assistance in placing orders (detecting a drug-drug interaction before the order for a medication is actually placed), and receiving an alert electronically after a significantly abnormal test result (Keeler & Newman, 2001). Increasing the effectiveness of the clinical decision-making process should also lead to higher efficiency of that process, which should consequently lead to fewer errors being made and fewer resources being consumed. Among many problems highlighted by Majeed (2003), was the fact that necessary information was often difficult to obtain or simply unavailable, and what was available did not always support the clinical decision-making process.

Improved access to records means dramatically improved efficiencies in a variety of areas (Lucas, 1993). With the old paper-based system, the average turn-around time before laboratory and radiology reports reached the physician was several days. With the national program, diagnostic test results are available within seconds of being verified and has the potential of being brought to the physician's attention through their e-mails on the desktop or text message on a mobile (for telemedicine). In addition, the redundant orders that were often triggered by result delays have been virtually eliminated with the faster turnaround time, as well as with duplicate verifications for pharmaceutical orders (Majeed, 2003).

The national program will vastly improve communication between clinicians, particularly between nurses and physicians, and the emergency room and primary care physicians. It will give nurses instant access so that they can communicate with the doctors in the right way; the nurses are less frustrated because they do not have to go through the paper trail like they did before. These intangibles we know can be difficult to value but they are real enough to the participants.

CONCLUSION

The UK NHS is a highly institutionalised and complex system, which exists and operates both as a material-resource environment and a set of beliefs, rules, and ideas. Although these two environmental facets are conceptually distinct, material-resource environments are influenced by the institutional context. The selection of resources and how they are combined and deployed is determined by institutional beliefs and rule systems (Meyer & Rowan, 1991). By looking at the national program, this article has shown that implementing such a large IT project in the healthcare environment involves a supplier base that is seriously diverse, stretching from locally based specialists in particular applications and/or industry sectors to suppliers that are capable of applying a combination of sophisticated management techniques and technology investment to achieve new levels of process performance.

The primary contribution of this article has been to provide a theoretical basis drawing from institutional theory, which was used to analyse the NHS implementation of the national program. The theorisation goes beyond the relatively simplistic types of studies that dominate the IS literature today. Much to the contrary, it has been shown that an implementation strategy can accommodate elements such as the links between culture, contradiction and conflict, an analysis of detailed work patterns, and the dynamic and emergent nature of political involvement at national level.

The theory has been illustrated using limited empirical examples only, with a focus on the NHS systems, but it could be used to analyse any case study involving healthcare systems from any parts of the developed world. Viewed from a more critical perspective, however, any theory illuminates some elements of particular case situations and is relatively silent on others. The NHS has grown within an environmental niche that arose out of a complex interaction between the national healthcare environment, business environment, the organisational environment, and the people within the NHS. Changes within the organisation subsequently rendered the environment hostile to the national program, which was affected by its changing links with organisational structure and people, the changing responses of people within the NHS to the environment around them, and the changing individual and collective mindsets and understanding of those people. While a detailed discussion of ways in which this can be achieved is beyond the scope of this article, some broad approaches have been mentioned.

In the current environment of increasing demands for better quality of healthcare from patient and seemingly reduced amount of funding from national governments, the need for suitable institutional theory is increasingly common and the IS field must increase its understanding of the problematic issues involved and approaches to resolving them. It is hoped that this article makes a modest contribution to these goals.

REFERENCES

Brown, T. (2001). Modernization or failure? IT development projects in the UK public sector. *Financial Accountability & Management, 17*(4), 363-381.

Connecting for Health. (2004). *Business plan.* Retrieved May 2005, from http://www.connectingforhealth.nhs.uk

Covaleski, M. A., Dirsmith, M. W., & Michelman, J. (1993). An institutional theory perspective on the DRG framework, case mix accounting systems and healthcare organizations. *Accounting, Organizations and Society, 18*(1), 65-80.

Currie, W. L., & Guah, M. W. (2006). IT-enabled healthcare delivery: The UK National Health Service. *Information Systems Management, 23*(2), 7-22.

Department of Health (DoH) (UK). (2000). *NHS plan: An information strategy for the modern NHS*. London: Author.

DiMaggio, P. J., & Powell, W. W. (1983). The iron cage revisited: Institutional isomorphism and collective rationality in organizational fields. *American Sociological Review, 48,* 147-160.

DiMaggio, P. J., & Powell, W. W. (Eds.). (1994). *The new institutionalism in organizational analysis*. Chicago: University of Chicago Press.

Doolin, B. (2004). Power and resistance in the implementation of a medical management information systems. *Information Systems Journal, 14,* 343-362.

Grabowski, M., & Lee, S. (1993). Linking information systems application portfolios and organizational strategy. In R. D. Banker, R. J. Kauffman, & M. A. Mahmood (Eds.), *Strategic information technology management: Perspectives on organizational growth and competitive advantage* (pp. 33-54). Hershey, PA: IGI Global.

Guah, M. W., & Currie, W. L. (2004). Application service provision: A technology and working tool for healthcare organization in the knowledge age. *International Journal of Healthcare Technology and Management, 6*(1), 84-98.

Guah, M. W., & Currie, W. L. (2005). *Internet strategy: The road to Web services*. Hershey, PA: IGI Global.

Heathfield, H., Pitty, D., & Hanka, R. (1998). Evaluating information technology in healthcare barriers and challenges. *British Medical Journal, 316,* 1959-1961.

Hendy, J., Reeves, B. C., Fulop, N., Huchings, A., & Masseria, C. (2005). Challenges to implementing the national program for information technology: A qualitative study. *British Medical Journal, 420,* 1-6.

Herzlinger, R. E. (1989). The failed revolution in healthcare—The role of management. *Harvard Business Review,* 95-103.

Institute of Medicine. (2002). *Crossing the quality chasm: A new health system for the 21st century.* Washington, DC: National Academy Press.

Keeler, J., & Newman, J. (2001). Paperless success: The value of e-medical records. *HIMSS Proceedings, 2*(45).

Lowndes, V. (1996). Varieties of new institutionalism—A critical appraisal. *Public Administration, 74,* 181-197.

Lucas, H. C. (1993). The business value of information technology: A historical perspective and thoughts for future research. In R. D. Banker, R. J. Kauffman, & M. A. Mahmood (Eds.), *Strategic information technology management: Perspectives on organizational growth and competitive advantage* (pp. 359-3744). Hershey, PA: IGI Global.

Luftman, J. (2000). Assessment business IT alignment maturity, *Communications of the AIS, 4*(14), 1-51.

Majeed, A. (2003). Ten ways to improve information technology in the NHS**.** *British Medical Journal, 326,* 202-206.

March, J. G., & Olsen, J. P. (1989). *Rediscovering institutions: The organizational basis of politics.* New York: Free Press.

Markus, M. L. (1983). Power, politics and MIS implementation. *Communications of the ACM, 26*(6), 430-445.

Martin, J. B. (2003). Effectiveness, efficiency, and the value of IT. *Journal of Healthcare Information Management, 17*(2).

Meyer, J. W., & Rowan, B. (1991). Institutionalized organizations: Formal structure as myth and ceremony. In W. W. Powell & P. J. DiMaggio (Eds.), *The new institutionalism in organizational analysis.* Chicago: University of Chicago Press.

Miranda, S. M., & Saunders, C. S. (2002). The social construction of meaning: An alternative perspective on information sharing. *Information Systems Research*.

Mohan, J. (2002). *Planning, markets and hospitals* London: Routledge.

National Audit Office (NAO). (2004). *Improving IT procurement.* Report by the Comptroller and Auditor General, HC 877 Session, 2003. London: The Stationary Office.

North, D. (1990). *Institutions, institutional change and economic performance.* Cambridge, UK: Cambridge University Press.

Sambamurthy, V., & Zmud, R. W. (1994). *IT management competency assessment: A tool for creating business value through IT.* Working paper. Financial Executives Research Foundation.

Scott, W. R., Ruef, M., Mendel, P. J., & Caronna, C. A. (2000). *Institutional change and healthcare organizations: From professional dominance to managed care.* Chicago: University of Chicago Press.

Stevens, P., Schade, A., Chalk, B., & Slevin, O. (1993). *Understanding research: A scientific approach for health care professionals.* Edinburgh, UK: Campion Press.

Tolbert, P. S., & Zucker, L. G. (1994). Institutional analysis of organizations: Legitimate but not institutionalized. Institute for Social Science Research working paper. University of California, Los Angeles.

Vogel, L. (2003). Finding value from IT investments: Exploring the elusive ROI in healthcare. *Journal of Healthcare Information Management, 17*(4).

Wanless, D. (2002). *Securing our future health: Taking a long-term view.* London.

Wanless, D. (2004, February). *Securing good health for the whole population.* London.

Weber, R. P. (1990). *Basic content analysis* (2nd ed.). Newbury Park, CA: Sage.

This work was previously published in Journal of Information Technology Research, Vol. 1, Issue 1, edited by M. Khosrow-Pour, pp. 14-26, copyright 2008 by IGI Publishing (an imprint of IGI Global)

Chapter 5.3

Informatics Application Challenges for Managed Care Organizations:

The Three Faces of Population Segmentation and a Proposed Classification System

Stephan Kudyba
New Jersey Institute of Technology, USA

Theodore L. Perry
Health Research Corporation, USA

Jeffrey J. Rice
Independent Scholar, USA

ABSTRACT

Organizations across industry sectors continue to develop data resources and utilize analytic techniques to enhance efficiencies in their operations. One example of this is evident as Managed Care Organizations (MCOs) enhance their care and disease management initiatives through the utilization of population segmentation techniques. This article proposes a classification system for population segmentation techniques for care and disease management and provides an evaluation process for each. The three proposed operational areas for Managed Care Organizations are: 1) Risk Status: early identification of high-risk patients, 2) Treatment Status: compliance with treatment protocols, and 3) Health Status: severity of illness or episodes of care groupings, all of which require particular analytic methodologies to leverage data resources. By applying this classification system an MCO can improve its ability to clarify internal goals for population segmentation, more accurately apply existing analytic methodologies, and produce more appropriate solutions.

INTRODUCTION

Population segmentation is the term broadly applied to technologies used to correctly identify and target the right patients for care and disease management program interventions. Many MCOs are using these technologies, including those containing predictive modeling techniques and quantitative applications, to enhance patient care and optimize available resources. With the rapidly growing use of population segmentation and predictive modeling today, it is essential to understand the relative strengths and weaknesses of different types of population segmentation techniques, including those employing predictive methods. The purpose of this article is to propose a classification system for the different types of population segmentation techniques and their usefulness in addressing the independent and interactive roles of risk status, treatment status, and health status in patient evaluation initiatives.

Organizations across industry sectors have intensified their initiatives to increase operational efficiency through effective resource allocation, and the health care sector is no exception. Given the increased level of competition in today's' digital, information economy, organizations are faced with the task of increasing productivity by more efficiently allocating available resources in producing goods and services to meet the demands of their customers. One of the greatest issues facing the health care industry today is managing patients who suffer from chronic illnesses. Currently, approximately 100 million Americans have at least one chronic condition and this is expected to rise to over 150 million Americans in the next 20 to 30 years (Faughty, 1999; Institute of Medicine, 2001). Furthermore, chronic conditions are the leading cause of death, disability, and illness in the United States, accounting for over 75% of direct medical expenditures (Landro, 2002).

The health care industry has been faced with a number of additional factors that have increased the complexity of managing available resources. Some of these include an increase in the aging population, costs for defensive medicines, optimizing existing health care facility usage (e.g., staffing doctors and nurses along with designated bed utilization rates) and the introduction of new organizations such as HMOs and PPOs (Smith-Daniels, Schweikhart, & Smith-Daniels,1988). One way Managed Care Organizations are attempting to improve their efficiencies in treating illnesses is through the development and management of robust data resources and the utilization of analytic techniques to identify patterns and trends in patient populations. With this information, efficiency can be enhanced by more accurately identifying the sources of resource demand of specific customer segments and initiating strategic health care management policies and better allocating available resources to meet those demands (Heskett, 1983; McLoughlin, Yan, & Van Deirdonck, 1995).

Analytic Methods for Health Care Management

The utilization of analytic techniques in strategic management is increasing (Shook, 2000). More formal analytic techniques such as stochastic trees have been utilized to help increase operational efficiencies by enhancing the decision making process in medical treatment procedures (Hazen, 1992, 2000). Other analytic methodologies involving data mining techniques enable decision makers to identify patterns in clinical-, claims- and activity-based historical data, to better understand explanatory relationships in data and create models to more accurately predict future resource demand (Xiaohua, 2005). Artificial neural networks are computer algorithms that identify relationships in historical data that can be used for classification and prediction (Bishop, 1995; Swingler, 1996). Reducing the uncertainties in process resource requirements through enhanced predictive capabilities is seen to increase efficiency across industry sectors (Kudyba & Hoptroff, 2001).

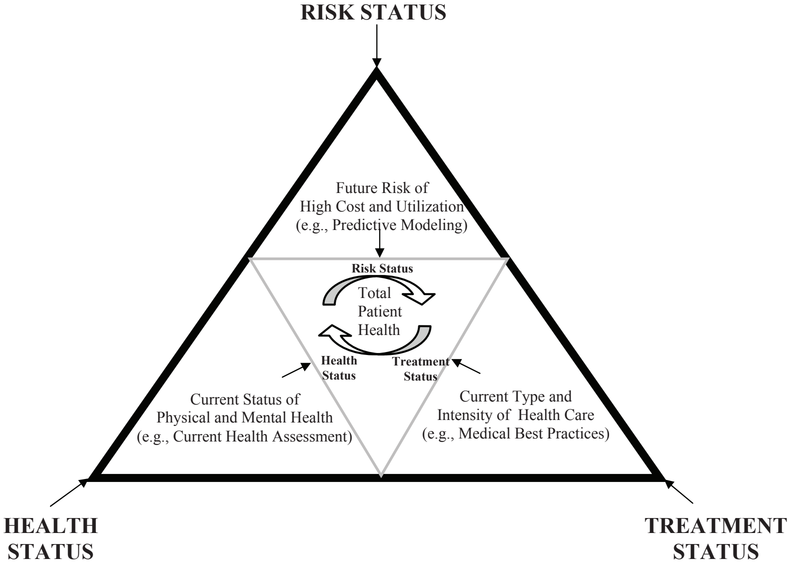
More effective disease management through data analysis can assist our current health care system to fill the ever-increasing gaps in health care service, management, and treatment. Disease management programs utilize both cost-based and health-based rationales for prevention and health promotion, emphasizing medical best practices and evidence-based medicine. Usually, outcomes are evaluated on the basis of clinical/therapeutic improvement or compliance, financial/cost reduction, and behavioral/emotional enrichment (Hunter & Fairfield, 1997; Leider & Krizan, 2001). Ultimately, the success of disease management programs often depends upon the ability to target an appropriate intervention to the appropriate patient, where population segmentation enhances MCOs' ability to accomplish this.

The following section of this article provides more detailed background on the application of population segmentation techniques to enhance health care efficiency and introduces three primary areas where they can be utilized by MCOs. A detailed analysis of the required analytic objective corresponding to three primary health care assessment areas (e.g. Risk Status, Health Status and Treatment Status) is then provided. The criteria for categorizing population segmentation methods according to the three primary assessment areas are then described.

APPROACHES TO POPULATION SEGMENTATION AND PREDICTIVE MODELING AND A PROPOSED CLASSIFICATION SYSTEM

Research addressing the use of quantitative-based decision support systems to enhance efficiency in the health care sector is on the rise given the development of data resources and availability of sophisticated analytic methods (Walchzak, Brimhall, & Lefkowitz, 2006; Raghupathi, 2006). There is great interest today in the application of population segmentation and predictive modeling to enhance care and disease management programs by correctly focusing resources and interventions on the segment of a population who would benefit the most from interventions (Ash, Zhao, Ellis, & Sclein, 2001; Cousins, Shickle, & Bander, 2002; Ridinger & Rice, 2000). While

Figure 1.



A single patient may be looked at from each of the three perspectives.

most analytic approaches share a common goal, to enhance a care or disease management program's ability to improve quality of care while lowering overall cost, they are optimized to address this goal in different ways. We propose a classification system to clarify the objective of the most commonly used population segmentation and predictive modeling approaches.

The proposed classification system divides the methodologies based upon their useful functionality in addressing three primary operational areas for MCOs. The three proposed classifications are Risk Status, Treatment Status, and Health Status (see Figure 1). The benefits of this classification system are to enable MCOs to clarify their primary objective, thereby enabling them to select a methodology that best fits their need and ultimately achieve better disease management solutions.

Disease management programs make use of population segmentation to improve the efficiency and effectiveness of their interventions. Population segmentation approaches often serve different objectives such as early identification of high-risk patients, identifying compliance with treatment protocols, or categorizing patients by severity of illness for payment adjustments or outcomes reporting. It is important to use the appropriate methodology to best meet the information requirements of a specific intervention. Depending upon the MCOs' focus and intervention(s), some disease management programs might use one approach while other programs might use two or more approaches.

For disease management purposes, predictive modeling is defined as utilizing currently available data to prospectively identify an individual's risk of a specific outcome. Thus, one may look at a patient's claims or survey data to determine if the patient has an increased risk of future hospitalization, high cost of care, or some morbidity event (Kudyba, Hamer, & Gandy, 2005). As will be described next, each of the population segmentation applications (i.e., health status, treatment status, and risk status) has a predictive component, but not all are optimized for predicting future risk. The following section will describe the objectives required for each of the three areas of application (assessment) and clarify the appropriateness of corresponding population segmentation approaches.

THREE PRIMARY AREAS OF ASSESSMENT FOR MCOS (RISK STATUS, TREATMENT STATUS AND HEALTH STATUS)

Risk Status

Risk status refers to a patient's likelihood for specific clinical outcomes (e.g., myocardial infarction), financial outcomes (e.g., significant increases in future health care costs), or utilization outcomes (e.g., emergency department or hospital visits). It can also refer to the probability of future risk for developing certain medical conditions, such as obesity or cardiac disease (Perry, 2007). Risk status focuses on the probability of future events, making this classification of population segmentation optimally predictive in nature. Predictive modeling techniques for this area range from simple linear equations to complex neural network forecasting techniques (Grana, Preston, McDermott, & Hanchak, 1997; Kiernan, Kraemer, Winkleby, King, & Tylor, 2001). These may include seasonal adjustment methods and trend lines (Cote & Tucker, 2001), and heuristics including uncomplicated rules-based algorithms to multifaceted decision support techniques (Ferreira et al., 2001). Obviously, the mathematical or logical technique used to assess risk status is highly dependent upon the type of risk being evaluated. Regardless of the methodology, the objective of evaluating a patient's risk status is the same, prediction of an unknown future event.

A recent study conducted by Kiernan et al. (2001) compared two prediction techniques, logistic regression and signal detection, to assess individuals who are at risk for being overweight. This study was based on survey data from 1,635 White and Hispanic men and women. Body mass index (BMI) was used to define "overweight" for this population, and predictor variables used included gender, ethnicity, age, and educational level. Results from the study demonstrate that both methodologies had similar predictive accuracy and identified a similar set of risk predictor variables. Nevertheless, these methods did not classify the same individuals into population subgroups. Notably, a very high risk group (less educated, young Hispanic adults) was hidden by the logistic regression analysis but was revealed by the signal detection analysis. These results demonstrate the importance of selecting the best technique of population segmentation to identify a high-risk population.

Logistic regression was utilized to predict the probability of asthma-related hospital admissions for asthma members in a large HMO (Grana et al., 1997). A predictive model was built from administrative data (e.g., medical, pharmacy, laboratory, and enrolment files) associated with over 54,000 asthma patients. Asthma-specific utilization, pharmacy data, and length of enrolment were found to be the best predictors of future asthma-related admissions. Results were evaluated by the predicted number of admissions compared with the actual number of admissions, broken down into 10 deciles. Analysis of the top three deciles resulted in a sensitivity and specificity score of 0.70 and 0.71, respectively. These results demonstrate how claims data alone can be used to accurately predict future hospitalizations for patients within a population.

Risk status technologies are optimized for predicting future risk. In addition to applications in disease and care management programs, this category of population segmentation, which employs predictive modeling techniques, is also the type of segmentation technology that is currently emerging in underwriting, rating, and payment adjustment. Population segmentation that focuses on Risk Status is best suited for correctly identifying and targeting the highest risk patients and thus is the most predictive of the three classifications. The next operational area which can be addressed by population segmentation methodologies involves Treatment Status for patients.

Treatment Status

Treatment status focuses on the actual care that a patient is receiving, or in other words, the type and intensity of health care delivered. Treatment status encompasses an assessment of medical best practices or evidence-based medicine protocols. It is often evaluated as part of a physician profiling system. Obviously, not all patients are alike; there is variability in both mental and physiological responses to treatment regiments. Likewise, not all physicians are alike; there are differences in education and training as well as in personal attitudes. Nevertheless, evidence-based clinical practice guidelines can help to manage this inevitable variation. Within a disease management framework, treatment status becomes a very important population segmentation application, especially when attempting to manage and coordinate the health care delivery for thousands of chronically ill patients. Often, there is a gap between recommended standards of care and the treatment received by chronically ill patients (Muney, 2002). Only through careful evaluation of a patient's treatment status can these treatment gaps be identified and addressed.

Research on treatment status includes studies such as that conducted by O'Connor, Sperl-Hillen, Pronk, and Murray (2001), to investigate clinical-based practice characteristics related to best practices within chronic disease care. The objective of the study was to identify those features shared by successful primary care clinics. Seven primary care practices managing patients with diabetes, hypertension, lipid disorders, or heart disease were examined. Data from each of these clinics were compiled and treated as individual case studies. Results from this study illustrate that focusing on treatment status of chronically ill patients can facilitate significant improvements in health outcomes within 1 to 2 years in adults with diabetes, hypertension, or lipid disorders. For example, a 20% reduction in risk for a major cardiovascular event (on a population basis) was reported. This study, as well as others (Heller & Arozullah, 2001; Solberg, Reger, & Pearson et al., 1997; Wagner, Austin, & Korff, 1996), illustrates the benefits of improving treatment status in chronically ill patients, which results in better clinical and financial outcomes.

While treatment status has some predictive value and is an important component of care and disease management, it is not optimized for true predictive modeling. For example, we can use a population segmentation methodology to address treatment status to identify two patients that have elevated cholesterol and are not being appropriately treated with antilipidemic medication. Both patients are at increased risk for poor clinical outcomes, so there is some predictive component to this methodology. However, we cannot immediately infer if both patients are at co-equal risk. To add to the example, if one of the patients is 35 years of age with a family history of hyperlipidemia and cardiac disease and the other patient is 85 years of age without any current cardiac disease, then clearly the two patients are not at equal risk for cardiovascular complications in the future. Treatment Status is optimized to identify gaps in treatment, and is therefore not optimized to identify patients' Risk Status or for predictive modeling. One final area of focus for MCOs entails analytic requirements for Health Status applications.

Health Status

Health status refers to the current standing of a patient's clinical, physical, and mental health. Population segmentation techniques to address Health Status are utilized to describe a patient's current health relative to other patients. Health Status technologies generally serve one of two broad purposes: 1) classifying patients by health status for outcomes measurement and comparison purposes, or 2) categorizing patients into similar severity levels for assessing treatment intensity or for payment adjustment design. Other health status methods are utilized to group patients according to their likely treatment needs and resource consumption during a current episode of care (Baker, 2002). Currently, many health care organizations are using proprietary grouper software for patient/provider profiling, utilization/clinical benchmarking, disease/case management activities, and quality improvement initiatives.

There is a relationship between current health status and health outcomes. Goetzel, Anderson, Whitmer et al. (1998) conducted a study of the Health Enhancement Research Organization (HERO) database in order to estimate the impact of modifiable health status factors on health care expenditures. Overall, individuals who had poor health status had significantly higher expenditures than individuals who had a better health status in 7 of the 10 health status categories (depression, high stress, high blood glucose levels, high/low body weight, former tobacco users, current tobacco users, and high blood pressure). Moreover, individuals with poor health status in multiple categories had much higher medical expenditures than those without. For example, those with heart disease, psychosocial, and stroke profiles had 228%, 147%, and 85% higher expenditures, respectively. This study indicates that patients' health status is associated with at least near-term increases in the likelihood of incurring future high medical costs (Anderson, Whitmer, & Goetzel, 2000; Leutzinger, Ozminkowski, Dunn et al., 2000).

Despite the correlation between health status and future health outcomes, general population segmentation technologies that are optimized for Health Status are not optimized for predictive modeling. For example, two patients who are in critical condition may score similarly on a GHA. Both patients are likely to incur substantial costs in the near term and are obviously at short-term risk for poor clinical outcomes. However despite the same GHA score, we cannot immediately infer if both patients are at the same risk for long-term health outcomes or long-term expenditures. To continue the example, if one of the patients is 70 years of age with terminal cancer and the other patient is 25 years of age and was recently in a traumatic accident, then the outcomes may be dramatically different over a 12-month time frame. Health Status is optimized to correctly classify patients vis-à-vis their current health, and is therefore not optimized to identify patients' Risk Status or for predictive modeling.

EVALUATION CRITERIA OF POPULATION SEGMENTATION METHODOLOGIES FOR MCO AREAS OF ASSESMENT

An important first step in evaluating population segmentation and predictive modeling techniques is to define the specific purpose and goal of the modeling initiative. To date, the evaluation process has often been complicated because of a lack of clarity in the specific goal for potential applications. In addition, there is often a lack of clarity within the MCO for what would be done with the information once obtained. For example, the care and disease management departments might envision early identification of at risk patients, the provider network department might envision provider profiling on quality metrics, and the finance department might plan to use the information to enhance underwriting or rating. While all of these are reasonable goals, they may not all be obtainable with a single technology, and it is highly unlikely that a single technology will perform optimally well for all purposes.

The evaluation process should begin with a definition of the purpose and goal of the application, where multiple goals, should be prioritized. This is important when balancing trade-offs in performance. Once this is achieved, the best class of population segmentation technology must be selected to meet this goal. For Risk Status applications, the goal is to apply and evaluate the predictive modeling accuracy. The focus is on accuracy metrics such as positive predictive value, true/false positive rates, true/false negative rates, sensitivity and specificity at various screening thresholds, and ROC or R-squared values. For each metric, it is important to ascertain how the metrics have been validated and if they will generalize to a particular MCO setting. For Treatment Status applications, the goal is to evaluate the comprehensiveness and accuracy of the assessments. The focus is on number of diseases covered, number of evidence-based standards covered, the quality of the algorithms used (i.e., are they disclosed or hidden in "black box" technology?), and the source of the standards (evidence-based, proprietary, etc.). The Treatment Status system's accuracy must also be considered. This typically involves an assessment of the sensitivity and specificity of classification with respect to treatment status. Applications based upon both survey and claims data invariably produce some errors. Consequently, it is important that the assessments produce reasonable information that will be clinically acceptable, providing a sound basis for intervention decisions. For Health Status applications, the evaluation focuses on the system's ability to correctly classify patients into comparable groups or cohorts. For example: (1) What is the accuracy of the system's prediction in categorizing patients into a certain level of health or episode of care? (2) Can the system be generalized and can the results be used to compare to other groups or over time? and (3) Is the system well accepted by the provider community if it is to be included in payment schemes? If a single system purports to provide current health status and also predicted future health outcomes, then it is important to evaluate the accuracy metrics as described above for both the current health status prediction and the future health outcomes prediction.

Existing population management approaches fail to fully utilize information derived from these three statuses. The difficulty in integrating multiple data sources and data types has resulted in the optimization of operational systems based on single sources. Obviously, positive outcomes have certainly been achieved using this type of single source methodology, which focuses interventions vis-à-vis highly specific, singular data sources or assessments (Huffman, 2005; Ropka, 2002). However, as described in this article, when faced with the penultimate operational challenge of population management (i.e., delivering limited resources to the right patients at the right time) it becomes increasingly important to use information derived from multiple sources in order to decrease the probability of incorrect allocation of these resources.

The informatics approach described in this article is not without limitations. This approach requires extensive IT resources and IT system architectural changes. It is also very data intensive and requires the coordination and management of large amounts of data.

CONCLUSION

In this article we have proposed a classification and evaluation method for population segmentation approaches used in care and disease management. Risk Status, Treatment Status, and Health Status assessments each provide useful information to forecast the best allocation of resources and interventions within a population of interest. For example, a disease management company might be interested in managing those patients who are at high risk for future hospitalizations. In this example the disease management company could use information from population segmentation approaches in order to focus resources on the segment of the population with the highest probability of future hospitalizations. However, the analysis of each assessment application is optimized differently: Risk Status is optimized for the prediction of future events, Treatment Status is optimized for the identification of gaps in medical care, and Health Status is optimized for the classification of patients' current state of physical and mental health. Clearly, in order to capitalize on the strengths of population segmentation methodologies, health plans need to understand the primary functionality of a given population segmentation methodology in conjunction with the required objective of the particular assessment application and, subsequently, select the most appropriate modeling approach that best fits their purposes.

As MCOs increasingly rely upon care and disease management programs to fill gaps in health care service and delivery, correctly identifying and targeting patients for program interventions has risen in importance. Though risk status is clearly the application that is optimally predictive in nature, it cannot alone be used to evaluate, assess, and allocate interventions to a given population. Population segmentation methodologies addressing current treatment status and health status, as well as anticipated risk status, are the most effective and logical way to move forward with an overall intervention strategy. Meanwhile, it is important to differentiate between these three approaches, because they have been optimized for different goals. Clarity in purpose and focused evaluation against that purpose will provide MCOs with the best techniques. Consequently, MCO disease management programs that truly integrate/utilize all three approaches will best succeed in accomplishing the main goal of focusing the right resources on the right patients while increasing quality of care and decreasing overall medical expenditures.

REFERENCES

Anderson, D.R., Whitmer, R.W., & Goetzel, R.Z., et al. (2000). Health enhancement research organization (HERO) research committee. The relationship between modifiable health risks and group-level health care expenditures. *American Journal of Health Promotion*, *15*, 45-52.

Ash, A.S., Zhao, Y., Ellis, R.P., & Schlein, K.M. (2001). Finding future high-cost cases: Comparing prior cost versus diagnosis-based methods. *Health Services Research*, *36*, 194-206.

Baker, G.B. (2002). Integrating technology and disease management—the challenges. *Healthplan Magazine, 43*, 60-66.

Bishop, C. (1995). *Neural networks for pattern recognition*. Oxford University Press.

Cousins, M.S., Shickle, L.M., & Bander, J.A. (2002). An introduction to predictive modeling for disease management risk stratification. *Disease Management, 5*, 157-167.

Cote, M.J., & Tucker, S.L. (2001). Four methodologies to improve health care demand forecasting. *Healthcare Financial Management, 5*, 54-58.

Ferreira, F.L., Peres, Bota, D., Bross, A., Melot, C., & Vincent, J.L. (2001). Serial evaluation of the SOFA score to predict outcome in critically ill patients. *Journal of American Medical Association, 286*, 1754-1758.

Foughty, T. (1999). Accomplishing health improvement through diabetes disease management. *Drug Benefit Trends, 12,* 43-45.

Goetzel, R.Z., Anderson, D.R., Whitmer, R.W., et al. (1998). The relationship between modifiable health risks and health care expenditures: An analysis of the multi-employer HERO health risk and cost database. *Journal of Occupational and Environmental Medicine, 40*, 843-854.

Grana, J., Preston, S., McDermott, P.D., & Hanchak, N.A. (1997). The use of administrative data to risk-stratify asthmatic patients. *American Journal of Medical Quality*, *12*, 113-119.

Hazen, G.B. (1992). Stochastic trees: A new technique for temporal medical decision modeling. *Medical Decision Making, 13*, 227-236.

Hazen, G. (2000). Preference factoring for stochastic trees. *Management Science*, *46*(3), 389-403.

Heller, C., & Arozullah, A. (2001). Implementing change: It's as hard as it looks. *Disease Management and Healthcare Outcomes, 9*, 551-563.

Heskett, L. (1983). *Shouldice Hospital Ltd*, Rev. 1/88. Boston, MA: Harvard Business School.

Huffman, M. (2005). *Implementing outcome-based homecare: A workbook of OBQI, care pathways and disease management.* Jones and Bartlett.

Hunter, D.J., & Fairfield, G. (1997). Managed care: Disease management. *British Medical Journal, 315*, 50-53.

Institute of Medicine. (2001). *Crossing the quality chasm: A new health system for the 21st century.* Washington, DC: National Academy Press, Committee on Quality of Health Care in America.

Kiernan, M., Kraemer, H.C., Winkleby, M.A., King, A.C., & Taylor, C.B. (2001). Do logistic regression and signal detection identify different subgroups at risk? Implications for the design of tailored interventions. *Psychological Methods, 6,* 35-48.

Kudyba. S., Hamer, B., & Gandy, W. (2005, December). Enhancing efficiency in the health care industry. *Communications of the ACM, 28*(12), 107-110.

Kudyba, S., & Hoptroff, R. (2001). *Data mining and business intelligence: A guide to productivity.* Hershey, PA: Idea Group.

Landro, L. (2002, January 4). Technology programs make disease management easier. *The Wall Street Journal, Health Journal*.

Leider, H.L., & Krizan, K. (2001). Disease management—a great concept, but can you implement it? *Disease Management*, *4*, 111-119.

Leutzinger, J.A., Ozminkowski, R.J., Dunn, R.L., et al. (2000). Projecting future medical care costs using four scenarios of lifestyle risk rates. *American Journal of Health Promotion*, *15*, 35-44.

McLaughlin, C., Yang, S., &Van Dierdonck, R. (1995). Professional service organizations and focus. *Management Science*, *14*(7), 1185-1193.

Muney, A.M. (2002). Evidence-based medicine needs to be promoted more vigorously. *Managed Care, 11*, 10-12.

O'Connor, P.J., Sperl-Hillen, J.M., Pronk, N.P., & Murray, T. (2001). Primary care clinic-based chronic disease care. Features of successful programs. *Disease Management and HealthCare Outcomes, 9*, 691-698.

Perry, T. (2007), December). *Identification and prediction of chronic conditions for health plan members using data mining techniques: In data mining methods and applications*. Taylor Francis.

Raghupathi, W. (2006). Designing clinical decision support systems in health care: A systemic approach. *International Journal of Healthcare Information Systems and Informatics*, *2*(1).

Ridinger, M.H., & Rice, J.J. (2000). Predictive modeling points way to future risk status. *Health Management Technology, 21*, 10-12.

Ropka, M.E. (2002). Symptom status and functional status outcomes: Humanistic outcomes in obesity disease management. *Obesity Research, 10*, 42S-49S.

Smith-Daniels, V., Schweikhart, S., & Smith-Daniels, D. (1988). Capacity management in health care services: Review and future research directions. *Decision Sciences*, *19*, 889-919.

Solberg, L.I., Reger, L.A., & Pearson, T.L., et al. (1997). Using continuous quality improvement to improve diabetes care in populations: The IDEAL model: Improving care for diabetics through empowerment, active collaborations and leadership. *Joint Commission Journal on Quality Improvement, 23*, 581-592.

Swingler, K. (1996). *Applying neural networks: A practical guide*. New York: Academic Press.

Wagner, E.H., Austin, B.T., & Korff, M.V. (1996). Improving outcomes in chronic illness. *Managed Care, 4*, 12-25.

Walczak, S., Brimhall, B., & Lefkowitz, J. (2006). Nonparametric decision support systems in medical diagnosis: Modeling pulmonary embolism. *International Journal of Healthcare Information Systems and Informatics,* (1), 2.

Xiaohaua, H. (2005). Temporal rule induction for clinical outcome analysis. *International Journal of Business Intelligence and Data Mining*, *1*(1), 122-136.

This work was previously published in International Journal of Healthcare Information Systems and Informatics, Vol. 3, Issue 2, edited by J. Tan, pp. 21-31, copyright 2008 by IGI Publishing (an imprint of IGI Global).

Chapter 5.4

Preparing Healthcare Organizations for New IT Systems Adoption:

A Readiness Framework

Robert Breas
National IT Institute for Healthcare (NICTIZ), The Netherlands

Matthew Waritay Guah
Erasmus University, The Netherlands

ABSTRACT

Information systems exist for hospitals but even the most advanced systems concentrate on relatively simple coordination, resource allocation and documentation aspects of healthcare operations. At the same time the need to improve health care performance by means of more sophisticated IT systems is widely felt. In practice, however, the adoption of new IT is usually a difficult and a very slow process. To analyse the underlying reasons, we identified a set of key bottlenecks in the IT adoption process by interviewing large groups of healthcare actors. We conclude that health care organizations should be better prepared in order to facilitate easier IT systems' adoption. To do so, a readiness framework is considered to be helpful, the contours of which are sketched in this article. It is also discussed how, based on clarified clinical pathways, workflow management can assist in framing optimization of resource utilisation, clinical decision-making, staff training and quality improvement in healthcare delivery. [Article copies are available for purchase from InfoSci-on-Demand.com]

INTRODUCTION

Recent drive to automate hospital information has focused on the formal implementation of electronic health records. These systems are largely relational databases that focus on transaction-based intra-enterprise applications. Yet only a limited number become fully functional, scalable, distributed systems with interoperability. Based on these observations, it is widely felt that more sophisticated information systems are needed to support health care performance based on the concept of clinical pathway optimisation. The adoption however of such integrated distributed information systems takes place at a very slow rate (Aarts 2005; Stoop 2005). Underlying reasons given in popular literature relate to the misunderstanding of healthcare business processes.

Healthcare processes are very complex and dynamic due to the involvement of clinical and administrative tasks, large data volumes, large numbers of patients and personnel with different tasks requiring specific knowledge. Healthcare is a business where many changes occur (i.e. (new) treatments, drugs, equipment, protocols, and legislation). These changes have their influence on the instantiated processes that need adjustment (Anyanwu et al; 2003).

Observation of the dynamic character of healthcare system and the implementation of IS at Erasmus MC (medical centre) led towards the following research question.

Which internal factors of IS implementation affect healthcare organizations' readiness for new systems?

The following sub-questions assisted in finding answers to the central research question.

- What are the consequences of IS implementation in health care?
- What is the impact of IS implementation on organization?
- What initial choices need to be made before an IS implementation decision in a healthcare organization?

The article is structured as follows. The next section describes the potential workflow management (WfM) and how WfM affects healthcare IS. That will be followed by a brief description of actor network theory (ANT) before a sketch on key bottlenecks related to the introduction of new IT as found in the scientific literature and selected by using criteria taken from change management. The design and results of the empirical research will integrate the content into a coherent view that is used to sketch a readiness framework for new IT adoption in complex healthcare environment. Finally, we discuss the high potential of WfM to provide optimised healthcare, provided that the healthcare organisation at stake has been sufficiently prepared for adopting of WfM systems. We finalize this article by presenting our conclusions.

What is Workflow Management?

In the last couple of years notion was growing about whether data processing in complex organizations should not only be based on integrated data management, but also on integrated process management. Organization processes usually define the order and time of data creation and alteration. Workflow management (WfM), also referred to as structured process management, is an important ingredient for data processing and data management in many cases. Automated support is needed to effectively and efficiently execute process management in complex environments and situations. WfM, from a general perspective, can be seen as administrative logistics. Like physical logistics where the right goods are delivered at the right place and time, WfM takes care of delivering the right information at the right time and by the right person (Grefen, 2001).

Workflow is an abstraction of a business process. Normally a workflow comprises a number of logical steps, known as tasks. These tasks consist of dependencies among tasks, routing rules and participants. A task can require human involvement, or it might be executed automatically by IS applications (Cardoso et Al, 2004). Some well established definitions of WfM in literature are given below.

The ultimate goal of workflow management is to make sure that the right persons execute the proper activities at the right time (Orlikowski, 2000). Although it is possible to do workflow management without using a workflow management system, most people associate WfM with WfM systems.

Cardoso (2002) defines WfM as a workflow model, which is customized to accommodate specific business process structures. Workflows are designed based on business processes. These processes already exist in an organization and need to be improved or managed better. Once the design phase of the model is completed, instances are created to carry the actual steps described in a given workflow. During their execution, the workflow instances can access legacy systems, databases, applications and can interact with users. Workflow systems are flow-independent; they control a data flow among tasks is graphically described during the workflow design phase. This makes applications independent from the underlying workflow system.

Workflow management is a technology supporting the reengineering of business and information processes (Georgakapoulos, 1995). WfM involves:

a. Defining workflows, e.g., describing those aspects of a process that are relevant to controlling and coordinating the execution of its tasks. It will require the skills of individuals or information systems to perform each task.
b. Providing for fast (re)design and (re)implementation of processes such as business needs and information systems change. To effectively support WfM, organizations must evolve their existing computing environments to a new distributed environment that:
    - Is component-oriented, i.e. it supports integration and interoperability among loosely coupled components corresponding to Heterogeneous, Autonomous and Distributed (HAD) legacy, current and new systems;
    - Supports workflow applications corresponding to business or information process implementations accessing multiple HAD systems;
    - Ensures the correctness and reliability of applications in the presence of concurrency and failures;
    - Supports the evolution, replacement, and addition of workflow applications and component systems as processes are reengineered.

The remaining of this section aggregates the above definitions for a more comprehensive one that suits the article's optimal objectives. The above definitions share three factors of importance to our interest in healthcare IS implementation: people, processes, and IS. The other definitions weren't complete on those factors, and lacked at least one of them. Our agreed definition of WfM is the customisation of workflow to accommodate specific business process structures. The goal is to have the right persons execute proper activities at the right time. Workflows are designed based on existing business processes in an organization that need to be improved or managed better. Therefore they support the reengineering of business and information processes. They define aspects of processes that are relevant and necessary for controlling and coordinating the execution of functional tasks. This will require the skills and input of individuals and the usage of Information Systems to perform each task. During the execution of tasks, workflow instances support integration and interoperability among loosely coupled components corresponding to Heterogeneous, Autonomous and Distributed (HAD) legacy and new systems. WfM must also be able to access legacy systems, databases, applications and set-up an interaction with users. It also must ensure the correctness a reliability of applications in the presence of concurrency and failures. Used applications are independent from the underlying workflow system.

The addition of all these factors may not be able to explain why adoption of new IT is so difficult (Guah, 2000). The difficulty is not due to problems related with software or hardware or to limitations of technologies in use. Systems fail because they are built on the wrong assumptions, incorporate problematic models of medical work or implementation is not seen as an organisational change (Berg et al. 2003).

Reflecting these observations, we recognize that organizations might not be well prepared for adopting new IT solutions. This case study on lack of readiness for IS implementation in healthcare organization contains interviews with a set of relevant healthcare actors in Erasmus MC, the largest medical centre in The Netherlands. The main goals of the case study were:

a. to show what we have found as the key bottlenecks in the IT adoption process,
b. based on these key bottlenecks found (and those presented in literature) to sketch the contours of a readiness framework to present in this article, and
c. to illuminate why and how, after having finished the preparation phase, workflow management has great potential to improve quality in complex healthcare delivery (Breas, 2007).

This research shows conflict between the tendency to build internal but somewhat restrictive systems and the need to plan for future interoperability, multi-functionality and scalability by the hospital management to avoid a too limited operational success and acceptance.

Actor Network Theory

Actor-Network Theory (ANT) is a well-known theory from within the field of science and technology studies that has developed conceptual constructs to deal with the processes through which technologies are developed and influence societies. Though ANT has a relatively short history, it is a multi-disciplinary field and unlike the field of information systems, it allows a deeper devotion to theoretical and explanatory studies, without assuming an intellectual responsibility for guiding professional practice (Latour, 1999).

The authors have selected ANT as a framework for analysis due to a number of reasons:

- It is well established with an important hinterland of work explaining, critiquing, developing and applying the theory; including application to information systems in the healthcare sector (Heathfield, Pitty, & Hanka, 1998);
- It has been comparatively stable, with later presentations building on the original theory, probably because the theory is "owned" by a particular group of followers (Latour, 1986);
- It overcomes some important limitations of the "IT as an enabler" perspective of general management science literature that are based on technological determinism and can thus be presented as a complementary approach to information system research.

ANT Concepts

The "actor-network" concept was developed by Michel Callon, Bruno Latour and John Law during the course of the 1980s as a recognition that actors build networks combining technical and social elements and that the elements of these networks, including those entrepreneurs who have engineered the network, are, at the same time, both constituted and shaped within those networks (Law, 1999).

The unique position of technologies in ANT recognizes that IT does not evolve under the impetus of scientific logic unlike common suggestions by technological determinism. IT does not possess an inherent momentum that allows it to do what Latour (1986) describes as passing through a neutral social medium. Bijker and Law (1992) similarly concludes that "technologies mirror societies" considering they are continuously shaped and reshaped by the interplay of a range of heterogeneous forces within the networks. Therefore IT is as much an actor in the networks as are the human parties.

Papers on ANT often develop their arguments in an empirical context (Latour, 1999; Law, 1999) with tales that tend to be heroic. They narrate how actors, within a specified period, manage to constitute themselves and their networks; thus treating the world as a set of related bits and pieces with no social order. There are only endless attempts at ordering through the formation and stabilization of networks (Latour, 1999). By telling stories and tracing histories rather than taking snapshots, ANT proves itself as "a pragmatic, recursive sociology of process with an interest in the uncertain processes that generate power and size" (Law, 1999). By clarifying power relationships in organizational settings, ANT helps us understand how actors are defined, associated and obliged to remain faithful to their alliances.

Bottlenecks

At this moment healthcare organisations are focussing more on the existing processes. Klischewski and Wetzel (2001) proclaim a couple of sticking points that exist in the healthcare environment concerning processes.

- The first sticking point they discuss is the lack of overall responsibility for either the process or it's planning. The process mostly relies on the ability and commitment of individual providers to flexibly shape the service according to their special insights about the patient's case (Klischewski and Wetzel, 2001). A lack of fixed responsibilities seems to be the crux of this problem;
- Secondly, there is a problem relating to the exchange of patient information. Clear rules are needed for documentation of patient records and the exchange of patient information;
- The third point concerns the monitoring of the process status. The healthcare providers involved have little oversight about the complete process, its current status or further development. Healthcare providers often lack information about deviations from tacitly assumed ways to proceed, or are unable to obtain this knowledge (Klischewski and Wetzel, 2001).

What often is forgotten, while implementing an IS related product, is that such an implementation will fundamentally affect the structure and processes in a health care organization. This is a core reason for failure of the implementation (Berg et al. 2003).

What is needed is a mutual transformation of the organization and the (level of) technology. Work tasks and information flows will be affected or changed. This will also affect relationships between (groups of) health care professionals. Discussions about data access among health care professionals will be inevitable and can lead to political and social issues (Berg et al. 2003).

An IS implementation should not be run as only a technical project. Organizational structures, routines and roles should be managed as well. This means that adequate user involvement is extremely important by development and by implementation of IS that must be accepted by the different users. A good fit between work processes, and involved characteristics like roles, and IS is evident. System specifications and implementation plans should be discussed among the different users and IS department. Interdependencies between work tasks should be made clear and less abstract for the users and IT-department during such discussion (Berg et al. 2003).

These identified sticking points by Klischewski and Wetzel result in a set of requirements regarding the software support for inter-organizational services in healthcare, or in other words Workflow Management. They claim four main requirements for the design process:

- **Flexibility support:** The support of the process has to provide flexibility and dynamic selection and configuration of services as the process moves on. The steps in the process also need to be transparent to the parties involved;
- **Interoperability:** Patient information between different physicians and other healthcare providers must be exchangeable and shareable. Therefore software components must be compatible with each other for digital information exchange;
- **Customer Orientation:** Service delivery has to consider the possibly changing customer concern and the subtleties in customer satisfaction. This goes beyond efficiency criteria of underlying processes and has to do with understanding the customer concern and with service customization, e.g. the availability of services;
- **Agreement Process:** The parties involved have to formulate the entire service process, e.g. the kind of service delivery, IS support (Klischewski and Wetzel, 2002).

These requirements are directly related to financial aspects, which also have an important role in healthcare. For this article the financial aspects were considered out of scope.

EMPIRICAL RESEARCH

Three methods of data collection were adopted. First, the researchers assembled a range of academic, government and industry studies on the healthcare sector in The Netherlands. This material proved invaluable for understanding some of the societal, economic, political, cultural and technical differences in today's healthcare delivery and that of the past decades. Second, we attended various meetings, workshops and exhibitions on Duthcare healthcare systems. Some of these events were focused on general topics (i.e. IT in healthcare, patient services, hospital management and professional best practice), with others more focused upon specific activities. These events generated many useful research contacts

We engaged in primary data collection, conducting around 25 open-ended and semi-structured interviews during the nine months period, with a range of actors (i.e. health service professionals and administrators, clinicians, IT researchers, and Erasmus MC IT deparmental staff).

Data Collection

Data was collected using questionnaire in the Obstetrics department and the outpatient clinic. Goal of the case study was to determine the level of efficiency and make measurements for pinpointing where more efficiency could be achieved. Two important aspects of the case study were the process analysis and the time measurement research, were every worker (from secretary till physician) had to register time spent on their tasks. This data was used to find out what and where the primary bottlenecks for IS and healthcare were. Figure 1 demonstrates the bottlenecks observed in the decision structure:

- Decisions are made by people who don't have a clear overview of the work floor;
- Lack of involvement of different actors with different functions during decisions;
- The IS department's primary task is to respond to the requested demand;
- Responsibilities about project tasks are ambiguous.

Lack of Alignment between Existing Processes and IS

Many IS implementations, which were reviewed in this case, weren't based on the workflow of the specific unit. This means that as a result, systems did not have a high compatibility with processes. Other than that, functionalities within implemented systems weren't used to the full capacity. Without a good alignment with processes, IS implementations were not optimal effective and efficient as they could be. A better alignment can result in better patient quality and a reduction in costs.

Involvement of Relevant Actors at Decision Moments

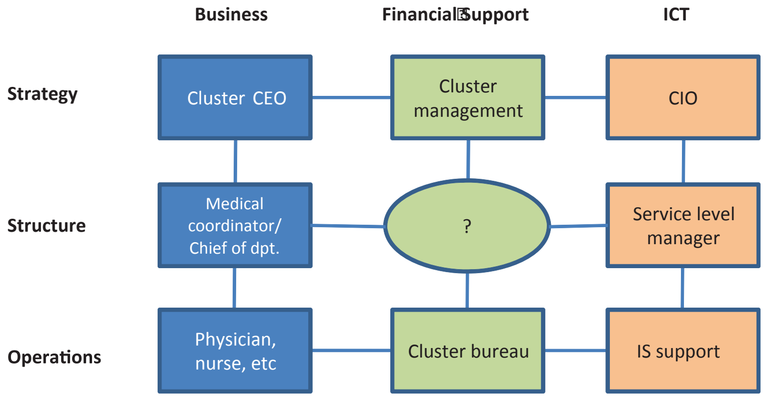
At this moment the medical staffs are the only ones making decisions about which systems to use and what the necessary specifications are needed. The staffs cooperate with the IS department and have information meetings in which decisions are made only from their perspective. Input from other actors, such as physician assistants and nurses, are not taken into consideration. This group are the end users of the specific system because the staff physicians are less involved in the primary care process. Lacking the input of that group is eventually a loss for the workability of the system/application.

Due to staff lack of full knowledge on the level of operational management, their decisions carry a risk of an IS implementation resulting in incomplete fit with the unit. To recapitulate, the people who have to work with the system are very important. They are responsible for the unit to function well. Involvement of more actors is needed to make sure that IS implementations can have a good fit within the unit.

Existence of Inefficient Administration

Across Erasmus MC, most units have high numbers of information systems. E.g. the Obstetric unit uses twenty-three mini-systems just for registering different kinds of patient information. The people who work at the Obstetric unit perceive this high number of used systems as normal. Due the vastness of systems, a lack of communication between them exists. As a result a lot of patient information has to be inputted more than once, which means redundancy. Another danger of redundancy is clarity about where the most recent patient information is registered and whether this information is retrieved. In our opinion this has a negative effect on the quality of patient care. Further research on this topic is necessary.

Figure 1. Business and IT roles, adapted for the Erasmus MC (Adapted Maes, 1999)



Decision Structure

As stated earlier this chapter, many decisions are made by the medical staff. The disadvantage they have is the lack a good oversight of the primary process. Their knowledge is better suited on the tactical and strategic levels of the unit. In combination with the lack of a balanced involvement of actors during the decisions made during development this results in non-optimal decisions about IS. A clear structure for making decisions is necessary. The decision structure must consist of three layers, the strategic, tactical and operational layer. The different actors with their different area of knowledge are categorized in such a way that decisions are optimal knowledge supported.

These four bottlenecks contribute to a low adoption of IS within the hospital with a coherent view in Figure 1.

The horizontal lines, between business and IS, represent common language and understanding. Semantics are of great importance among lines of communication. There is a need for a common discussion between people on the business side and people on the IS side. The horizontal lines represent transfer operational resources and experiences towards sustainable strategic assets (Maes, 1999).

Within the model, all different roles must be fullfilled and anchored. This is needed for a good communication flow between people which have the same semantics. The emphasis must also lay on communication (Gartner 2005). For the case of the Erasmus MC, the important central role as process managers is not fullfilled. Also the roles of physician, nurse etcetera on the operational business side and the service level manager aren't anchored that well. As a result alignment of business and IS is very hard, perhaps impossible, to achieve.

Contours of Readiness Framework

Adjusting the decision structure is necessary to gain efficiency. In the new categorization decisions are made by the actors who have the best knowledge within their layer. The relation of the IS department must be of a more cooperative character instead of a customer/principal relation. The IS department can also act as mediator between the management layer of the unit and with their own project group this way. The result must be a general oversight on the project by the IS department and not just on a split up of the project into the layers. For this to work, the most important change must be made by the people. They are the enabler for change.

Nevertheless, IT is increasingly becoming an important actor based on its changing roles in the delivery of healthcare. As IT becomes "enabler" of necessary organizational change with the Dutch healthcare sector the effect of IT projects will depend on the individual circumstances (Westert and Verkleij, 2006). The mainstream literature has avoided hypotheses of causality between IT innovation and particular organisational or societal effects in critical industries like healthcare (Guah, 2009).

Beside that decisions must be made at the right place: other than the requirements that are described above, Grefen (2001) defines an additional set of criteria for WfM. His criteria set out what kind of data is needed to develop and create a WfM. Grefen (2001) defined the following criteria:

- **Process Specification:** The process specification contains a detailed description of the workflow process. By saving this specification in a database, elements within the specification become accessible;
- **Organization Specification:** The specification of the organization contains the description in which the workflows have to be executed. In this organization model,

descriptions of actors, functions, groups etc. are developed;

- **Information Specification:** The structures of information, which are manipulated by workflows according to the information model of the WfM, are described in this point;
- **Situations in Current Cases:** The situation on "current" cases contains relevant situation and context information for the execution of every case;
- **Historical Information:** Historical information is the information of cases of which the implementation is completed. This information is merely used within the function of an archive. This information can also be aggregated.

These criteria should be used as a guidance principle when developing and arranging WfM.

POTENTIAL FOR WFM IN HEALTHCARE

Uncertainties Faced by Current Decision Structure

The medical staff that may lack a good oversight of the primary process makes many decisions. Their knowledge is better suited on the tactical and strategic levels of the unit. In combination with the lack of a balanced involvement of actors during the decisions made during development this results in non-optimal decisions about IS. A clear structure for making decisions is necessary. The decision structure must consist of three layers, the strategic, tactical and operational layer. The different actors with their different area of knowledge are categorized in such a way that decisions are optimal knowledge supported.

The observed bottlenecks of the decision structure are:

- Decisions are made by people who don't have a clear overview of the work floor;
- Lack of involvement of different actors with different functions during decisions;
- The IS department's primary task is to respond to the requested demand;
- Responsibilities about project tasks are ambiguous.

Adjusting the decision structure is necessary to gain efficiency. In the new categorization the actors who have the best knowledge within their layer make decisions. The relation of the IS department must be of a more cooperative character instead of a customer/principal relation. The IS department can also act as mediator between the management layer of the unit and with their own project groups this way. The result must be a general oversight on the project by the IS department and not just on a split up of the project into the layers. For this to work, the most important change must be made by the people. They are the enablers for change.

The Current Decision Structure must be Adjusted on the Following Points:

- Decisions must be made at the right place: This automatically means that the right persons make the decisions. The knowledge of the medical staff is mostly on the tactical and strategic level. Their knowledge on the operational level is much less. Their interest also differs from the other actors. The primary task of the medical staff is about research and education. These are the factors they will be judged upon at the end of the year. The physician assistants are the ones that are mostly responsible for giving care to the patient. The incentives of the medical staff differ much from the incentives nurses or physician assistants have. Decisions are influenced by the role and incentives of the decision maker. A clear structure for the levels of decisions is therefore necessary.

- IS knowledge is necessary: at this moment the IS department finds themselves solely responsible for the executions of the demand by the customer within the hospital. The relations between the IS department and organizational units, was observed as a principal/customer relation. This relation must be transferred to more of a team relation. This can be reached if one or more representatives from the IS department, depending on the situation, should be present at the different management layers.

What could be another solution is the mediator or middleman. This middleman should give advice on the business level of the unit. The middleman can be seen as an information manager. This function requires that mediation between the different management layers takes place and that the functionalities of the system are specialized.

The result of this structure must be that the quality of consultation and the focus is improved. The advantage is that the execution lines are shorter and results can be achieved sooner. As a result of this, the people will experience more involvement of the IS department. This experience can influence the creation for a good basis for the IS implementation. The shared responsibility for the succeeding of the project will enhance each other. Without reorganizing the decision structure, readiness for the implementation of an IS will be low.

Resolution of Implementation Problem

Healthcare work is a social process. It involves simultaneously dealing with sick individuals, each of which have their own problems and needs, and is connected with other physicians and organizational units. Because of the nature of healthcare work, standard organizational solutions never wholly fit the individual needs of a patient. Healthcare workers are therefore constantly compromising between the problem and solution to give the best care to the patient (Berg et al. 2003). Standardisation of healthcare pathways could provide a possible solution for giving better suited healthcare for the patient and centralizing the patient within the process.

A clinical pathway is the care process that a patient goes through during sickness. It starts with a health complaint and ends after the patient is treated for the health complaint. A clinical pathway displays all the care activities of the treatment that a patient has to follow. Care activities are organized around the patient. This must reduce inter-doctor variation, minimize delays in a treatment and decrease resource use (Lin et al, 2000). A clinical pathway coordinates the treatment procedure and also defines the quality of care that is provided at each activity (Smagghe et al, 2005). The main goal of a clinical pathway is to improve the quality of care while costs are decreased.

The advantage of a clinical pathway overview is the possibility to plan care activities in advance. Most appointments in healthcare are dependent of previous care activities or appointments and of available capacity at other locations within the organization, e.g. an x-ray is needed before the first consult with a physician. The description of the steps within the process helps to make the pathway mutual dependency insightful and offers a better planning. Criteria for quality can also be fixed within the clinical pathway (Bal and Bont, 2005).

When talking about planning up-following care activities in a clinical pathway, it is interesting to take a closer look at Order Management. The goal of clinical pathways is to organize the care activities around the patient. It provides the corresponding ideal sequence and timing of physician and staff actions to achieve the predefined goals with optimal efficiency (Pearson et al 1995). Reasons to use clinical pathways are thus mostly about improving the quality of care and/or reducing costs of a certain product of service. Strongly related is the timely execution of the treatment within the clinical pathway.

Implementation of clinical pathways can be difficult for the following reasons:

- A great deal of time, skill and effort is needed to find and analyse the highest quality evidence available. This quality is essential when making clinical pathways;
- Medical knowledge is changing on a continuous basis. Therefore clinical pathways should also be improved continuously, to be certain that the highest quality is obtained;
- A clinical pathway cannot have all the answers on individual cases;
- Implementation of clinical pathways can face organizational and/or cultural challenges. For example the resistance from physicians against standardisation of medical work (Smagghe et al, 2005).

Order Management (OM) is not about replacing paper forms for electronic versions. OM is about the facilitation of health care workers for initiating and protection of the total sum of health care activities that incorporate the treatment of the patient. OM is the electronic guarding of the healthcare pathway.

The goal of OM is:

- Providing quality on a consistent level;
- Supporting working on a basis of protocols, standardisation;
- Input control and decision support;
- The realisation of time reduction;
- during the application and execution of applications;
- Monitoring the progress of the clinical path.

Examples where OM would prosper are on the area of: medication, radiology, the operating theatre, laboratory, nursing activities, and transport requests. These aspects should always be taken in account when setting up an OM system (Reingoud, 2006).

Functionalities of OM are:

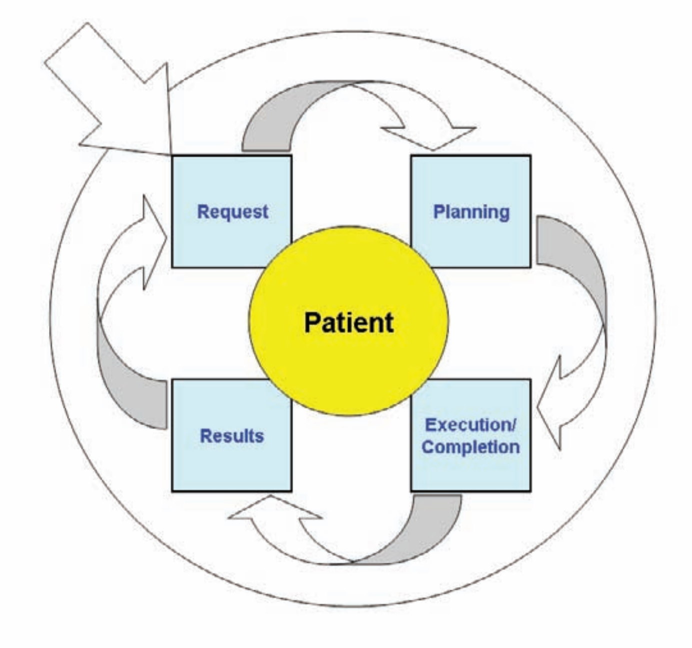
- Monitoring of individual activities in the clinical pathway;
- Giving oversight of individual activities within the clinical pathway;
- Giving oversight in time, for planning purposes;
- Identifying status change and deviations of the predefined norms;
- On clinical paths based access for (lab) results and reports;
- Order application;
- Order planning;
- Order execution;
- General oversight;
- Placing and interfacing the information in the Electronic Patient Record (Reingoud 2006).

For a patient to be treated effectively in a clinical pathway, integration of processes is a key aspect for success. This change can only be achieved when changes in the organisational structures are met. This process includes registering a planned activity (electronically) and the activity being requested, planning of the activity's execution, returning the status of the activity, giving feedback on the activity. Across all of these steps, having the data available electronically can provide opportunities for monitoring of the process.

Order execution comprehends the, administrative, status of the patient in the pathway. Within OM, there is a process of continuous feedback. With this feedback and general oversight of the physician, continuous improvement of the process of the patient is possible. As a result the patient gets the most optimal treatment and unnecessary researches will not be done.

When a patient has an appointment with the physician the physician sends out a request, e.g.

Figure 2. Shows the order management process



a blood test. This request is planned in time with needed resources such as personnel. When the execution of the request takes place the physician who gave the order gets a notification. The next step is that results are returned to the physician and choices about further care activities can be taken.

CONCLUSION

The article has argued why the WfM is important by sketching key issues related to the research problem. The authors have also identified the bottlenecks as suggested in the scientific literature. These bottlenecks are often due to the difficulty in involving physicians during IS implementation, especially if they do not perceive a need to change clinical working practices. Notwithstanding, Erasmus MC has been heralded in The Netherlands as a teaching hospital with technology that would make medical care more cost effective and increase patient safety. Occasionally, there exists perception that making the delivery of care more time and resource efficient is not a clinical necessity. This article has shown that such perception of IS in the healthcare sector is a result of a rather poor understanding of the long-term benefits of improving patient care by changing medical work practices.

The research also showed a rich picture of WfM that includes practical issue of use and implementation and policy issues related to organization strategy and changing healthcare practices in The Netherlands. While the authors acknowledge the complexity of integrating those issues into a comprehensive approach, this article suggest there could be times when less restrictions apply to who can enter orders for the purpose of increasing patient care quality. That's because focussing on subatomic tasks to increase patient safety could occasionally result in decrease in patient safety in the overall process of care. Finally, IS implementation process interacts with an overall healthcare systems that includes healthcare workers at various levels of the healthcare delivery process or patient pathway. The healthcare organization is therefore at the central of any work in this critical sector. Attention must therefore be given to situations when clashes might occur between the rationality of IS that is expressed in technical and functional specifications and the actual use of such system by a healthcare worker. The decision whether to use the system, how to use the system and when to use the systems then becomes more important than just the cost and benefit of implementing a new healthcare information system.

RERFERENCES

Aarts, JECM (2005). Understanding implementation: a sociotechnical appraisal of the introduction of computerized physician order entry systems in Dutch and American hospitals. Unpublished doctorial thesis Erasmus.

Anyanwu K., A. Sheth, J. Cardoso, J. Miller, K. Kochut (2003). Healthcare Enterprise Process Development and Integration. Journal of Research and Practice in Information Technology, Vol. 35, No. 2. May 2003.

Bal R., A. de Bont. 2005 Taakherschikking en ICT in de Zorg. In: Kennis in Netwerken: Jaarboek ICT en samenleving 2005. J. de Haan & C. van 't Hof 2006. Amsterdam: Uitgeverij Boom. 2005 (113-126).

Berg, M., J. Aarts, J. van der Lei, 2003. ICT in Healthcare: Sociotechnical approaches. In: Methods Inf Med 2003; Volume 42, p. 297-301.

Bijker, W.E., and Law, J. (eds), (1992) Shaping Technology/Building Society: Studies in Sociotechnical Change, MIT Press, Cambridge, MA

Breas, R.A. (2007). Workflow Management, "the" challenge for health care. An unpublished Masters thesis, Erasmus University Rotterdam.

Cardoso, J. 2002. Workflow Quality of Service and Semantic Workflow Composition. Department of Computer Science, University of Georgia, Athens, GA.

Cardoso, J., R.P. Bostrom, A. Sheth (2004). Workflow management systems vs. ERP systems: Differences, Commonalities, and Applications. Information Technology and Management 5, 319–338, 2004. Kluwer Academic Publishers

Ciborra, C. And Hanseth, O. (1998). From tool to Gestell, agendas for managing the informtaion infrastructure. Information Technology & People, Volume 11, Number 4, pp.305-327.

Doolan, D.F., Bates, D.W., James, and B.C. (2003). The use of computers for clinical care: a case series of advanced U.S. sites. Journal of American Medical Information Association. Volume 10, Number 1, pp. 94-107.

Freed, D.H. (2004). Hospitalists: evolution, evidence, and eventualities. Health Care Management. Volume 23, Number 3, pp.238-256.

Georgakolpoulos, D., M. Hornick 1995. An overview of Workflow Management: From process modelling to workflow automation infrastructure. Distributed and Parallel Databases, vol. 3, (119-153) 1995

Gerrard, M. (2005). "Business/IT Alignment a Critical Factor When Determining IT's Role", Gartner Report. (http://www.gartner.com)

Grefen, P.W.P.J. (2001). Workflow Management: Geautomatiseerde ondersteuning voor integrale procesbesturing. Alphen aan den Rijn: Samsom.

Guah, W.M. (2009). Managing very large IT projects in businesses and organizations. IGI Global:PA, pp. 99-115.

Heathfield, H., Pitty, D. and Hanka, R. (1998). Evaluating Information Technology in Healthcare: Barriers and challenges, British Medical Journal 316: 1959–1961.

Klischewski R. & I. Wetzel, (2002).. Service flow Beyond Workflow? Concepts and Architectures for Supporting Inter-Organizational Service Processes.

Klischewski R. & I. Wetzel, 2001. Service flow Management for Health Provider Networks. Hamburg: Jahrestagung (pp. 313-319)

Latour, B. (1986) The Powers of Association in Law, J. (ed), Power, Action and Belief: A New Sociology of Knowledge?, Routledge & Kegan Paul, London, UK

Latour, B. (1999) On Recalling ANT in Law, J. and Hassard, J. (eds) Actor Network Theory and After, Blackwell Publishers, Oxford

Latour, B. (2005). Reassembling the Social: An Introduction to Actor-Network-Theory (Oxford: Oxford University Press).

Lin, F., S. Chou, S. Pan, Y. Chen. 2000. Mining Time Dependency Patterns in Clinical Pathways. Proceedings of the 33rd Hawaii International Conference on System Sciences - 2000

Maes,R. “Reconsidering Information Management Through a generic Framework”, 1999, University of Amsterdam.

Orlikowski, W.J. (2000). Using technology and constituting structures: a practice lens for studying technology in organizations. Organization Science. Volume 11, Number 4, pp.404-428.

Pearson, S. D., D. Goulart-Fisher, T.H. Lee. 1995. Critical Pathways as a strategy for improving care: Problems and Potential. Annals of Internal Medicine. Volume 123 Issue 12; (p.p. 941-948)

Reingoud, A. 2006. EMC Order Management Adviesrapport. Version 1.1, July 2006. Erasmus MC Rotterdam

Smagghe D., M. Segers, P.J. Spy-Anderson, N. Benamou, N. Eddabbeh. 2005. Model of Good Practice Tools for Risk Reduction and Clinical Governance. In: The Journal on Information Technology in Healthcare 2005 (3) 114: 117-124.
Stoop, A.P. (2005). Evaluating ICT applications in health care. Studies from a Sociotechnical Perspective.Universal Press, Veenendaal

This work was previously published in International Journal of Healthcare Delivery Reform Initiatives, Vol. 1, Issue 2, edited by M. Guah, and J. Hsu, pp. 25-38, copyright 2009 by IGI Publishing (an imprint of IGI Global).

Chapter 5.5

Developments in Modelling Organisational Issues in Healthcare:

Multi Method Modelling

Kirandeep Chahal
Brunel University, UK

Herbert Daly
Brunel University, UK

Tillal Eldabi
Brunel University, UK

Ray J. Paul
Brunel University, UK

ABSTRACT

Healthcare organisations increasingly use simulation and modelling techniques to analyse their procedures and policies. Modelling activities attempt to help meet the challenges, constraints and requirements for efficiency encountered in the modern healthcare environment. A variety of techniques are used, often applied in different roles and by different functions in the organisation. Recent research has investigated the benefits of considering multiple approaches in the analysis of problems. This chapter briefly introduces the use of simulation and modelling in healthcare and the factors driving the increasingly widespread use of these techniques. Simple examples show how individual methods may be applied to model healthcare problems. The recent emergence of multi method approaches to modelling is examined and, focusing specifically on healthcare, examples of how these new ideas may also be applied in healthcare modelling are presented. Finally the challenges to implementing such new approaches effectively in a healthcare environment are discussed.

DOI: 10.4018/978-1-60566-030-1.ch012

INTRODUCTION

Studies in Healthcare Informatics propose a wide range of new technologies and techniques for use in modern healthcare environments. Many applications of Information and Communications Technology (ICT) in healthcare focus on using information systems, innovative devices, and specialised learning environments for medical practitioners to support the delivery of healthcare services. An area occasionally overlooked in healthcare informatics literature however is the use of computer based modelling to investigate the organisational and policy issues which underlie effective healthcare service delivery. In 2006 the UK organisation the Royal Society produced a report on the future impact of ICT in UK healthcare (The Royal Society 2006). Among the available technologies and changing trends, the report identified simulation and modelling as an effective tool that may be used to predict demand, evaluate costs and improve service overall. This chapter highlights the use of computer based modelling on organisational problems in healthcare and focuses on how a recently proposed approach to developing models, multi method modelling, can enhance the effectiveness of their application.

Until recently the subject of organisational and policy modelling has enjoyed a low profile in healthcare informatics literature. Some older texts such as Sheaff & Peel (1995) and van Bemmel & Musen et al. (1997) make no reference to the topic at all, however, as Eldabi & Paul et al. (2007) indicates, the number of published studies in this area has grown rapidly in recent years. In some health informatics texts, such as Davies & Bensley (2005), modelling is grouped in the wider category of decision support techniques. This has sometimes served to obscure the role of organisational modelling and the particular differences between the methods applied. Some common approaches used in modelling the problems of healthcare organisations include Econometrics, Discrete Event Simulation, System Dynamics and Markov Modelling. While each is individually effective, recent developments in modelling methodology propose that an integrated perspective of the methods may address the challenges of healthcare modelling particularly well.

This chapter provides an introduction to organisational modelling techniques for readers of healthcare informatics literature who are unfamiliar them. By way of illustration, two simple examples of how organisational healthcare issues may be formulated for analysis using simulation techniques are presented. For those familiar with such studies an emerging strand in modelling methodology, multi method modelling, is introduced with a review of key literature and results in this area. The application of multi method modelling to healthcare issues is discussed in detail. Factors which make this approach particularly appropriate for healthcare problems are presented as well as how features of the models may influence their effective deployment. Five examples of recent healthcare studies which have used multi method approaches successfully are briefly reviewed. Finally the future challenges to applying this approach in healthcare modelling are presented. References to key literature are provided throughout to support the reader in further research.

THE CHANGING PROFILE OF MODELLING IN HEALTHCARE

Using abstract models to understand the behaviour of a subject is common in disciplines such as economics and engineering, as a result where these disciplines overlap with healthcare, models are often used. Increasingly however models are also being applied to issues of process, organisation and cost in healthcare using a wide range of techniques. Briggs & Claxton et al. (2006) presents some approaches for evaluating costs including decision trees, Markov modelling and simulation techniques. Morris & Devlin et al. (2007) discusses economic and statistical models.

Fone & Hollinghurst et al. (2003) provides an extensive survey of healthcare modelling studies, particularly where simulation methods are used, and identifies four main areas for their application; hospital scheduling and organisation, infections and communicable diseases, costs and economic evaluation and screening.

Several different influences are reported as making healthcare modelling increasingly attractive. Davies & Bensley (2005) cites the new challenges for healthcare providers driven by changing demographics and social trends. Young & Brailsford et al. (2004) suggests that the high expectations of service expected from healthcare users may interest policy makers in established modelling approaches. Briggs & Claxton et al. (2006) cites the policy of public health bodies in Australia and Canada requiring the systematic evaluation of all new devices, procedures and pharmaceuticals prior to their approval and adoption.

Increasingly institutional factors in healthcare organisations, such as mandatory requirements for data collection and performance reporting, also support the use of modelling. The widespread availability of on site computing capacity, via workstations and an hand held devices and increasing levels of computer literacy in the workforce mean that models can be readily implemented and their findings easily presented to policy makers.

The Varied Role for Modelling in Healthcare

The general benefits of modelling are the ability to investigate the effects of different decisions on a problem or system without committing significant resources or affecting the real situation adversely. As such, using organisational models it is possible to investigate the behaviour of healthcare systems in different circumstances, applying possible policy responses and reviewing the consequences.

Because of the scale of healthcare organisations the financial and resource costs of poor policy or decision making can be significant. The critical role of healthcare in providing medical treatment means that the evaluation of risk is of the upmost importance. The high cost of failure for healthcare organisations also requires that risk is reduced where possible.

Modelling in healthcare therefore is used to support four main areas of interest for policy makers and professionals:

- Planning and design of services
- Investigation of observed behaviour
- Building descriptions of processes
- Evaluation of financial and resource costs

Service organisation and delivery schemes can be planned and tested using modelling techniques. This may be required in the planning of new services; for example new departments or wards. It may be used to plan the reorganisation of existing services. Once represented using an appropriate model the design may be tested with data to ensure that it meets performance targets. Rohleder & Klassen (2002) provide an example of such a modelling study for clinics investigating prospective systems of appointment scheduling.

Healthcare processes and systems may be studied in order to make predictions about their behaviour or investigate unexpected performance. Models may be used to predict outcomes based on a number of relevant factors or possibly suggest areas in the system where improvements may have the most effect. Lane & Monefeldt et al. (2000) provides an example of this kind of study, investigating the dynamic behaviour of an Accident and Emergency Department.

Modelling may also be used to understand or document an existing process or system. In some circumstances healthcare organisations act as complex systems, evolving to solve problems and sometimes producing counterintuitive behaviour. Creating models provides an opportunity to investigate and document how a system works; which may be a valuable training tool for the professionals who must manage the system in future. Conrick & Dunne et al. (1999) describes the use of simulation models in the education of nurses.

Some modelling studies focus specifically on the costs, benefits and resource allocation problems of healthcare processes including the implications of different choices and policies. Briggs & Claxton et al. (2006) describes a number of such studies, including principles and techniques for carrying them out. Briggs & Claxton et al. (2006) also contrasts modelling with use of experimental trials.

SIMULATION MODELLING IN HEALTHCARE STUDIES

Simulation models use software to recreate the activities or structure observed in the problem, in order to generate outcomes which are comparable with the behaviours in the problem. In practice the implementation of most models is computer based, including the Markov models described in Briggs & Claxton et al. (2006). However the relationship between simulation models and computer implementation is different in that, although they may be conceptualised to some extent, they are entirely impractical without, computing resources.

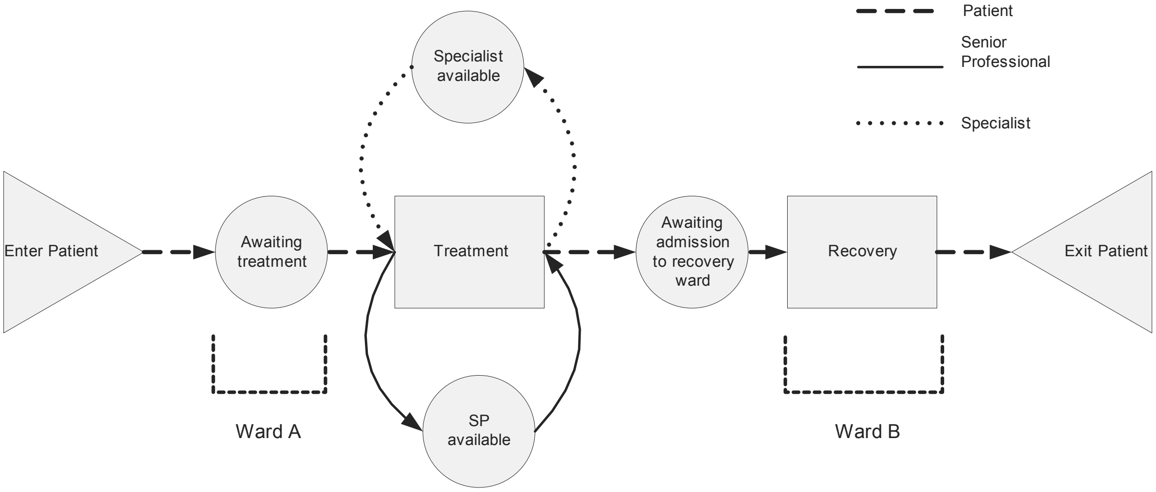
The use of simulation approaches for modelling healthcare issues has received a great deal of attention recently. Eldabi & Paul et al. (2007) describes a dramatic increase in healthcare simulation studies since 2000. Two styles of simulation modelling, System Dynamics (SD) and Discrete Event Simulation (DES), well established in other disciplines have been used widely in healthcare studies. Another emerging form of simulation, Agent Based modelling (ABM), less widespread due to its relative immaturity has also been used in healthcare studies; Kanagarajah & Lindsey et al. (2006) provides an example. This section briefly introduces SD and DES modelling.

Discrete Event Simulation Modelling in Healthcare

Discrete Event Simulation modelling is a technique well established in disciplines such as manufacturing and scheduling. Some key texts include Banks (2001) and Law & Kelton (2000). DES models attempt to imitate the observed behaviour of the problem, typically by using stochastic distributions to generate events and quantities typical for the system. Problems are often conceptualised as networks of queues and servers. The behaviour of the real system is imitated by estimating distributions for the arrival of entities at the queues and the dispatch of entities by the servers. A number of notations may be used to describe their logic including queuing diagrams, flowcharts and Activity Cycle Diagrams (ACDs) described in Paul & Balmer (1993). Consider the example of a treatment ward A with regular patient admissions. Patients wait for treatment, after treatment they enter a recovery ward B until they are ready to leave. The treatment requires one senior professional and two specialists in order to go ahead. An ACD of this problem may be described by Figure 1.

The three entities move between the states defined in the ACD. Service processes require all related entities to be available in order to begin and release them when complete. The simulation reproduces behaviour observed in the real system. An investigation of the problem may proceed by varying factors such as the arrival rate for the patients, the distribution of time required for treatment or recovery and the number of specialists and professionals available. The output of the model is monitored to establish how performance is affected as the variables are changed. Jun & Jacobson et al. (1999) provides an extensive review of some recent healthcare studies using DES.

Figure 1. Simple DES model of a healthcare problem



System Dynamics Modelling in Healthcare

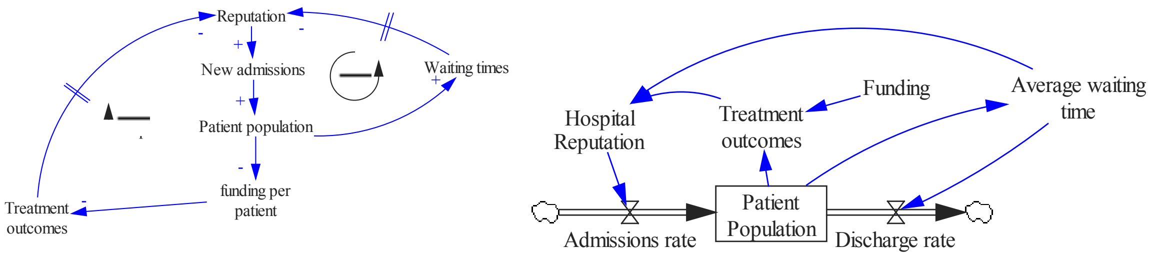
System Dynamics modelling is a technique well established in disciplines such as socio-economic and business modelling. Some key texts include Forrester (1961) and Sterman (2000). SD models attempt to reproduce the causal structure of the problem, identifying components and feedback loops that are the cause the dynamic behaviour observed in the system. Models attempt to focus on the systemic properties of the problem caused by the interaction of flows, interdependencies and delays. They may also include “soft variables”, qualities that are not measured directly yet are proposed to influence behaviour. There are two common forms of notation Causal Loop Diagrams (CLDs), which capture the conceptual relationships in the problem, and Stock-Flow diagrams which describe the structure in the model in more detail. Only Stock-Flow diagrams are implemented as simulations. Both are described in detail by Sterman (2000).

Consider the simple example of a hospital operating on a fixed level of external funding. Patients may chose the hospital due to its reputation based on a combination of the treatment outcomes and waiting times reported. Treatment outcomes are influenced by the level of funding per patient and waiting times by the current size of the population. CLD and stock flow models of this problem may be described by Figure 2.

The description shows how quantities flow through the system in feedback loops and the active mechanisms which may produce interesting dynamic behaviour. The model is intended to provide an impression of the dynamic trends resulting from the system structure rather than reproduce observed behaviour exactly.

An investigation of the problem may vary parameters such as the starting population, the length of the delay in affecting hospital reputation and the effect of the two influences on that factor. The output of the model is used to discuss long term behaviour and the consequences of structural change. Dangerfield (1999) provides an extensive review of some recent healthcare studies using SD.

Figure 2. Simple SD model of a healthcare problem



REALISING EFFECTIVE HEALTHCARE MODELLING

Modelling techniques are usually applied to large or sophisticated problems perhaps containing hundreds of variables. Although the two simulation examples presented are very simple they illustrate the impact models may have in the four areas of interest described previously:

Changes to either service could be planned using the models as prototypes to determine the likely effects. For example the effect on patient throughput of using two recovery wards could be planned using the DES model and then perhaps compared with the effect of adding an extra specialist alternative. The models could be used to recreate unexplained behaviour observed in the problem and investigate their likely causes. For example if an increase in funding leads to an unexpected decline of the hospitals reputation the SD model could be used to investigate whether the effects of delays in the system could provide an explanation and what the long term consequences may be.

The process for providing the service in each case is documented by the models and they may provide an aid to discussion in reviewing the processes which, unlike a written description, is dynamic and pliable. Simulation models can therefore communicate the problem effectively to those familiar with the problem yet uninitiated in any modelling technique. With regard to financial evaluation; as with all models containing quantitative variables cost predictions based on the output are fairly straightforward so long as both overheads and unit costs can be accurately established.

The simple descriptions presented above also illustrate well the role played by those making the model. The individual or team responsible for creating the model must investigate the problem and formulate its detail into an abstract form which can be simulated appropriately. Evidence collected from the primary sources is used to develop the basic structure of the model but also to determine and the refine quantitative aspects of the model too. This may require interacting with personnel, studying key documents, taking measurements first hand and conducting experiments. Through the process of modelling, modellers are able to develop, and perhaps disseminate, a detailed and insightful understanding of the problem. The acquisition of this knowledge is considered to be a powerful indirect benefit of modelling.

Also apparent from the two studies is their difference in approach; The DES model emphasises the effects of the stochastic qualities of a problem, whereas the SD model emphasises the endogenous feedback properties. As a result of these differences, the investigation and analysis required for each of them focuses on different parts of the problem. Each approach is considered to be independently effective and as a result modellers using different systems rarely question the framework of assumptions contained within the approach they are most familiar with.

Table 1. Methods compared by four multi method studies

	Meadows & Robinson	Lane	Morecroft & Robinson	Schieritz & Milling
SD	●	●	●	●
DES		●	●	
ABM				●
Econometrics	●			
I/O analysis	●			
Opiiation	●			

Considering trends in healthcare modelling, Eldabi & Paul et al. (2007) note an interest among subject experts to combine the different methods in their studies. For example one respondent of the authors, when asked to identify current trends, states the “need for much greater integration between disciplines”. This chapter now considers this idea in more detail by discussing the basic principles requires as well as practical issues and developments.

THE MULTI METHOD APPROACH TO MODELLING

The requirement for modelling techniques to be used combined and used together has caused a new and interesting theme in modelling methodology to emerge. Described simply as Multi Method Modelling, its roots lie in early discussions between groups of modelling practitioners, their search for the fundamental basis of their own method and comparisons with other approaches. Recent developments in this theme have been stimulated by the widespread use of modelling techniques and a new generation software tools offer more flexible modelling solutions.

Distinctions between methods, it is argued, has led to a separation of modelling specialists into method oriented groups which has affected the field to the extent that communication across method boundaries becomes difficult, if not entirely unproductive. Meadows & Robinson (1985) describe this as paradigmatic relationship between practitioners. The multi method research them aims to clarify and evolve the relationship between different modelling methods.

Multi Method Modelling: Background and principles

The key premise of the multi method approach is that understanding more than one method can help improve the practice of modelling. This requires, at least, an understanding of how approaches differ fundamentally, that is often uncommon for subject specialists to posses. Several authors have attempted to address this issue and have included a variety of methods in the discussion. The subject of their work is summarised in Table 1.

Lane (2000) focuses on communication between communities of modellers who use different systems, identifying differences between the two methods and also how different modes of communication can benefit practitioners in areas of common interest. Meadows & Robinson (1985) examine the assumptions underlying different methods and their modelling process using a number of case studies. Morecroft & Robinson (2005) focuses on differences in the features and properties of models created using two different systems. They provide a detailed example of the two methods at work on a single problem by way of illustration. Schieritz & Milling (2003) compare

Table 2. Summary descriptions of five different modelling methods

Modelling Paradigm	Realisation	Description
Agent Based Simulation	Simulation	Imitating the behaviour of a problem using granular entities with encapsulated behaviour
Discrete Event Simulation	Simulation	Imitating the behaviour of a problem using processes and passive entities, based on events
Markov modelling	Stochastic	Using a state based view of a problem and the probability of transition between states to analyse potential behaviour
System Dynamics	Simulation	Identifying flows, stocks, and feedback in a problem in order to analyse systemic behaviour
Econometrics	Statistical	Applying statistical techniques to test relationships between problem data variables or analyse problem variables variation over time.

two different methods and the contrasting ways in which they attempt to achieve similar ends. This list of studies is by no means exhaustive but represents a range of starting points in the comparison of systems that covers a variety of methods. Table 2 briefly describes five different modelling methods that have recently been used to model problems in healthcare.

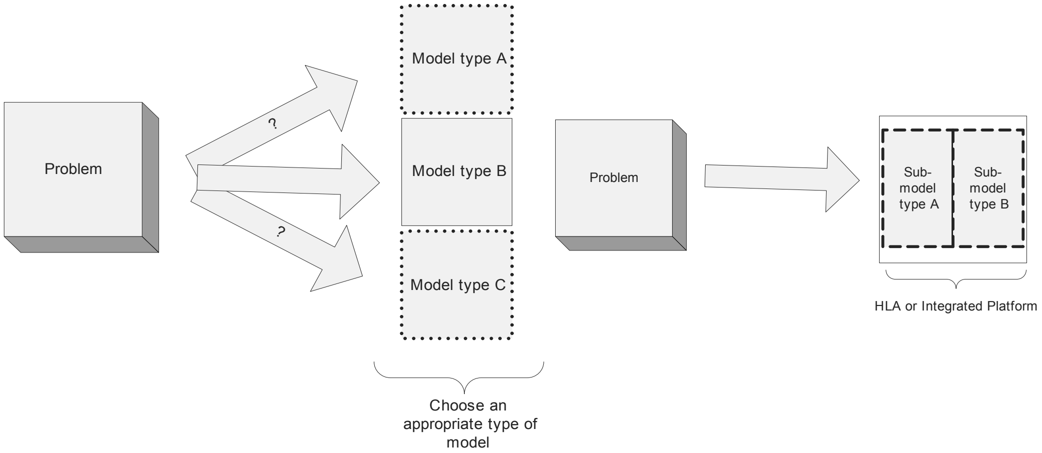
Realisation refers to the mechanism by which implemented models to produce their results. It is often the case that where the same realisation mechanism is used the process may differ significantly. For example Discrete Event Simulation (DES) typically uses stochastic simulation with variable time steps, System Dynamics (SD) uses deterministic simulation with fixed time steps, whereas Agent Based Modelling (ABM) may use either method. In practice computer based modelling is used to implement all five systems.

The comparisons of four studies use a wide range of criteria to isolate distinct properties for different methods, however at present there is no widely agreed definitive list; perhaps because the properties identified are so dependant on what they are compared with. However it is generally recognised that different kinds of models have different properties and the methods propose a different conceptualisation of the problem. Comparisons usually focus on issues such as the use of random variables, the use of data, representing feedback and verification. Some general themes in modelling are also revealed, for example, the role of models in communication, qualitative and quantitative properties of modelling and the benefit of the model as a product compared with modelling as a process. As this strand of research develops it has been proposed that the multi method approach may lead to the development of new integrated forms of modelling where the properties of the model are determined strictly by the properties of the problem.

Practical Applications

A number of studies have been made based on multi method ideas. These range from general developments in for methodology to studies focusing on a particular application area such as manufacturing, supply chain management or healthcare. Themes in these studies may differ considerably; Lorenz & Jost (2006) and Chahal & Eldabi (2008) analyse the choice between different methods, whereas Borshchev & Karpov et al. (2002) discuss the use of an integrated software platform which supports three different modelling methods. However from these and other studies two main practical strands are notable. The first is studies which provide a considered approach to choosing an appropriate modelling method for a given problem. The second are studies which attempt to combine different

Figure 3. Common modes of multi method modelling from literature



kinds of model into a hybrid form either by logical partition of the problem or joining existing models. (see Figure 3)

APPLYING MULTI METHOD MODELLING TO ISSUES IN HEALTHCARE

Considering the developing profile of healthcare modelling and the relative immaturity of multi method approaches it may be expected that each may be of little benefit to the other at their current stages of development. On the contrary, to date, the ideas have aroused considerable interest in healthcare modelling circles. This section discusses some of the reasons that a multi method approach has the potential to deliver significant benefits for modelling in healthcare. Some existing work on multi method modelling in healthcare is also reviewed.

Why Healthcare?

A number of factors account for the interest in using a multi method approach to model healthcare problems and in different organisations the reasons vary. However four reasons it may be especially relevant are listed below and described in turn:

- Variety of healthcare modelling problems
- The benefits of integrating functional views
- Requirements for data and analysis
- Issues of scale and limitations of technology

Healthcare modelling embraces a wide variety of problems. Healthcare organisations are very rich in terms of the types of properties that may usefully be modelled. For example modelling the probabilities of events in one area may be as important as modelling paths through a system or modelling population sizes and costs in another. In each case the nature of the problems differs significantly and an appreciation of several methods equips healthcare modellers to deal with each problem effectively by using an appropriate method.

Healthcare organisations are often complex and contain many different functions focusing on their own targets and goals. An integrated view of problems is often useful but unavailable. The different models functions use, often reflect their different view of the problem. For example an economic policy function may rely on econometric

Figure 4. Composite models combine the views of different functions

modelling, while an operational policy function may use DES modelling. A multi method approach provides a framework for integrating views and exploring how different functions relate to each other, for example by creating a single composite model from those used by two different functions; illustrated in Figure 4.

Different methods have different requirements for the use of formal numerical data and different problems may differ in the amount of formal data available. For example Econometric modelling requires high quantities of formal data in the conceptualisation and construction of models though more moderate quantities are required for validation. SD modelling typically relies on a mixture of formal and informal data in conceptualisation with more formal data used in model construction and validation. Similarly DES may rely on a variety of information sources in conceptualisation with more formal data required in construction, for example in determining appropriate distributions and significantly more, generated by the model, being used in validation. These properties are described in Table 3. The choice of an appropriate modelling method may be based on the alignment of the data available from the problem and the data requirements of the method.

Due to their diversity, issues in healthcare may vary in the scale and level of detail required to analyse them effectively. Problems may be considered over different organisational boundaries. For example models may examine at ward level, department level or hospital level. Problems may be defined in terms of the individuals, generalised behaviour or wider trends. Modelling may cover different time periods such as short, medium and long term scenarios. All these factors determine how actors or entities in the problem are represented. Entities in a healthcare model, for example, may represent beds, patients, ambulances or staff.

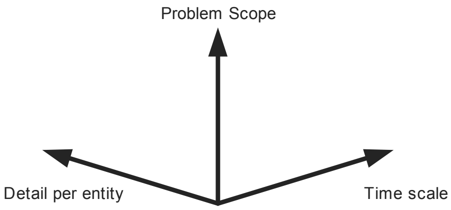
Although different models may require a similar level of effort to conceptualise, in implementation the resources required for the same problem in terms of memory, processor time and mass storage may be significantly different. The factors determining the overall resource requirements for a model are a combination of the level of detail required for each entity, the total number of entities required typically determined by the problem scope and the timescale considered by the model. This relationship is represented in Figure 5.

In this respect different models have different characteristics; ABM typically uses a very high level of resources per entity, modelling the state and processing the actions of each entity in the problem individually. Modelling the same problem

Table 3. Comparing requirements for numerical data at different stages in the modelling process

	Conceptualisation	Construction	Validation
Econometrics	High	High	Moderate
SD	Low	Moderate	Moderate
DES	Low	Moderate	High

Figure 5. Factors determining modelling resource load



in DES would typically use simpler passive entities with behaviour defined in terms the service processes, requiring fewer resources. Even fewer would be required in the SD model where entities typically would be modelled as continuous streams without individual states or behaviour.

One solution to very high resource requirements is to increase the computing resources available until the problem becomes tractable. This is often proposed in healthcare modelling using GRID computing techniques. An alternative solution to applying raw computing power is the use of a multi method approach to conceptualise the problem using a different modelling system. Due to the difference in resource requirements, problems which are intractable using one approach may be tractable by applying another where the overall resource requirement is lower.

Review of Existing Projects

This section briefly reviews some existing and notable multi method studies which focused on healthcare problems. The studies use a variety of methods to achieve range of modelling goals.

Smith, van Ackere (2002) demonstrates an integration of SD and Econometric modelling. The study reviews an NHS problem of understand issues of supply and demand in elective surgery and how behaviour is affected by waiting times and the cost of private treatment. The paper describes how an SD model is developed based on the concepts of the econometric model. The study notes how the difference in approach provides a view of the problem which includes its previously unappreciated dynamic qualities.

Karnon (2003) compares an evaluation of a healthcare treatment using both Markov modelling and DES. Different characteristics of the methods are noted and an example is used to illustrate their different conceptualisation of patient pathways. The problem of evaluating adjunct therapy in the treatment of breast cancer is described. Two models are developed and compared. The conclusions of the paper remark on the differences in their flexibility and resource requirements of the two methods.

Brailsford & Lattimer et al. (2004) describe the analysis of capacity in emergency departments based on SD and DES models. The study describes the problems of resource allocation and capacity facing an emergency unit and explains the choice of SD and its benefits for the main modelling activity, the process and the findings of the study. The paper explains how a DES model was used to examine a particular feature of the problem in more detail which would not have been practical using SD alone.

Cooper & Brailsford et al. (2007) reviews three methods used in the economic evaluation of healthcare problems; DES, decision trees and Markov models. The different properties of the three approaches are described as well as criteria for choosing between them based on the properties of the problem. The study produces a flow chart describing a process for determining which method is most appropriate to a given problem.

Rohleder & Bischak et al. (2007) describes the use of DES in the design for the performance of several patient servicing centres. The study notes that despite the accuracy of the DES modelling on implementation the centres could not sustain the planned capacity. The paper demonstrates how a complementary SD study could have highlighted this issue from the outset.

CONSIDERING FUTURE CHALLENGES

As the use of modelling becomes more widespread in healthcare the potential to adopt a multi method approach increases. This section is concerned with some of the challenges for the successful use of multi method modelling in the future. As work in this area is ongoing it is not possible at this stage to present solutions, simply outline the obstacles to be overcome.

A fundamental challenge to multi method working is overcoming poor communication between subject specialists. Integrated views of modelling require an understanding of the principles and benefits of different approaches. Where this understanding is superficial the resulting studies may be poor and lack validity. This may be addressed though education and the development of guidelines for multi method teams that work to establish the necessary skills.

A key factor in the development of multi method modelling for healthcare applications is the awareness of good practice. It is a challenge to find an effective platform to communicate successes and failures of the approach to the modelling community. An important benefit of recording the practical experiences of applying these methods may be an appreciation of where they are best not applied. It is also a challenge therefore to establish the situations where multiple models can genuinely add value to a study rather than merely cost and complexity.

A practical challenge is the development of integrated tools that support multi method studies. Currently few tools exist which provide a common platform for the development and comparison of multi method models. Specialist tools currently offer superior ease of use in most cases. An important focus for multi method tools may be features for comparing the output of the different models and navigating the modelling structures, in particular mapping between equivalent structures in the different models.

Multi method modelling is occasionally presented as a revolutionary approach that will eventually unify other methods. It has also been proposed that a standard notation for unifying modelling systems may be developed. This position is very much in advance of current state of research and it is questionable whether such a development would either feasible or beneficial. As with all innovative methodological developments, it is a challenge not to inflate the potential benefits of the approach beyond those that can be supported in fact.

CONCLUSION

This chapter has examined the use of modelling to explore the issues that effect healthcare organisations. The application of modelling and simulation to organisational issues in healthcare is sometimes overlooked by healthcare informatics literature. An overview was provided of the role for modelling studies in healthcare and current developments shaping the practice. Some of the principles, applications and key approaches used were reviewed and number of studies and texts are referenced, providing examples of how modelling methods are used in healthcare. The emerging practice of multi method modelling was presented, including some examples of the approach in healthcare. Future challenges to exploit this new approach effectively were also presented.(Explain what went on and th e lessons learned)

The current interest of public health policymakers in measuring performance and evaluating the effectiveness of healthcare processes makes the modelling of organisational issues increasingly relevant. As new projects are undertaken and healthcare models routinely commissioned, familiarity with modelling methods may become a core skill for healthcare managers and model processing a major use of informatics in healthcare. The realisation that the choice of model significantly influences the perspective on the problem is becoming established. Coiera (1997) recognises this to be a basic principle of healthcare informatics and as such devotes to the whole first chapter to basic concepts in models and modelling. As the use of modelling techniques becomes more common throughout healthcare organisations, the benefits of a multi method approach may increase in significance.

REFERENCES

Banks, J. (2001). *Discrete-event system simulation* (3rd Ed.). Upper Saddle River, NJ: Prentice Hall.

Borshchev, A., Karpov, Y., & Kharitonov, V. (2002). Distributed simulation of hybrid systems with AnyLogic and HLA. *Future Generation Computer Systems*, *18*(6), 829–839. doi:10.1016/S0167-739X(02)00055-9

Brailsford S. C., Churilov L. & Liew S-K., (2003). *Treating ailing emergency departments with simulation: an integrated perspective.*

Brailsford, S. C., Lattimer, V. A., Tarnaras, P., & Turnbull, J. C. (2004). Emergency and on-demand health care: modelling a large complex system. *The Journal of the Operational Research Society*, *55*(1), 34–42. doi:10.1057/palgrave.jors.2601667

Briggs, A., Claxton, K., & Sculpher, M. J. (2006). *Decision modelling methods for health economic evaluation*. Oxford: Oxford University Press.

Coiera, E. (1997). *Guide to medical informatics, the internet, and telemedicine.* New York: Chapman & Hall.

Conrick, M., Dunne, A. & Skinner, J., (1999). *Learning together: Using Simulation to foster the integration of theory and practice.*

Cooper, K., Brailsford, S. C., & Davies, R. (2007). Choice of modelling technique for evaluating health care interventions. *The Journal of the Operational Research Society*, *58*(2), 168–176.

Dangerfield, B. C. (1999). System dynamics applications to European health care issues. *The Journal of the Operational Research Society*, *50*(4), 345–353.

Davies, R., & Bensley, D. (2005). Editorial. *The Journal of the Operational Research Society*, *56*(2), 123. doi:10.1057/palgrave.jors.2601930

Eldabi, T., Paul, R. J., & Young, T. (2007). modelling in healthcare: reviewing legacies and investigating futures. *The Journal of the Operational Research Society*, *58*(2), 262–270.

Fone, D., Hollinghurst, S., Temple, M., Round, A., Lester, N., & Weightman, A. (2003). Systematic review of the use and value of computer simulation modelling in population health and health care delivery. *Journal of Public Health*, *25*(4), 325–335. doi:10.1093/pubmed/fdg075

Forrester, J. W. (1961). *Industrial dynamics*. Cambridge MA: M.I.T. Press.

Jun, J. B., Jacobson, S. H., & Swisher, J. R. (1999). Application of discrete-event simulation in health care clinics: A survey. *The Journal of the Operational Research Society*, *50*(2), 109–123.

Kanagarajah, A. K., Lindsey, P., Miller, A., & Parker, D. (2006). An explorarion into the uses of Agent-Based modeling to Improve Quality of Health Care. In Minai, A., Braha, D. and Bar-Yam, Y., *Proceedings of the 6th International Conference on Complex Systems. 6th International Conference on Complex Systems*, Boston, MA, (1-10). 25-30 June, 2006. Cambridge, MA: The New England Complex Systems Institute.

Karnon, J. (2003). Alternative decision modelling techniques for the evaluation of health care technologies: Markov processes versus discrete event simulation. *Health Economics*, *12*(10), 837–848. doi:10.1002/hec.770

Lane, D. C., Monefeldt, C., & Rosenhead, J. V. (2000). Looking in the wrong place for healthcare improvements: A system dynamics study of an accident and emergency department. *The Journal of the Operational Research Society*, *51*(5), 518–531.

Law, A. M., & Kelton, W. D. (2000). *Simulation Modelling and Analysis*. New York: McGraw Hill Higher Education.

Lorenz, T. & Jost, A., (2006). *Towards an orientation framework in multi-paradigm modeling*.

Meadows, D. H., & Robinson, J. (1985). *The electronic oracle: computer models and social decisions*. Chichester, UK: Wiley.

Morecroft, J. & Robinson, S., (2005). *Explaining puzzling dynamics: Comparing the use of system dynamics and discrete event simulation*.

Morris, S., Devlin, N. J., & Parkin, D. 2007. *Economic analysis in health care.* Hoboken, NJ: J. Wiley & Sons.

Paul, R. J., & Balmer, D. W. (1993). *Simulation modelling*. Bromley, UK: Chartwell-Bratt.

Rohleder, T., & Klassen, K. (2002). Rolling Horizon Appointment Scheduling: A Simulation Study. *Health Care Management Science*, *5*(3), 201–209. doi:10.1023/A:1019748703353

Rohleder, T. R., Bischak, D. P., & Baskin, L. B. (2007). Modeling patient service centers with simulation and system dynamics. *Health Care Management Science*, *10*(1), 1–12. doi:10.1007/s10729-006-9001-8

Schieritz, N. & Milling, P.M., (2003). *Modeling the Forest of Modeling the Trees: A comparison of System Dynamics and Agent-Based Simulation*, July 20-24.

Sheaff, R., & Peel, V. J. (1995). *Managing health service information systems: an introduction.* Buckingham, UK: Open University Press.

Smith, P. C., & Van Ackere, A. (2002). A note on the integration of system dynamics and economic models. *Journal of Economic Dynamics & Control*, *26*(1), 1–10. doi:10.1016/S0165-1889(00)00025-7

Sterman, J. (2000). *Business dynamics: systems thinking and modeling for a complex world.* London: Irwin/McGraw-Hill.

The Royal Society, (2006). *Digital healthcare: the impact of information and communication technologies on health and healthcare*.

Van Bemmel, J. H., Musen, M. A., & Helder, J. C. (1997). *Handbook of medical informatics.* Heidelberg, Germany: Bohn Stafleu Van Loghum; Springer Verlag.

Young, T., Brailsford, S., Connell, C., Davies, R., Harper, P., & Klein, J. H. (2004). Using industrial processes to improve patient care. *British Medical Journal*, *328*(7432), 162–164. doi:10.1136/bmj.328.7432.162

KEY TERMS AND DEFINITIONS

Agent Based Modelling: A simulation based modelling approach, where the problem is represented the using software entities with some degree of autonomy. The behaviour observed in the problem is recreated through the interaction of the entities, known as agents, which are typically modelled using data objects with encapsulated behaviour. Models may exhibit complex emergent behaviour even where the rules governing individual behaviour are relatively simple. They are sometimes considered to combine the analytical features of both system dynamics and discrete event modelling.

Discrete Event Simulation: A simulation based form of modelling in which patterns of events in the problem are recreated so that the timing and resource implications can be examined.

The events generated usually include the arrival and departure of entities from the system or one of its sub processes. Timing and quantities in the model are typically generated by implementing appropriate stochastic distributions. Law & Kelton (2000) provides a comprehensive introduction to this form of modelling.

Econometric Modelling: A form of modelling based on the integration of statistical measurements of problem variables with economic theory. Models are based on empirical data collected from the problem and variables may be treated as deterministic or stochastic. A wide variety of statistical techniques are used to measure the quantities in the problem and assess their underlying distributions. These may be used to test hypotheses about the problem and make predictions about future behaviour or the likely effects of policy changes.

Multi Method Modelling: An emerging area in modelling methodology where techniques from different modelling disciples are combined inorder to analyse a single problem. The premise of this approach is that different methods have different features which can, in some cases, be used to support a more effective study. There is particular interest in applying this approach to healthcare problems because of the potential to extend existing model, integrate different stakeholder views and overcome technical limitations in some studies.

Modelling Resource Load: A concept used to compare the relative resource costs of modelling studies using different methods. For small scale studies the difference in resources required may be negligible, however in large studies this factor may be used to determine the most appropriate choice of modelling method. The differences in between methods in problem conceptualisation and model implementation determine the resources necessary to implement the model. In assessing the scale three key factors are relevant; the scope, or size of the problem; the required amount of detail per entity; the time scale considered by the study.

Markov Modelling: A form of modelling based on stochastic processes where the discrete states of a problem and the possible transitions between them are analysed. Systems represented as a network of states with paths between nodes weighted according to their probability of their occurrence. Paths and cycles in the system can be analysed mathematically to determine the likelihood of overall outcomes. The Markov property requires that the probability of transition between two states is dependant only on the current state and the problem must be formulated accordingly.

Organisational Modelling: Modelling undertaken to understand or analyse the effects of the structure, processes, and policies of an organisation. The role of organisational modelling is typically to understand complex observed behaviour, to prototype new policies and configurations or to document existing processes. In healthcare organisations such studies are increasingly used to investigate costs, patient flows and the utilisation of scarce resources. These studies may be contrasted with problems where organisational issues have negligible or no impact; in healthcare these may include anatomical and epidemiological modelling.

System Dynamics Modelling: A systems-oriented simulation based modelling approach first proposed in Forrester (1961). Models are based on the causal structure of the problem including the perceptions of the actors. Two levels of modelling are possible; Qualitative modelling using influence diagrams and causal loop analysis or quantitative modelling using Stock-Flow diagrams and computer simulation.

This work was previously published in Handbook of Research on Advances in Health Informatics and Electronic Healthcare Applications: Global Adoption and Impact of Information Communication Technologies, edited by K. Khoumbati; Y.K. Dwivedi; A. Srivastava; B. Lal, pp. 190-204, copyright 2010 by Medical Information Science Reference (an imprint of IGI Global).

Chapter 5.6

Managing ICT in Healthcare Organization:

Culture, Challenges, and Issues of Technology Adoption and Implementation

Nasriah Zakaria
Universiti Sains, Malaysia

Shafiz Affendi Mohd Yusof
Universiti Utara, Malaysia

Norhayati Zakaria
Universiti Utara, Malaysia

ABSTRACT

The objective of this chapter is to illustrate a case study of a medical research institute in Malaysia in order to discuss issues pertaining to ICT adoption in healthcare organizations, in particular exploring the culture, challenges, and issues of ICT adoption among medical teams, patients, etc. In this chapter, we examine the question of 'What are the challenges of implementing ICT in healthcare organizations?' Some of the lessons learned from the case study were: ICT was successfully adopted and implemented based on several factors such as supportive organizational culture, competent IT workers, committed IT department and heavy investment on ICT infrastructure. Yet challenges also arise which hinges upon factors like initial deployment of outside IT resources or expertise for ICT implementation, lack of user training and continuous communication between involved parties in the initial stage.

DOI: 10.4018/978-1-60566-030-1.ch010

INTRODUCTION

This chapter consists of six sections highlighting issues on information and communication technology (ICT) adoption and implementation. The first section discusses the phenomenon of ICT adoption in healthcare institution. Second, we include literature reviews based on three perspectives that oftentimes pose challenges to the deployment of ICT: (1) organizational, (2) people, and (3) technology. Third, we highlight the methodology of the study in this chapter which is a case study. In this section, we provide the background of a single case study -- a medical research institute in Malaysia -- to illustrate lessons learned and challenges of ICT adoption and implementation. Fourth, we present our findings which is the detailed descriptions of the issues and challenges based on an analytical framework called 5Ws (what, when, why, where, and who) as well as from the three perspectives mentioned above. Fifth, we provide the discussions in light of lessons learned and the contribution of the study. Lastly, the chapter concludes by summarizing the findings for healthcare institutions that intend to adopt and implement ICT in their organizations and presents the directions for future research undertakings.

In the era of globalization and information age, healthcare industries are intensely promoting and adopting ICT to improve patient care. When more and more patients as health consumers seek and prioritize quality in their lives through enhanced healthcare treatments and services, it places great demands on the health care industry's information-handling abilities and infrastructure (Bodenheimer, 1999). As supported by a recent World Bank (2006) report, "Reliable information and effective communication are crucial elements in public health practices. The use of appropriate technologies can increase the quality and the reach of both information and communication."

In line with this, Malaysia as a developing country has invested heavily in ICT with the mission and vision to improve patient care. Malaysia realizes that patients with healthy lives are better able to maintain healthy minds, healthy lifestyles, and a balance between work and family. In a similar vein, healthcare service organizations also seek for optimal strategies and solutions to increase their medical services. When introducing ICT, these organizations need to consider carefully the challenges that arise from it such as whether the organizational culture is supportive towards any ICT adoption and implementation, whether the organization can build ICT infrastructures that are efficiently and effectively, and whether the organization is willing to recruit, select, and employ competent human resources to use ICT as tools.

For example, according to the study by Mass and Eriksson (2006), when ICT was introduced and hospital staff were unprepared for changes because there was no adequate information given by the technology providers, the immediate result was a lack of knowledge of the new clinical requirements, and users who were ignorant of how to use the new technology; the larger consequence, was a slowed process of implementation and adoption. On the other hand, organizations like hospitals have now realized the potential of integrating ICT into their organization. Technology is reshaping organizations by blending their information systems with rapidly advancing telecommunication technology (Frenzel & Frenzel, 2004). In addition, management teams feel that having ICT integrated into their systems will improve and strengthen healthcare systems in the future. Ragam (2007) asserts that successful ICT adoption will lessen errors considerably, if not totally eliminate them. In addition, according to the World Health Organization, technologies form the backbone of services to prevent, diagnose and treat illness and disease. ICTs are only one category of the vast array of technologies that may be of use, but given the right policies, organization, resources and institutions, ICTs can be powerful tools in the hands of those working to improve health (WHO, 2004).

Besides ICT becoming the catalyst factor for economic growth, it serves as an essential medium of communication between patients and medical teams. Studies have shown that in face-to-face encounters, patients often refuse to share or disclose their illness to support groups such as medical teams, family or friends, even when such disclosure can help them cope with terminal illness. Whether ICT will make patients more or less willing to disclose their information to the support group or family members is still unknown. Hence, the main purpose of this chapter is to understand ICT adoption and implementation issues in one case study of a Malaysian hospital as an example of a health-care institution. In this chapter, we will investigate one overarching research question: What are the challenges of implementing ICT in healthcare organizations?

CULTURE AND CHALLENGES OF ICT ADOPTION AND IMPLEMENTATION

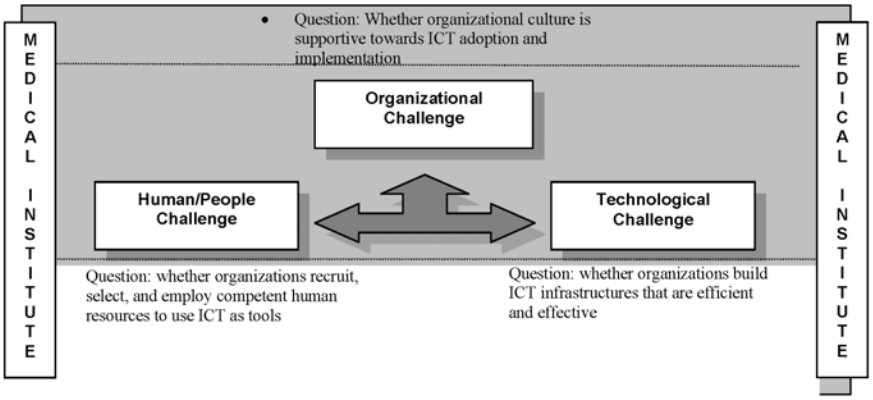
In this section, we first provide some definitions on basic concepts such as culture, organizational culture, and information system culture. We also provide the linkages between these different layers of culture. Second, we also present some literature reviews on ICT adoption and implementation based on the conceptual framework (see Figure 1). In specific, we investigated the culture of ICT adoption among the medical teams and support staff in the hospital environment. Culture can be defined as the way of life or the way things are done. Cultural values are usually associated with nations, though a particular nation may consist of subcultures and even subcultures (Holt & Wigginton, 2002). In addition, Robbins (1996) defines national culture as "the primary values and practices that characterize a particular country" (p.48). Culture differs in many aspects and exists between countries based on cultural dimensions introduced by several theorists. The following paragraphs explore in more detail the three types of culture with which we are concerned: national, organizational, and IS.

A cross-cultural theorist, Geert Hofstede (1980) has conducted hundreds of studies to examine the impact of cultural values on many aspects of organizational behaviors and management practices. His study illustrates national culture based on four dimensions--power distance, uncertainty avoidance, individualism vs. collectivism, and masculinity vs. femininity. Each dimension describes a different area of the cultural impact on management practices. For example, power distance illustrates the willingness of a person to accept the inequality of power in an organization. The second cultural value, individualism vs. collectivism, refers to the 'sense of belonging' a person feels when it comes to job satisfaction and tasks. Third, uncertainty avoidance explains the level of risk and uncertainty that people are willing to accept and undertake. The last dimension, femininity and masculinity, describes the difference between people who are ambitious, hardworking, committed and task oriented as opposed to people who are caring, and relationship-oriented.

Organizational culture comprises the atittudes, experiences, beliefs and values of an organization. According to Schein (1992), organizational culture can be defined as "A pattern of shared basic assumptions that the group learned as it solved its problems of external adaptation and internal integration, that has worked well enough to be considered valid and, therefore, to be taught to new members as the correct way you perceive, think, and feel in relation to those problems" (p.34)."Thus the impact of organizational culture is extensive and intense in organizations where it is manifested in concepts such as 'the way we do things around here,' or certain rites and rituals of the company, 'our company climate,' 'our common practices and norms', and 'our core values.' Schein (1985) suggests three levels of culture: artifacts, espoused values, and basic underlying assumptions. These organizational levels definitely overlap with the national background of an individual, which might create conflicts.

Besides organizational culture, another layer of cultural values that need to be emphasized is the information system (IS) culture. What is an IS culture? There is no clear distinction of this type of culture since it overlaps with national and

Figure 1. Conceptual framework of challenges in managing ICT in healthcare organizations



organizational culture. To avoid any confusion with the already multifaceted cultural values in this chapter, we will limit our definition of IS culture to one particular instance, that of the organizational culture of the developer of the ICT and the users who either adopt or reject the technology that he or she uses in an organization. Extending the work of Hofstede, IS culture can be defined as the set of values and practices shared by the members of an organization involved in information activities; this includes people like IT professionals, managers, and end-users. IS culture is thus a subset of an organizational culture, with unique values that are attached to the IT department. IS culture might resist technologies which threaten to change their current status, power, and working habits, especially when they may violate some of the groups' shared values. IS culture may also be more or less compatible with certain forms of IT; when that is the case, the result can be resistance to IT changes, failure in ICT adoption, and lack of implementation. In other words, the way people perceive the usefulness and ease of use of a given ICT will be impacted by the existing national culture – in this case, that of the medical teams as well as the support staff – together with the common practices, artifacts, espoused values and underlying assumptions of the developer(s) in an organization.

On the overall, culture is complex and multifaceted (Fan, 2000). As such, national culture is interrelated to organizational culture, professional culture (e.g. medical teams as doctors and nurses), as well as the IS culture. All these layers of cultural values can affect the way people handle innovation and ICT adoption. For instance, a study by Aggouram & Ingham (2003) found that when an organization attempts to standardize their information system, culture plays an important role as it affects the success of such task. Besides the multifaceted layers of culture, we also need to address the challenges that are confronted by people when a new technology is introduced. The key question is whether or not people are able to adopt the newly introduced ICT and if yes, what is the culture surrounding the ICT adoption and what are the challenges encountered by an organization?

Challenges of ICT Adoption

Based on the following conceptual framework (Figure 1), there are three aspects that we examined pertaining to the issue of ICT adoption in the hospital which are (1) organizations, (2) human, and (3) technology. Without a doubt, ICT has played a significant role in organizations such as hospitals and will continue to play a greater role in the aim of enhancing healthcare services. ICT is no longer just a business tool but an integral part of the organization's strategies. ICT impacts not only the IT department but every area or department in the organization since ICT is responsible for the integration of information across the entire organization. Based on empirical studies, the challenges of ICT arise from three barriers: organization, people and technology (Nambisan & Wang, 1999; Lorenzi & Riley, 2003; Nøhr, 2005; Pare, 2007; Tanriverdi & Iacono, 1999). These challenges and issues must be managed critically and effectively in order for an organization to function successfully via the use of ICT tools and applications.

Organizational Challenges

One of the most widely discussed questions on ICT implementation in hospitals is the cost of ICT investment – that is, the cost of the hardware and software needed to run the healthcare system. This could be actually high depending on the latest cost of software on the market, but it can also be relatively high, for example particularly costly to hospitals located in rural areas where not enough investment is made in updating or changing to new healthcare systems. In addition, organizations must consider costs associated with planning, specifying requirements, customizing and re-customizing systems, training providers, and reengineering the delivery of healthcare systems to accommodate hospitals. Miller and West (2007) suggest that the initial cost of implementing an Electronic Medical Record in a health center may be as high as $US54,000 to $US64,000 per participating physician, with ongoing costs of $US21,000 per physician per year. The key question is thus who will bear the expensive costs of ICT investment?

Another important organizational challenge is the organizational culture. An effective and efficiently managed organization normally ensures that their managers and employees understand the basic beliefs and policies governing behavior both within the organization and in external business relationships. The concept of organizational culture encompasses not only the organization as a whole, but also the individuals who are part of, or interact with it. According to Zakaria and Mohd Yusof (2001), a culture that promotes change is thought to be a more nurturing environment for technology users than a culture that promotes stability and certainty. Resistance towards usage of ICT in healthcare systems will frequently surface unless the culture is receptive towards changes, and unless people are ready to both accept new ideas and, more importantly sustain the changed conditions in the future.

Human/People Challenge

Human resources are the most important assets that contribute to organizational success. With the introduction of complex and rapidly evolving technology, organizations oftentimes are limited by the scarcity of skilled employees and experienced managers needed to operate the newly introduced ICTs. It is recommended that IT managers and their top management have a plan to cope with skill shortages because organizations that fail to manage their present staff stand little chance of obtaining and retaining outstanding individuals. Human resources that are reliable and full of capabilities will also increase the efficiency and effectiveness of the ICT. Therefore, organizations need to ensure they can recruit, train, and retain talented IT experts. This issue is directly related to organizational performance as well as individual performance; significant contributions that materially improve an organization's performance have oftentimes been made by a small number of individuals. Another important aspect is that reliable and competent IT expertise can disseminate operations and services much faster than people who do not know or understand how to use ICTs. Thus user training must be in place in order to bring users up to a tolerable level of competence which in turn increases the user acceptance of technological change. User training must be included in all phases of ICT adoption, from the initial stage up to the implementation stage. As suggested by Johnson (2001), three important tasks need to be included: educating the healthcare professionals, conducting research to understand the importance of ICT to stakeholders, and advocating for ICT use in organizations.

Technological Challenge

Without doubt, ICT is changing the way health care functions. With ICT tools, organizations can enhance healthcare services electronically where barriers like time, distance and space no longer matters. What matters is the quality of services. For instance, health care organizations can offer more efficient and various services for health consumers such as ability to access their own health records, browse the Internet for further information and knowledge about one's illness, communicate freely and speedily between patients and doctors, and reach out to online communities of patients that suffer the same illness for psychological support. However, with the amplified role played by ICT, there are some technological challenges that arise such as ease of use, usability, information security and compatibility of the system with the existing one. All the challenges transpire as a result of the technological change undergone at the organizational as well as individual level. Technological change is defined as "the change period, during which something new is planned and introduced, e.g. the period associated with the introduction of new processes that have major new technological ingredients" (Wild, 1990, p.55). The challenges that stem from such changes need to be managed. According to Benjamin and Levinson (1993), "The greater the functionality of an IT system, the more levels of learning and adjustments are required to use it (p.30)." In support of that, Zakaria and Yusof (2001) suggest that readiness and willingness to learn about the new technology at a greater depth and the customization of each of the processes are key issues that need to be taken into account when planning or undergoing technological change. Only then can the learning and transition processes during ICT adoption and implementation be a success.

METHODOLOGY

A Case Study of a Medical Research Institute in Malaysia

A case study is an ideal methodology when a holistic and in-depth investigation is needed (Feagin, Orum, & Sjoberg, 1991). Following storytelling logic, it seeks a deep understanding of a single organization by analyzing its social context (Dyer & Wilkins, 1991). In order to describe a rich story, case researchers approach the field as closely as possible and apply theoretical constructs in ongoing social settings. The descriptive and interpretive nature of storytelling enables researchers to investigate the process by which an artifact comes to obtain its characteristics (Dyer & Wilkins, 1991). It is a backward tracing of artifact history and an analytical conceptualization of the artifact. In other words, a case study is an act of taking an artifact's history apart and reassembling it within a contextual frame. Through these processes, researchers identify the intricacies of a particular context.

In this study, we use case study as a qualitative method because it is most relevant in exploring ICT adoption in a new setting, in this case--Malaysia. Our case study focuses on one medical research institute (MRI) situated in the northern part of Malaysia. The institute is part of a research university which also has its own teaching hospital located in the eastern part of Malaysia. This research institute's mission is to educate and train more medical and dental professionals in conducting medical research. In addition, the institute also provides outpatient services to the local community. At the same time, the medical research institute is planning to open its own research hospital to be fully operational in the year 2010. They hope to become one of the biggest tertiary and advanced medical centers and to meet the medical demands in the northern part of Malaysia.

In terms of Malaysian healthcare system, there are three types of funding: government, semi-government and private funding. In our case study, the medical research institute is part of a semi-government funding scheme because it is part of a higher learning (university) institution. This means that part of the ICT investment is taken care of by the Ministry of Higher Education, so in our case study, since this is a government run medical institute the medical cost is very minimal. In terms of policy, there is no comprehensive policy in regard to ICT use in hospital or healthcare organizations in Malaysia. In this case, the medical research institute adopts the policies used by the university's teaching hospital. In addition, most clinicians were working with teaching hospitals before they joined the medical research institute and were familiar with the policies.

Using a Malaysian medical institute as a case does not mean that the challenges of medical informatics as illustrated in this chapter are unique to Malaysia. We are more interested in pointing out that implementation and adoption of ICT in hospitals involves challenges and issues that need to be addressed by any organization. Malaysia is just one case in point, and though the case maybe unique to Malaysia it implies that other healthcare organizations may experience the same challenges when implementing and adopting ICT applications.

Data Collection

We began collecting preliminary data with the research objective of exploring the challenges faced by a single healthcare organization during the early stages of ICT adoption and implementation. According to Yin (2003), a case study is a research design that allows a researcher to understand a phenomenon in depth and provides richer insights about the problems being researched. Based on the case study approach, we employed structured interview to elicit as much data as possible pertaining to the phases, challenges, and problems encountered during the technological adoption period.

In order to understand the nature of ICT implementation and adoption in the institute, we had in-depth interviews with two key people in the institute: the clinical director and IT Director. We met the respondents a few times and spent many hours interviewing them to obtain their perspectives on ICT adoption and implementation. The clinical director is responsible for overseeing numerous medical specialties like oncology, psychiatry, dentistry, family health, pediatrics, internal medicine, and obstetrics & gynecology. She is also responsible for providing the space and tools for postgraduate research in the institute. The ICT director oversees all the design, development and implementation of ICT systems within the institute. These include the ICT infrastructure to support information and communication exchange within the institute. In the clinical setting, the IT department is responsible for developing a healthcare information system (HIS) within the institute. The HIS includes patient medical records (e-clinical) linked with the radiology information system (RIS) and laboratory information system (LIS) as well as nurses' station, billing, social work department and inventory. The system was completed and launched on March 2006, the same time as the outpatient clinics began to operate.

Interview Protocol and Validity of Case Study

The process of creating the interview protocol started in a formal researcher's meeting where, we, the researchers brainstormed the main issues pertaining to ICT adoption specifically in Malaysia context. The focus was on the overall picture of ICT adoption that affected different stakeholders in the organization. The researchers then decided that the protocol should be divided into two categories. The first category contained questions related to historical background of the organization. We adopted 5W's type of questioning (what, where, when, how, and why) so that we could explore the organization.

For the second category, we used questions that could address the success and challenges of the organization when adopting ICT. For an example, one of the questions asked the participant to give example of a "success story" during ICT development process. There is also one broad question that deals with "barriers and challenges" faced by the IT department during deployment. The "barriers" question is further expanded by setting probing questions that look into human, technology and organizational issues such as asking *"How, if at all, does the communication between doctors and patients change when ICT is introduced?"*

After the first draft of the protocol was completed, we sent the protocol to several researchers who are expert in the qualitative field. To ensure validity, the panel researchers examine the protocol in terms of clarity, organization, relevancy, accuracy and language-use. Once the protocol was approved, the researcher's team went through a mock interview exercise in order to see the flow of the questions as well to know when to ask the probing questions. We also added some "scenarios" to help the main interviewer understood the meaning of each question in case the interviewer got stuck during the interview. All this exercise had helped the main interviewer to prepare for the interview.

Data Analysis: Content Analysis on the Interviews

Content analysis is an unobstrusive research technique used to explore a phenomenon that yielded rich descriptions (Krippendorf, 2004). Based on the interviews we conducted, we will discuss in detail several challenges surrounding the culture, adoption, design and implementation of Hospital Information Systems in a local context. The transcribed interviews were content analyzed. In the first set of data, since this is a preliminary study attempting to explore and understand the challenges of ICT adoption in a hospital context, we used 5Ws (what, why, when, where and who) analysis to elicit a picture of the overall IT system as well the process of development and deployment of such a system. The 5Ws analysis is a common elicitation tool which enables researchers to get in depth information from research subjects. Then, in the second set, the discussions of the findings center on the three potential barriers: organizational issues, human/people issues and technological issues. The findings are described in the following section.

DISCUSSIONS ON ICT ADOPTION IN HEALTHCARE: A CASE OF A MEDICAL INSTITUTION IN MALAYSIA

Exploring ICT Adoption Using the 5Ws Framework

What is E-Clinical System?

It is crucial to first define the concepts of ICT and electronic healthcare. We suggest using the following definition: *ICTs* are defined as tools that facilitate communication and the processing and transmission of information and the sharing of knowledge by electronic means; this includes the full range of electronic digital and analog ICTs, from radio and television to telephones (fixed and mobile), computers, electronic-based media such as digital text and audio-video recording, and the Internet (Frenzel & Frenzel, 2004). *Electronic healthcare*, or *e-health*, is an emerging field of health informatics that refers to the organization and delivery of health services and information using the Internet and related technologies. In a broader sense, the term characterizes not only a technical development, but also a new way of working, an attitude, and a commitment to networked, global thinking, in order to improve health care locally, regionally, and worldwide by using information and communication technology (World Bank, 2006). For purposes of our case study, we will also talk about the *e-clinical* system which is a healthcare information system (HIS) comprised of seven modules that serve eight clinical subspecialties in the institute. The motivation for creating such a system is to operate a paperless transaction in the medical setting. The development of this software was fully supported by the university's IT department, who provided software and hardware infrastructure as well as manpower for software development.

At this point, e-clinical has five full functioning modules which are registration, patient screening, clinical, laboratories / radiology, and billing / inventory. When patients first enroll in the system, they are entered into the out-patient registration by registration personnel. Next, patients' vital signs are recorded in the patient screening module by nursing staff. During patient-physician interviews, the clinical module is used and the information is dispersed into imaging, laboratory and pharmacy modules for different uses. In each module, all charges are connected with the billing module. The social department reviews cases where patients cannot afford medical care and provides necessary support for those patients. If patients are eligible to receive help, the billing information is sent directly to the social department module. The last module, inventory, is connected to the billing module in order to ensure medications and all other orders are in stock.

Why Develop In-House Electronic Medical Record (EMR)

One of the goals of this medical institution is to operate a paperless hospital. In doing so, the organization planned and developed an in-house EMR by customizing their own system using their local clinical requirements. The initial requirements were generated by the top management of the medical institute followed by a series of user feedbacks after the system was launched. Another motivation for developing the in-house system was to reduce costs. Development was also encouraged by their ability to get technical expertise from the university Information Technology division.

When the Roll-Out Takes Place

The system rollout took place in March 2006. The director of the research institute wanted the system to be available as soon as the outpatient clinic was open. The decision to roll out the system in parallel with the service was quite brave, and was, made even though there were issues in system design at that point. The IT personnel met regularly afterwards and listened attentively to user requests. Changes and modifications to the system were made directly and the IT people took time to sit down and help the users. The local champion participated in the IT daily meeting to report user requests and complaints. In this case, local champions are the first group of people who adopts ICT in this hospital.

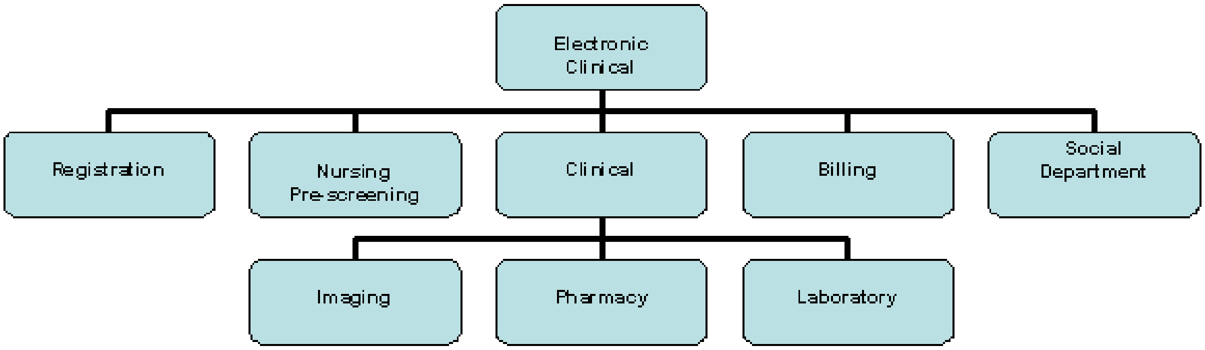
Where the ICTs are Introduced in the Institution

E-clinical operates in the outpatient clinic, laboratory, pharmacy and imaging centers.

Who are the Users

The users of the system include clinicians, nurses, and registration, billing, inventory and social department personnel. However, each user has limited access control as assigned by the IT department. For an example, the registration personnel can only enter and view patient registration and cannot access other modules. Most clinicians

Figure 2. General architecture of e-clinical system



have direct access to all patient information in order for them to track any patients with multiple diseases and get appropriate care from various medical specialties.

ICT Adoption: Issues on Organizations, Human, and Technology

In the context of the medical institute that we researched, we found that people, especially within the top management, were very receptive to and supportive of the organizational change. In other words, organizational change was part of the culture in which people are not only willing to accept changes but also accepted the role of the ICT and recognized the benefits that they would reap from using it. ICT is expected to facilitate the operations and change the way people in the institute work and the way they provide their medical treatments and services. All members of the board of directors, which is comprised mainly of clinicians, are very open towards ICT implementation in their organization. This is evidence that clinicians are actively accepting ICT in their work flow instead of resisting it, as found in many previous research studies. The institute's director himself made sure the e-clinical system was in place in parallel with the outpatient clinic opening because he wanted to make sure that the transitions went hand in hand. In addition to the sophisticated e-clinical system, the clinical director said that the institution has been using e-mail for their interactions with nurses and students.

Based on our case study, the IT director said one important lesson for future in-patient system development is to include all levels of users at the beginning of system development. For example, the IT department should get insights from registration personnel, nurses and clinicians from different specialties, billing officers, social workers, and any other potential users. The users would be able to give ideas on how to make their workflow as smooth possible, and may be able to see if some design would hinder their work process. In addition, they should review the requirements together with decision makers such as the institute's board of directors. All these inputs are important to ensure that ICT facilitates their daily routine and interaction with patients.

The IT director acknowledged the importance of local champion who becomes a liaison to the development team. During the initial roll-out phase, there were daily meetings among the developers and the clinical side on usage issues from the clinical side; the nurse champion was instrumental in gathering feedback from the clinical side and was able to suggest necessary remedies to the problems that occurred. The IT director mentioned that the local champion understood the day to day challenges in using the system because she was herself an avid user and knew the clinical environment well enough to be able to diagnose the problems faced by other users. The IT director also added that the local champion will be included in the early stage of inpatient system development. The advantages of an in-house development team were that it included knowledgeable end users as well as strong technical support from the university's IT department and an in-house developer that understood the system. The programmers were able to interact with the users and make changes instantly because they understand their own system in depth.

The institute only provided a few sessions of user training at the beginning of system deployment. There was no formal training afterwards. The IT director mentioned that most users refer to their own colleagues if they find problems when using the system. However, we feel that this organization should take extra measures to provide user training. The in-house training should be done in a consistent manner whereby training on the overall system and the potential uses of system would be cleared up among the users in the early stage. In a later phase, training should be provided as a continuous learning and improvement tool for the organization.

There were strong collaborative efforts between the IT department and the clinician side. After the system deployment, the IT people met the clinical end users every day to discuss any issues that arose. After a few weeks of daily meeting, the IT top management asked the programmers to work hand in hand with the users. At this point, all the programmers understood the nature of clinical use of the system. It is important to note that the process of cyclical communication is most important at the early stage of ICT adoption. What is even more effective is that the IT top management takes a leading and proactive role to ensure that the technological as well as organizational change transpires smoothly and effectively.

Based on the case study, one of the main questions during the interview was to understand the technology issues surrounding the development. As mentioned earlier, the medical research institute is part of a research university. The university itself has an established IT department that oversees all IT implementation in the university. The e-clinical system template was taken directly from the university's health center, which had been using an electronic medical record system that was designed by the university IT department. When the medical research institute began their own ICT initiative, they immediately adopted the university's electronic medical record system. However, the IT director said they had to do some minimal modifications because the medical research institute handles more medical specialties compared to the university's health center. For the modification process, MRI had to "borrow" the university's IT department programmers. The migration and modification process took several months during which programmers and MRI IT personnel traveled back forth (the university and MRI are 40 minutes away). This back and forth process was not an easy task, and eventually the top management decided to hire their own programmers to handle e-clinical. Finally, they obtained two full-time programmers to operate e-clinical. In addition, MRI also hired an IT manager to lead the development team. Even though MRI now has its own development team, they still rely on the university's IT department for technical advice. Besides the issue of adapting to the university's electronic medical record format, we also found that MRI did not have to spend any money on the software because all licenses are bought by the university. In this case, MRI was able to cut costs in the development system which is an added advantage to the organization.

In terms of infrastructure, there were some issues of physical layout during the initial phase. For example, there was some discussion about where to place the servers; later on they were able to create a separate space just to store the servers. The IT director added that there was no proper planning of where to install the hardware until later on, when they discovered how disorganized it was to have the servers in various places. In other words, when the decision to adopt ICT was made, people were excited at the idea and accepted the decision without taking into consideration many details like space. In future ICT efforts, they have decided to plan hardware space first. She also mentioned that careful planning has been done in the design of the new hospital building. The institute selected one commercial system, which handles the radiological information system; this commercial system is developed in the USA, thus it incorporates standards like DICOM in the system. The IT department has to take into account these standards when incorporating it with the e-clinical system. In addition, the IT department is exploring other suitable standards for their own system.

LESSONS LEARNED FROM THE CASE STUDY

In this section, we first present several key perspectives based on the lessons learned from the above case study to highlight the critical success factors and best practices of healthcare organizations. Subsequently, we present the contributions based on the case study. The following observations were made:

Plan the ICT Investment More Effectively

Since ICT investment is costly and time consuming, for example in getting the right supplier or vendor, top management needs to plan more proactively by taking factors like time, cost, and benefit into consideration. In the case of MRI, the decisions to invest in ICT applications were not solely made by the top management, particularly the IT Director. Instead, the ICT projects were adopted directly from the University with which the medical research institute has a strong affiliation. Thus in the initial planning stage of buying or adopting ICT and the process of making decisions, questions like what types of ICT to invest, what are the cost and benefits of using one particular or several applications, who are involved in decision making, and timeline to adopt the ICT were not discussed at length. Yet, initial planning is as important as any other stage of the ICT adoption. It is crucial that these issues be addressed at the initial stage of decision making processes and as early as possible so that any problems can be identified and solved much quickly. In the case of MRI, it is fortunate that the adoption of the e-clinical system was not much of a problem.

Recruit, Select, and Retain Local IT Experts

By having the in-house experts as gate-keepers, organizations will benefit by continuous improvements and modifications to suit the needs of the organizations. Additionally, IT experts will also become the main advocates for technological changes as well as the liaisons between users and support staff, because they will learn much faster than others. IT experts are expected to be more equipped with knowledge about the information technology systems and applications. Based on the MRI case, the top management strongly felt that when the IT people, e.g. the programmers, were recruited in-house, it was much easier to manage the time allocated for ICT adoption and to educate other users on the ease of use and usability of the new system. With such recruitment, MRI no longer needs to depend on the vendors for help as their own IT people can handle any ‘bugs’ or problems that they encounter. As a result, the ‘layperson’ or non-IT people in the institute have frequently consulted the IT experts for any kinds of problems and difficulties that they encountered not only during the early stage of ICT adoption and implementation, but also on a continuous basis. In essence, IT experts become the main source of reference to help the amateur users in the organizations.

Build a Strong Organizational Culture that Supports Technological Changes

When organizations provide a conducive and supportive environment for ICT, the adoption and implementation process becomes less problematic or challenging. People are more willing to try and use the technology in place. Although in our case study we observed less involvement in decision making and planning in the initial stage of ICT adoption, the organizational culture of the MRI was highly supportive. In fact the IT top management agrees that only with a supportive culture can ICT adoption be successful. As evidence, the processes of adoption and implementation were smooth in the MRI. Personnel at all levels knew that ICT would be part of the normal ways of doing things in the organizations. They welcome such changes because they know that ICT will simplify their work and help them provide their services. Without support, resistance may surface and adoption and implementation will take a longer time.

Involve All Users and Key People in the Organizations

These people can present their needs and provide perspectives on what is desired versus what are the obstacles. By using this strategy, the organization creates an awareness of the change that will take place. When people have first hand information on the changes that will take place, as well as an avenue to voice any grievances, frustrations and anxieties about such changes, they will be more willing and ready to accept such changes. In the end, people will adopt ICT more willingly and become more accountable towards the changes. Our MRI was a unique case because the decision to adopt ICT was not inclusive at the initial planning stage. Rather than "adopt" it was more an issue of "adapt," taking the existing e-clinical system from the other institution -- almost like having a customized system to fit within MRI. But once the e-clinical system was adopted and implemented, the IT director played an active role by ensuring all levels of users participated in the success of the systems. So there are continuous 'loop' feedbacks from end users that provide extensive inputs to programmers on what needs to be done and improved.

Provide Continuous User Training to All Levels of Users

From top management to lower management that will use ICT-- Training is essential at all stages of the transition because educating people on the ICT tools makes them familiar with the new work context, and eventually they become experts in using the tool. Training needs to be given phase by phase, for different people at different times. Top management may take precedence so that they can advocate changes to the subordinates.

Contribution of Study

Without doubt, making investments in ICT can be expensive, for examples in terms of the financial cost, time, and resources. Not only is the infrastructure becomes one of the main concerns for organization, but also the cost of recruiting, training, and sustaining the people as the human resources are as crucial. By looking at the findings based on the lessons learned, there are few implications that can facilitate organizations in managing the rate of ICT adoption among employees. Hence, the contributions of this study come in twofold. First, by looking at the dynamic layers of culture, it helps an organization to fully understand the underlying values of the employees as well as evaluate and improvise the organizational culture, structure, and processes. As such, organizations will incorporate a compatible culture that is consistent with its objectives, vision and mission. Second, organizations can take preventive measurements, proactive plans and strategies to overcome three challenges as previously mentioned (see Figure 1.0). For example, organizations need to invest in training programs for the medical teams and support staffs to use and adopt ICT such administering electronic medical records. Essentially, failure to use and adopt ICT effectively will result in unsuccessful management of patients and its healthcare services.

CONCLUSION AND FUTURE DIRECTIONS

It is obvious that the case study presented in this chapter comprises preliminary data on the practices and lessons learned from an organization that adopts and implements ICT – in this case an e-clinical system. As such, the case provides insights on a Malaysian context in which the effort for ICT adoption is partly supported by the government. In the future, as an emerging healthcare organization, it is expected that the medical research institute will be developing and integrating more ICT applications to support their mission of becoming an excellent medical research center. Although we have presented the issues and challenges surrounding an ICT implementation in the Malaysian health care environment, the challenges can be applied in any other organizational context or in different country-based perspectives. Inherently, there are some important lessons to be learned from this case study as illustrated above. In a nutshell, managing ICT adoption and implementation requires that the organization build effective communication among people who are involved in the technological change processes; create awareness of both the organizational and technological changes that are going to take place; develop continuous and rigorous training to increase familiarity, competency, and knowledge about the ICT to be used; recruit, select, and retain local IT experts to move the ICT adoption processes to success; and promoting supportive organizational culture that supports technological changes. Given these five lessons learned obtained from the case study, we suggest some fruitful questions for future research:

- How, if at all, does ICT change how healthcare delivers its services?
- How has patient care changed, and what are the trends?
- How, if at all, does the work of doctors and nurses change when ICT is introduced in a health care institution?
- How, if at all, does the communication between doctors and patients change when ICT is introduced?
- Does ICT deskill or facilitate doctors and nurses?
- What are the critical success factors for ICT adoption in healthcare organizations?
- How do organizations manage technological changes to ensure effective ICT adoption?

REFERENCES

Aggouram, H., & Ingham, J. (2003). In K. Kangas, (Ed.) National culture and the meaning of information systems success: a framework for research and its implications for IS standardization in multinational organizations, *Business Strategies for Information Technology Management.* Hershey, PA: IGI Global.

Benjamin, R. I., & Levinson, E. (1993). A framework for managing IT-enabled change. *Sloan Management Review*, ▪▪▪, 23–33.

Bodenheimer, T. (1999). The American health care system: The movement for improved quality in health care. *The New England Journal of Medicine*, *340*, 488–492. doi:10.1056/NEJM199902113400621

Dyer, W. G., & Wilkins, A. L. (1991). Better Stories, Not Better Constructs, To Generate Better Theory: A Rejoinder To Eisenhardt. *Academy of Management Review*, *16*(3), 613–619. doi:10.2307/258920

Fan, Y. (2000). A classification of Chinese culture. *Cross Cultural Management–An International Journal*, *7*(2), 3–10. doi:10.1108/13527600010797057

Feagin, J., Orum, A., & Sjoberg, G. (Eds.). (1991). *A case for case study*. Chapel Hill, NC: University of North Carolina Press.

Fiscella, K., & Geiger, H. J. (2006). Health information technology and quality improvement for community health centers. *Health Affairs*, *25*(2), 405–412. doi:10.1377/hlthaff.25.2.405

Frenzel, C. W., & Frenzel, J. C. (2004). *Management of Information Technology*, (4th ed.). Boston: Thomson.

Hofstede, G. (1980). Culture's Consequences: International Differences in Work-Related Values. Beverly Hills, CA: Sage.

Holt, D. H., & Wigginton, K. W. (2002). *International Management* (2nd Ed.). Mason, OH: Thomson Southwestern.

Johnson, K. B. (2001). Barriers That Impede the Adoption of Pediatric Information Technology. *Archives of Pediatrics & Adolescent Medicine*, *155*, 1374–1379.

Karahanna, E., Straub, D. W., & Chervany, N. L. (1999). Information technology adoption across time: A cross-sectional comparison of pre-adoption and post-adoption beliefs . *MIS Quarterly*, *23*(2), 183–213. doi:10.2307/249751

Lorenzi, N. M., & Riley, R. T. (2003). Organizational issues = change. *International Journal of Medical Informatics*, *69*(2/3), 197–203. doi:10.1016/S1386-5056(02)00105-3

Mass, M., & Eriksson, O. (2006). Challenges in the adoption of medical information systems. *Proceedings of the 39th Annual Hawaii International Conference on System Sciences* (HICSS '06), *5*, 95.

Miller, R. H., & West, C. E. (2007). The value of electronic health records in community health centers: Policy implications. *Health Affairs*, *26*(1), 206–214. doi:10.1377/hlthaff.26.1.206

Nambisan, S., & Wang, Y. M. (1999). Roadblocks to web technology adoption? *Communications of the ACM*, *42*(1), 98–101. doi:10.1145/291469.291482

Nøhr, C., Andersen, S. K., Vingtoft, S., Bernstein, K., & Bruun-Rasmussen, M. (2005). Development, implementation and diffusion of EHR systems in Denmark. *International Journal of Medical Informatics*, *74*(2–4), 229–234. doi:10.1016/j.ijmedinf.2004.04.025

Pare', G. & Trudel, M. (2007). Knowledge barriers to PACS adoption and implementation in hospitals. *International Journal of Medical Informatics*, ▪▪▪, 22–33.

Ragam, M. R. (2007). Information technology in healthcare creating a stronger healthcare system. *Asian Hospital & Healthcare Management*, *12*, 60–63.

Robbins, S. P., & De Cenzo, D. A. (1996). *Fundamentals of Management* (6th ed.). New York: Prentice Hall.

Schein, E. H. (1992). *Organizational Culture and Leadership*, (3rd ed.). San Francisco, CA: Jossey-Bass

Tanriverdi, H., & Iacono, C. N. (1999). Knowledge barriers to diffusion of telemedicine. In *Proceedings of the 20th International Conference on Information Systems*, Charlotte, NC, (pp. 39–50).

WHO. (2004). *eHealth for Health-care Delivery: Strategy 2004-2007*. Geneva, Switzerland: WHO. Retrieved from www.who.int/eht/en/EHT_strategy_2004-2007.pdf.

World Bank. (2006). *Connecting People, Improving Health: the Role of ICTs in the Health Sector of Developing Countries*, (pp.5-6).

Yin, R. K. (2003). *Case Study Research Design and Methods: Applied Social Research Methods*. Thousand Oaks, CA: Sage.

Zakaria, N., & Mohd Yusof, S. (2001). The role of human and organizational culture in the context of technological change. In *Proceedings of IEMC--Change Management and the New Industrial Revolution.*

Zonabend, F. (1992). The monograph in European ethnology. *Current Sociology*, *40*(1), 49–60. doi:10.1177/001139292040001005

KEY TERMS AND DEFINITIONS

Culture: includes knowledge, belief, art, morals, law, custom, and many other capabilities and habits acquired by a man as a member of a society.

Case study: is defined as a research strategy, an empirical inquiry that investigates a phenomenon within its real-life context. Case study research means single and multiple case studies, can include quantitative evidence, relies on multiple sources of evidence and benefits from the prior development of theoretical propositions.

Electronic medical records (EMRs): are computerized or electronic based health records of a person used by physicians, clinic or hospitals. It is a comprehensive record that combines information across multiple providers.

Information Communication Technology: defined as tools that facilitate communication and the processing and transmission of information and the sharing of knowledge by electronic means which includes the full range of electronic digital and analog ICTs.

Medical informatics: analysis and dissemination of medical data through the application of computers to various aspects of health care and provisions.

Organizational culture: comprises the attitudes, experiences, beliefs and values of an organization. It can also be dfeined as the specific collection of values and norms that are shared by people and groups in an organization and that control the way they interact with each other and with stakeholders outside the organization

Technological change: the change period, during which something new is planned and introduced, e.g. the period associated with the introduction of new processes that have major new technological ingredients.

This work was previously published in Handbook of Research on Advances in Health Informatics and Electronic Healthcare Applications: Global Adoption and Impact of Information Communication Technologies, edited by K. Khoumbati; Y.K. Dwivedi; A. Srivastava; B. Lal, pp. 153-168, copyright 2010 by Medical Information Science Reference (an imprint of IGI Global).

Chapter 5.7

Social Impacts of Mobile Virtual Communities on Healthcare

Alessia D'Andrea
IRPPS-CNR, Rome, Italy

Fernando Ferri
IRPPS-CNR, Rome, Italy

Patrizia Grifoni
IRPPS-CNR, Rome, Italy

ABSTRACT

Mobile technologies, such as PDAs, pocket PCs and cell phones, are transforming interpersonal communications, making them independent from a fixed location and then "situated nowhere". The widespread diffusion of mobile technologies combined with the popularity of virtual communities is giving rise to the development of mobile virtual community. Mobile virtual community has the great potential to serve information needs. A relevant application's domain for mobile virtual communities is healthcare, where the need for information is deeply felt and has a long-term nature. Mobile virtual healthcare communities encourage information exchange between patients, between physicians, and between patients and physicians. The exchange of information can be used for detecting patients and physicians that have common objectives in order to establish interaction among them.

DOI: 10.4018/978-1-60566-156-8.ch029

INTRODUCTION

Social relationships are a key component of human life. Whilst in earlier times communities were bound to the limitations of time and space, these restrictions are removed thanks the evolution brought by the Internet (Whitepaper, 2007). In the Web people organize themselves into virtual communities at the same manner they organise themselves in communities in the real word. A Virtual Community can be defined as an information source in which people share interests and information. It consists of tree elements;

- People interacting to satisfy their own needs or play special roles;
- A shared purpose, such as a need, an interest that provides the reason for belonging to the community.
- Communication systems and server architecture that support social interaction and promote a sense of been together.

The popularity of virtual communities, combined with the widespread diffusion of mobile technologies, such as PDA, pocket PC and cell phone, has given rise to the phenomenon of mobile virtual communities. Mobile virtual communities are considered to be the natural evolution of virtual communities. They can be seen as virtual communities to which mobile services are added. Using mobile technologies, users have an anytime-anywhere connection to their community. The use of mobile devices allows members of the community to communicate among them anywhere and anytime and not only if they are in the same physical place. In this way they can constantly have a connection with other members. The communication is both one-to-many and many-to-many. The participants of a mobile virtual community can exchange useful information by communicating and interacting with each other. Mobile virtual communities should be information rich and it should allow information available for many people because they improve and encourage social processes allowing interaction among colleagues, friends etc..

The aim of this chapter is to analyse the social impacts that mobile virtual communities have in the healthcare sector. Belonging to a mobile virtual healthcare community enables patients with diseases to interact in a virtual space with people that have the same experience. This interaction can allow the improvement of knowledge and the decreasing of problems. Moreover mobile virtual healthcare communities offer to physicians an opportunity to improve the awarness of patients' health conditions enhancing their satisfaction. They give the opportunity to increase the involvement of patients in their treatments improving access to health care information and communication possibilities between patients and physicians. The use of discussion forum gives physician the possibility to communicate with patients continuously allowing better information sharing. For patients with chronic illnesses, especially those in rural or outlying areas, consultation with an appropriate specialist can vastly improve the quality and outcome of their healthcare. Finally mobile virtual healthcare communities allow physicians to participate in continuous medical education at a time and location convenient for them, along with useful communication. The use of mobile virtual communities improves possibilities to maintain communication and collaboration with colleagues investigating the same subjects. Here physicians aggregate observations from their daily practice and then challenge or collaborate each others' opinions, accelerating the emergence of trends and new insights on medications, treatments and devices. They can apply the collective knowledge to achieve better outcomes for your patients.

The chapter is organized as follow. After a short introduction, which deals with some issues of categorization and definition of virtual communities, the chapter proceeds to analyse mobile virtual communities. Then the chapter first proceeds to describe mobile virtual communities/communication in healthcare sector and then it analyses three kinds of relationship: between patients, between patient and physicians and between physicians.

VIRTUAL COMMUNITY: A MULTIDISCIPLINARY CONCEPT

The term "virtual community" was even coined long before electronic communication in any form took place. It was a concern of many social theorists and scientists of the 19th and 20th centuries

(Reinhard and Wolkinger, 2003). There are many definitions of virtual community that depend upon the perspective from which they are defined.

From the technology perspective virtual communities are defined according to the software supporting them like newsgroup, list server, bulletin board, Internet Relay Chat (IRC), or Multi-User Dungeon (MUD). These software technologies support the communication within the community, and help in creating the boundaries of the community.

From the sociology perspective virtual communities are defined based on the strength and type of relationship. Etzioni and Etzioni (1999) define a virtual community as "a Web of affect-laden relationships encompassing group of individuals (bonding) and commitment to a set of shared values, mores, meanings and a shared historical identity (culture)". Romm, Pliskin and Clarke (1997) define a virtual community "as a group of people who communicate with each other via electronic media, such as the Internet and share common interests unconstrained by their geographical location, physical interaction or ethnic origin". Ridings et al. (2002) define virtual Communities as "groups of people with common interests and practices that communicate regularly and for some duration in an organized way over the Internet through a common location or mechanism".

Ferguson,et al. (2004) define virtual Communities as "groups of people drawn together by an opportunity to share a sense of community with like-minded strangers having common interest".

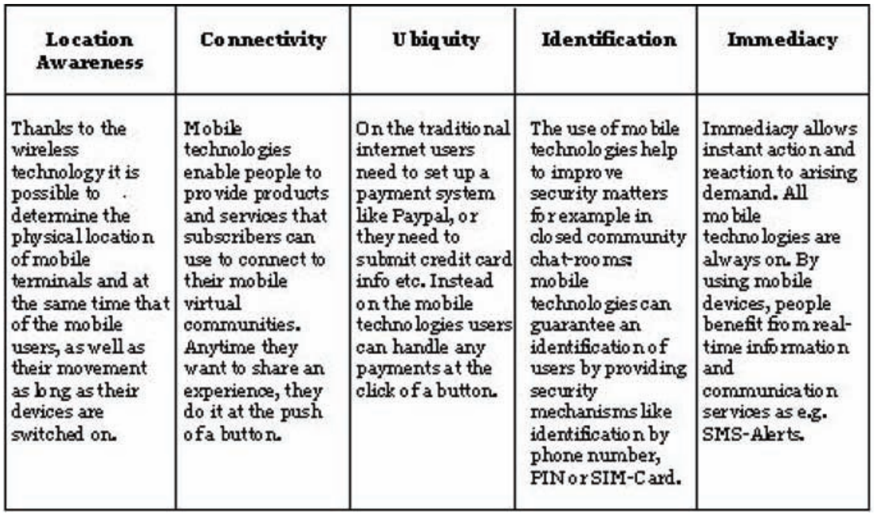
On the contrary Balasubramanian and Mahajan (2001) take an economic perspective and define a virtual community "as an aggregation of people, who is rational utility-maximizes, who interact without physical collocation, in a social exchange process, with a shared objective".

In all of these definitions virtual communities are described as social entities comprised of individuals who share information or other bases for social interaction.

The notion of information refers to the possibility to access to specific information regarding areas of interest. The exchanging of a lot of information in a virtual community, allows users to discuss about different questions and problems by creating a global vision about them. Within virtual community individuals can give information (by posting conversations) or get information (browsing information by posting questions). These information resources are socially helpful because they allow people to easily establish contact among them. A virtual community can be used also to improve the knowledge-sharing process using the experiences of the participants. The most effective way for allowing knowledge-sharing is the conversation. It is through conversation that we learn how to learn together. In a virtual community conversations can occur using a shared space where people can interact, creating new knowledge and, mainly, sharing knowledge. Therefore, common functionalities, provided by virtual community and aimed at sharing resources within the community, contain discussion boards, that provide individuals with the ability to post and reply to messages in a common area, whiteboard, that allows individuals to brainstorm together, draw graphical objects into a shared window etc, video/audio conferencing, that allows making virtual face-to-face meeting, and shared notepad, that provides community's members with the ability for cooperative writing and documents. Other functionalities concern the scheduling of common events and activities, the organization and retrieval of knowledge and the broadcast of shared documents on the Web.

Whilst the notion ofinteraction refers to the search of relationship during which individuals can share, with others, interests and experiences that can facilitate to overcome difficulties and to solve problems. Community is the process of bringing those who have interest in specific domain and

Figure 1. Mobile characteristics



Location Awareness	Connectivity	Ubiquity	Identification	Immediacy
Thanks to the wireless technology it is possible to determine the physical location of mobile terminals and at the same time that of the mobile users, as well as their movement as long as their devices are switched on.	Mobile technologies enable people to provide products and services that subscribers can use to connect to their mobile virtual communities. Anytime they want to share an experience, they do it at the push of a button.	On the traditional internet users need to set up a payment system like Paypal, or they need to submit credit card info etc. Instead on the mobile technologies users can handle any payments at the click of a button.	The use of mobile technologies help to improve security matters for example in closed community chat-rooms: mobile technologies can guarantee an identification of users by providing security mechanisms like identification by phone number, PIN or SIM-Card.	Immediacy allows instant action and reaction to arising demand. All mobile technologies are always on. By using mobile devices, people benefit from real-time information and communication services as e.g. SMS-Alerts.

remove interaction barriers, to build trust and relationships among the members of the community. In the created community each member develops his/her own identity in relation to the community (Bouras, Igglesis, Kapoulas, and Tsiatsos, 2005). The members' interactions over time help members in creating a network of trustees, composed of those who feel confident and comfortable with. This in return creates a reference source to ask for help when it's needed. An important factor in a community is the mutual engagement among community's members. Members whether joined the community voluntarily or were obliged to join and they can not be forced to contribute to it. Virtual community members should underline not only the content but also promote the social aspects as well if they wish to increase the success of their virtual community.

People have the need to be affiliated with others, because groups give individuals with a source of information and help in attaining goals and receiving social support. Social support plays a major role in influencing the well being of individuals. According to Turner, et al. (2001), the support received through virtual communities is perceived as helpful as support provided by real-world contact persons. Positive effects of online support are also mentioned by Gustafson and Maloney-Krichmar (2001). Both these studies report that members of online self-help groups superiorly cope with information about their disease due to the received support; furthermore, their emotional situation improves. A study conducted by Loader et al. (2002) identifies emotional as well as informational support as types of support provided by virtual relationships.

MOBILE VIRTUAL COMMUNITIES

Today we live in a mobile-devices-focused society. Mobile technologies, such as PDA, pocket PC and cell phone, transform interpersonal communications, which are independent from the fixed location, and result in the phenomenon of "situated nowhere," in which communication occurs everywhere. The ubiquitous form of communication allows people to micro-coordinate activities without prearranging an agreed-upon time and space. (Chih, 2007). Mobile technologies provide all the services that the traditional PC based Internet can offer. Even though the screen is smaller, it is not an obstacle. Everything is available on the Web, including its interactivity, can be avail-

Figure 2. Mobile virtual community application

able on mobile virtual communities. In order to analyse mobile virtual communities, it is useful to firstly illustrate mobile characteristics. Several studies specify mobile characteristics as classified by the chronology of their realization while others studies do not suggest any systematic order. On analysing the literature, we classify mobile characteristics into the following classes: location awareness, connectivity, ubiquity, identification and immediacy (Figure 1).

Mobile technologies are very useful to support people communication and interaction. Using the standard functions of mobile technologies people can communicate with others by sending photos, videos, etc. from a mobile device equipped with Internet functions. The Internet presents new opportunities for one to many and many to many interactions, creating a proliferation of virtual community. The popularity of virtual communities, combined with the widespread diffusion of mobile technologies has given rise to the phenomenon of mobile virtual community (Figure 2).

Rheingold (2006) asserts that a mobile virtual community "is characterized by blending the features of virtual communities and mobile communication, which are characteristic of affinity-based and local-acquaintance-based social communication". More specifically, mobile virtual communities are known as a platform for many-to-many communication, a platform for coordinating activities in geographic space, and an arena for socializing.

Mobile technologies extend computing and Internet into the wireless medium, and provide flexibility in communication and information sharing. By using mobile technologies, people can get an anytime-anywhere connection to their community und benefit from real-time information and communication services (Siew, 2001) Anytime/anywhere computing remove time and space constraints enhancing capabilities for communication, coordination, collaboration, and knowledge exchange. Users of mobile technology can access to the Internet and mobile applications whenever the need arises, such as when "travelling, wandering, and visiting". Examples of mobile virtual communities are Myspace and Facebook.

MySpace is a social networking Website offering an interactive, user-submitted network of friends, blogs, personal profiles, groups, music, videos and photos. MySpace is the world's sixth most popular English-language Website and the sixth most popular Website in any language, and the third most popular Website in the United States, though it has topped the chart on various weeks. It has become an increasingly influential part of contemporary popular culture.

Facebook is a social networking Website that allows people to communicate with their friends and exchange information. In Facebook users can select to join one or more participating networks, such as a high school, workplace, or geographic region.

MySpace and Facebook redefine the notion of community and encourage friends, family, colleagues and strangers to interact and exchange information.

Figure 3. Krebsgemeinschaft.de structure. ©2008 OSP Stuttgart. Used with permission.

Herzlich Willkommen bei der Krebsgemeinschaft für Brustkrebs

Es befinden sich **0** angemeldete Mitglieder auf der Seite.
Insgesamt registrierten sich **1844** Personen.

Um unsere Angebote optimal zu nutzen, sollten Sie sich auf der Krebsgemeinschaft registrieren, da bestimmte Bereiche nur Mitgliedern zugänglich sind. Haben Sie bereits einen Benutzernamen, können Sie sich gleich links oben anmelden.

Aktuelle Meldungen und Interessantes

Psychologische Beratung für Brustkrebspatientinnen
Kostenloses Hilfsangebot im Internet. Das Institut für Medizinische Psychologie an der Universität Tübingen bietet im Rahmen einer wissenschaftlichen Studie im Internet eine kostenlose Plattform an, die betroffenen Brustkrebspatientinnen die Möglichkeit geben soll, sich rasch, geografisch unabhängig und anonym per E-Mail psychoonkologisch beraten zu lassen.
Lesen Sie hier weiter.

MOBILE VIRTUAL HEALTHCARE COMMUNITIES

In this section we introduce the mobile virtual community concept for healthcare sector. The literature indicates a virtual community in healthcare sector as “a group of people using telecommunication with the purposes of delivering health care and education, and/or providing support, covers a wide range of clinical specialties, technologies and stakeholders” (http://www.ncbi.nlm.nih.gov/pubmed/16406472)..In respect of this definition, we can describe mobile healthcare virtual community as “a group of people using mobile technologies with the purposes of delivering health care and education, and/or providing support, covers a wide range of clinical specialties and people with the same medical problems”. An example of mobile virtual healthcare community is krebsgemeinschaft.de (see Figure 3).

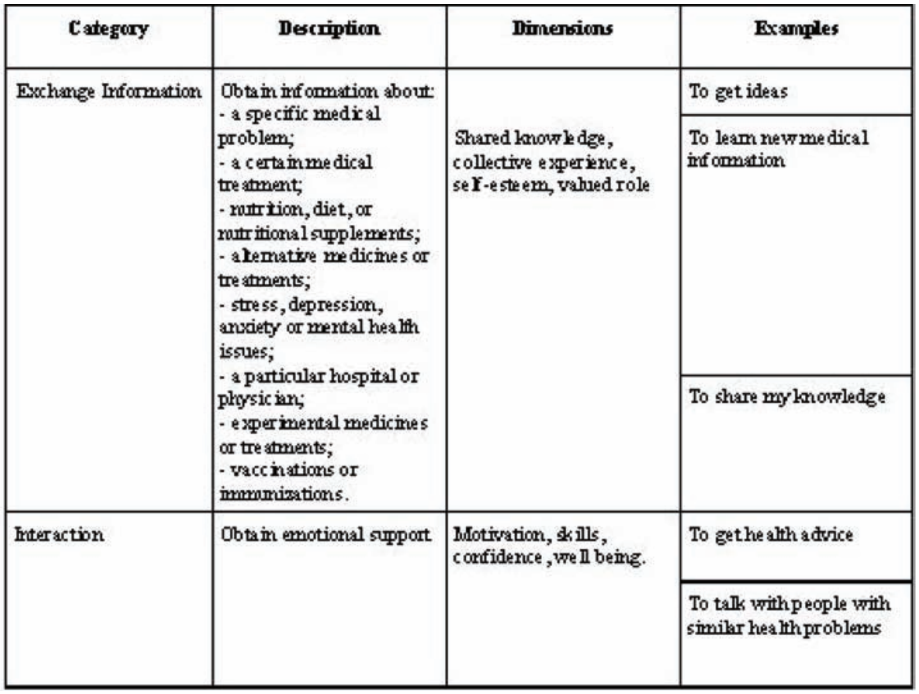
Krebsgemeinschaft.de has the potential to serve ubiquitous needs (Leimeister & Krcmar, 2003). Such an omnipresent problem situation exists in healthcare when patients develop a need for information and interaction, which exceeds the offer of physicians. Several studies demonstrate that there are different kinds of health information that people exchange in krebsgemeinschaft.de (Figure 4).

These kinds of information underline that usually patients want to become well informed about healthcare. Krebsgemeinschaft.de represents an unprecedented opportunity for patient self-education. This is due to the simplicity of use and to the fact that access and age barriers are rapidly disappearing and patients express their needs in using the krebsgemeinschaft.de to develop:

- Consumer-oriented health care models;
- The increase of health information;
- Actions that increase the possibility to access to best care.

For this reason patients see it as an important information source. This is particularly relevant for illness such as cancer. Also interaction and social support play a relevant role in positively influencing the well being of cancer patients (Leimeister & Krcmar, 2006). In krebsgemeinschaft.de people with particular health problems have the possibility to share information and potential solutions with other people; this can facilitate to overcome

Figure 4. Social aspects of krebsgemeinschaft.de

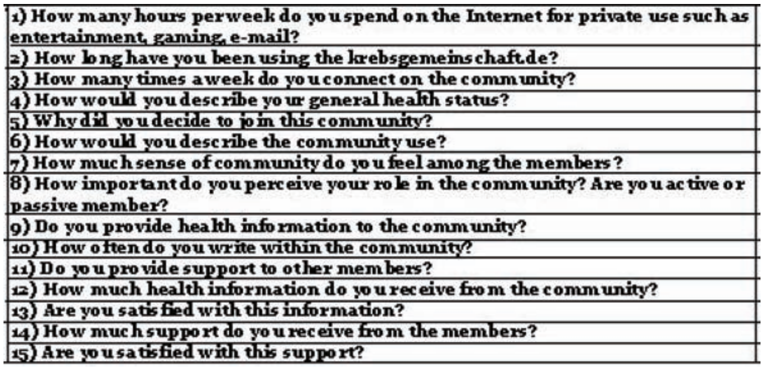


Category	Description	Dimensions	Examples
Exchange Information	Obtain information about: - a specific medical problem; - a certain medical treatment; - nutrition, diet, or nutritional supplements; - alternative medicines or treatments; - stress, depression, anxiety or mental health issues; - a particular hospital or physician; - experimental medicines or treatments; - vaccinations or immunizations.	Shared knowledge, collective experience, self-esteem, valued role	To get ideas
			To learn new medical information
			To share my knowledge
Interaction	Obtain emotional support	Motivation, skills, confidence, well being.	To get health advice
			To talk with people with similar health problems

difficulties and to solve that problems. In order to analyse how people use medical information and how they interact on krebsgemeinschaft.de we carried out an interview (Figure 5). The interview is short and it was designed to be less intrusive as possible. Twenty people, members of the mobile virtual community, were involved in the interview. The interview aims to analyse the frequency of community connections, the average time of each connection and the motivations that stimulate users to join community. Moreover, the interview aims to identify the level of satisfaction that users achieve in belonging to the community.

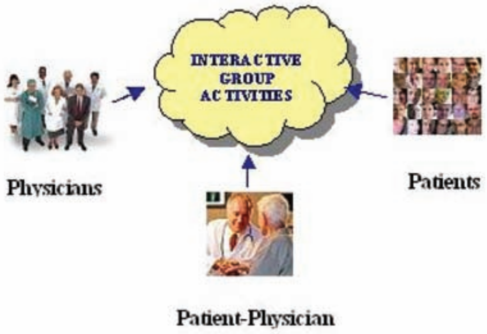
The results of the interview underline that members are interested in using information provided by other members and disclose personal experiences within the community. They demonstrate trust that information provided by other

Figure 5. Interview



1) How many hours per week do you spend on the Internet for private use such as entertainment, gaming, e-mail?
2) How long have you been using the krebsgemeinschaft.de?
3) How many times a week do you connect on the community?
4) How would you describe your general health status?
5) Why did you decide to join this community?
6) How would you describe the community use?
7) How much sense of community do you feel among the members?
8) How important do you perceive your role in the community? Are you active or passive member?
9) Do you provide health information to the community?
10) How often do you write within the community?
11) Do you provide support to other members?
12) How much health information do you receive from the community?
13) Are you satisfied with this information?
14) How much support do you receive from the members?
15) Are you satisfied with this support?

Figure 6. Interactive group activities



members is trustworthy and correct. As proof of this, interviewed people indicated that they have based their real-life actions on information gathered in the community.

INTERACTIVE GROUP ACTIVITIES

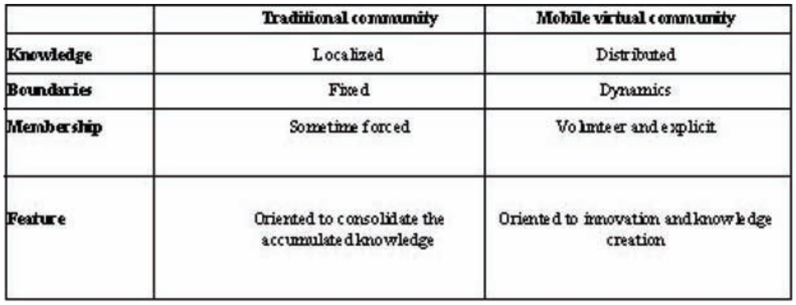
The mobile virtual healthcare communities are formed by people organised according to three major groups of activities (Figure 6):

The first is a group of professionals who actively seeks each other and share authentic information. Professionals from one part of the world with expertise in one particular field can share their experience with people from other parts of the world. Interaction can be purely unilateral (e.g. expert review of pathology slides and X-rays of cancer patients), or it can be bilateral (e.g. group of intensivists discussing the practices at their institutes). These groups also provide a cheap, fast and reliable mode of sharing relevant information or knowledge for the clinicians who often find it difficult to spare enough time from their busy schedules to attend conferences or courses in order to keep themselves up to date. Not to mention the cost of these events.

The second is a group of people that share common health problems (e.g. cancer, infertility etc). Mobile virtual healthcare communities mainly provide information and mutual support for users. They provide information concerning treatments, health insurance or particular medical problems. Mobile virtual communities are socially helpful because they allow people to easily establish contact among them and to have a mutual knowledge that is much more sound. People with particular problems have the possibility to share their problems with other people or with physicians that can facilitate to overcome difficulties and to solve problems. Emotional support in mobile virtual healthcare communities benefits from the absence of traditional barriers to access and the possiblity to assure online anonymity thath can be helpful for those who have stigmatizing or embarrassing conditions.

Third are a group of professionals and a group of patients. Patients see mobile virtual healthcare communities as a convenient way to interact with physician who is important to them. With the continued increased development of Internet, mobile virtual communities can be a simple, valid, convenient and inexpensive mechanism for interact. They can support the health care distribution

Figure 7. Traditional community vs mobile virtual community



	Traditional community	Mobile virtual community
Knowledge	Localized	Distributed
Boundaries	Fixed	Dynamics
Membership	Sometime forced	Volunteer and explicit
Feature	Oriented to consolidate the accumulated knowledge	Oriented to innovation and knowledge creation

process by allowing written follow-up clues, test results, as well as, a means for patients to easily contact their physician. The evolution of patient-physician communication shows that mobile virtual communities have a relevant impact on the way in which patients and doctors interact. Mobile virtual communities allow patients and physicians to share opinions and medical information every time and everywhere. Mobile virtual communities offer to physicians an opportunity to improve the awarness of patient's health conditions and enhance their satisfaction.

THE RELATIONSHIP BETWEEN PHYSICIANS

Regarding the relationships between physicians, mobile virtual healthcare communities allow them to participate in continuous medical education at a time and location convenient for them, along with:

- Useful communication and collaboration
- Knowledge sharing.

The use of mobile virtual healthcare communities improves possibilities to maintain communication and collaboration between physicians. In a virtual space physicians aggregate observations from their daily practice and then challenge or collaborate each others' opinions, accelerating the emergence of trends and new insights on medications, treatments and devices (Ebner, Leimeister & Krcmar 2004). Technology is an essential requirement of any mobile virtual healthcare communities to ensure an effective and rapid communications among physicians, especially distant ones. Technology used in mobile virtual healthcare communities allows transmitting, extending, saving and managing knowledge shared among community members. The most common technologies used in mobile virtual healthcare communities are the asynchronous tools, such as discussion boards, that provide physicians with the ability to post and reply to messages in a common area, whiteboard, that allows physicians to brainstorm together, draw graphical objects into a shared window etc, video/audio conferencing, that allows making virtual face-to-face meeting, and shared notepad, that provides community's members with the ability to create a document together (Malkary, 2005). Other functionalities concern the scheduling of common events and activities, the organization and retrieval of knowledge and the broadcast of shared documents to the Web.

Although technology cannot completely substitute face-to-face interactions, mobile virtual healthcare communities can foster the growth of knowledge sharing between physicians. In this sense mobile virtual communities will supplement, not supplant, traditional communities (Figure 7).

As Tab. 4 shows, virtual community supplements traditional community in creating a more dynamic environment oriented to innovation and knowledge sharing. In healthcare sector mobile virtual communities allow the enhancing of "meeting opportunities" between physicians. As consequence, emerge the increasing number of skills, competencies and "knowledge profiles" of each physician involved into the mobile virtual community. In this perspective, a mobile virtual community amplifies openness, interoperability, scalability, and extensibility of a traditional community. In the same time, this does not mean that in a mobile virtual community of creation face-to-face interactions are substituted by electronic communications. On the contrary, face-to-face interactions are enabled and supported by electronic communications that try to make easier, more immediate and less expensive the knowledge relations, amplifying their efficacy.

THE PATIENT-PATIENT RELATIONSHIP

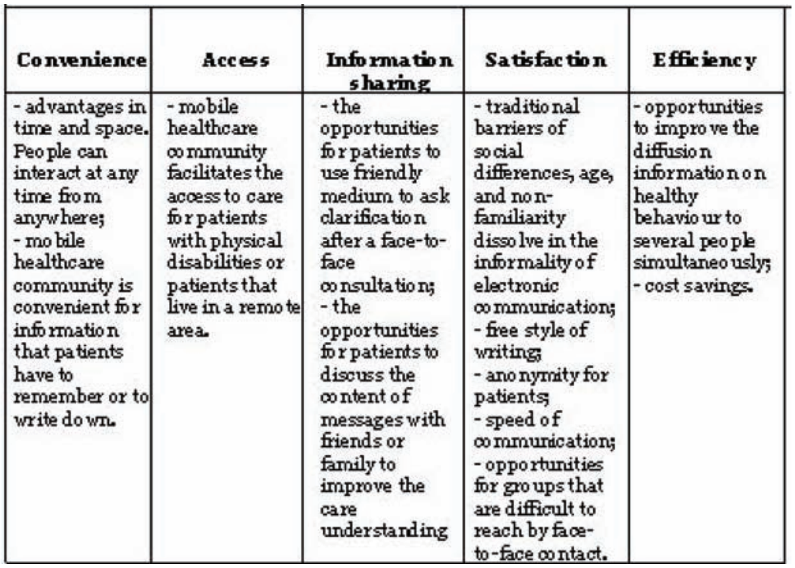
Patients' demands for information often increase after a diagnosis of a disease or during medical treatment. Patients may seek information to help them make sense of a diagnosis. Recent research on patients' information needs (Leimeister Arnold Y., Krcmar H. 2006) demonstrates a strong information interest in the following areas:

1. Side effects.
2. Explanation of disease and prognosis.
3. Treatment options and explanations of therapy.
4. Logistical issues (transportation, work, etc.).
5. Lifestyle issues (exercise, diet, sexuality, smoking).
6. Follow up/what happens after therapy finishes.
7. Support or self help groups, alternative medicine.

Besides demands for information, there is a desire to seek emotional support with other patients (Leimeister & Krcmar 2005). Several studies have identified five, interrelated forms of emotional support common to face-to-face and virtual mutual aid groups. These forms of emotional support help to reduce members isolation and empathy to enhance self-esteem and sustain hope. People join mobile virtual communities to experience a sense of community with others like themselves. To obtain this benefit, members must stay involved long enough to feel a sense of connection with other members. They are more likely to have this experience if they begin exchanging messages with other members. Researchers have found that when members write longer posts and ask questions, they are more likely to post again. There are various types of technologies used by patients to form and facilitate interactions within a mobile healthcare community. Some of these include:

- **E-mails:** the exchange of electronic messages between peers via e-mail is widespread. However, it is often a clumsy tool to be used to converse with other community members and it lacks security due to the high probability of deleting or misplacing mistakenly a document or a message.
- **Instant messaging:** exchanging messages simultaneously is a real-time approach used for immediate correspondence among individuals. Nevertheless, excessive instant messaging and/or many members participating in the same conversation can be annoying to users. In addition, it takes extra effort to save these conversations.
- **Newsgroup:** represents a repository of messages posted by many users from different locations. It can be considered as a virtual space where physicians exchange

Figure 8. Advantages of mobile virtual healthcare communities



Convenience	Access	Information sharing	Satisfaction	Efficiency
- advantages in time and space. People can interact at any time from anywhere; - mobile healthcare community is convenient for information that patients have to remember or to write down.	- mobile healthcare community facilitates the access to care for patients with physical disabilities or patients that live in a remote area.	- the opportunities for patients to use friendly medium to ask clarification after a face-to-face consultation; - the opportunities for patients to discuss the content of messages with friends or family to improve the care understanding	- traditional barriers of social differences, age, and non-familiarity dissolve in the informality of electronic communication; - free style of writing; - anonymity for patients; - speed of communication; - opportunities for groups that are difficult to reach by face-to-face contact.	- opportunities to improve the diffusion information on healthy behaviour to several people simultaneously; - cost savings.

ideas, discuss, communicate and even make friends.

- **Web conferencing:** refers to synchronous (live) meetings, Web seminars and applications sharing over the Web. In a Web conference participants can see whatever is on the presenter's screen, and simultaneously share applications (ex: spread sheet) and discuss matters of common concern.
- **Blogs:** is a cooperation environment that contains reverse chronologically order posts that are contained in a common Web page.
- **Wikis:** provide an effective virtual forum that allows physicians to add content and also to edit content supporting collaborative writing, opening discussions, interaction and Web-authoring. They also provide an asynchronous platform for virtual community, and with their capacity to archive different page versions can act as repositories, thereby enabling effective knowledge management. It is sure that the use of mobile virtual healthcare communities presents very clear advantages in different area (Figure 8).

THE PATIENT-PHYSICIAN RELATIONSHIP

Mobile virtual communities are rapidly changing the physician-patient relationship. They allow patients and physicians to share opinions and medical information every time and everywhere. Moreover, they offer to physicians an opportunity to improve the awarness of patient's health conditions and enhance their satisfaction. They also give the opportunity to increase the involvement of patients in their treatments and they improve access to health care information and communication possibilities between patients and physicians. Through the use of mobile virtual communities physician have the possibility to communicate with patients continuously allowing better data collection. (Leimeister & Krcmar 2003). For patients with chronic illnesses, especially those in rural or outlying areas, consultation with an appropriate specialist can vastly improve the quality and outcome of their healthcare. Mobile virtual communities can be used by doctors to send instant messages to patients reminding them when they need to take their medication. This serves to eliminate certain administrative costs that are associated with hospitalisations that result from not taking the prescribed medication at the correct time. People and doctors could also have a mutual knowledge that is much more sound *and mobile technologies*.

There are many potential benefits for patients and physicians who communicate in mobile virtual communities:

- patients may feel more comfortable in addressing sensitive, complex or personal issues;
- mobile virtual communities can solve problems related to large distances or patients' disability;
- patients can influence physician prescribing decisions by presenting product information they find online.

Mobile virtual communities have the potential to educate health consumer, by giving information on health and health services, supporting patient choice, guaranteeing convenience, anonymity, and quantity of information (Kane & Sands, 1998).

For incorporating virtual consultations into routine medical practice it is necessary to proceed on the basis of secure evidence.

It is important to understand the following aspects related to the communication between physicians and patients: how the communication by mobile virtual communities can be integrated with other modes to communicate the patient and physician preferences in the use of mobile virtual communities and identify people that most likely can benefit from virtual communication.

However mobile virtual community does not have the capability to reproduce the traditional relationship because of the impossibility of the physical presence. In fact medical practice includes complex processes as diagnosis, treatment, prognosis and these processes require the presence of the patient for several activities. Therefore, in conclusion we can observe that mobile virtual communities can modify and integrate the traditional physician-patient relationship but, at the moment, cannot replace this relationship.

CONCLUSION

Mobile technologies represent a familiar part of the lives of many people today. They give virtual words a new character, with the simultaneosly information exchange. On the virtual space, mobile virtual communities are accessible by mobile devices. Mobile virtual communities have the great potential to serve ubiquitous information and communication needs. This applies especially to the healthcare sector where the need for information and communication is deeply felt and of a long-term nature.

In this chapter we analysed the social impacts that mobile virtual healthcare communities have on relationships between: 1. patient and physician; 2. patients; and 3. physicians has been shown.

With respect to the first relationship the evolution of patient-physician communication shows that mobile virtual communities have a relevant impact on the way in which patients and physician interact. Mobile virtual communities allow patients and physicians to share opinions and medical information every time and everywhere and offer to physicians an opportunity to improve the awarness of patient's health conditions and enhance their satisfaction. They also give the opportunity to increase the involvement of patients in their treatments and they improve access to health care information and communication possibilities between patients and physicians. Through the use of mobile virtual healthcare communities physician have the possibility to communicate with patients continuously allowing better data collection. For patients with complicated cases or chronic illnesses, especially those in rural or outlying areas, consultation with an appropriate specialist can vastly improve the quality and outcome of their healthcare. Moreover mobile virtual communities can be used by doctors to send instant messages to patients reminding them when they need to take their medication. This serves to eliminate certain administrative costs that are associated with hospitalisations that result from not taking the prescribed medication at the correct time.

Concerning the patient-patient relationship, the use of mobile virtual communities enables patients with long-term chronic diseases to interact with people that have the same experience (Ferguson, 1998). This interaction can allow a decrease of the problem. Online anonymity can be helpful for those who feel embarrassment discussing their health conditions. Mobile virtual communities mainly provide information and mutual support for users. They provide information concerning treatments, health insurance or particular medical problems. Information shared between users includes reports on how the disease was contracted and how it affects daily life.

Regarding the relationships between physicians, mobile virtual communities allow them to participate in continuous medical education at a time and location convenient for them, along with useful communication. The use of mobile virtual communities improves possibilities to maintain communication and collaboration with colleagues investigating the same subjects. In a virtual space physicians aggregate observations from their daily practice and then challenge or collaborate each others' opinions, accelerating the emergence of trends and new insights on medications, treatments and devices. They can apply the collective knowledge to achieve better outcomes for your patients.

In sum on discussing the social impacts of mobile virtual communities on the traditional physician-patient relationship, patient-patient relationship and physician-physician relationship, we emphasize that they are transforming these relationships. One of the most important advantages of mobile virtual communities is that they promote the opportunity for users to interact with more people than in the past. Is it clear that these communities don't have the capability to reproduce the traditional relationship because of the impossibility of the physical presence. This is mainly valid for medical practice that includes complex processes such as diagnosis, treatment and prognosis. These processes require the presence of the patient for several activities. However the information exchange can be used for detecting patients and physicians that have common objectives and share common interests in order to establish communication and interaction among them.

REFERENCES

Bouras, C., Igglesis, V., Kapoulas, V., & Tsiatsos, T. (2005). A Web-based virtual community. *Int. J. Web Based Communities*, *1*(2), 127–139. doi:10.1504/IJWBC.2005.006058

Chih, H.L. (2007). Understanding the Design of Mobile Social Networking: The Example of EzMoBo in Taiwan. *Journal of media and culture, 10*(1).

Demiris, G. (2006, August). The diffusion of virtual communities in healthcare: Concepts and challenges. *Patient Education and Counseling*, *62*(2), 178–188. doi:10.1016/j.pec.2005.10.003

Ebner, W., Leimeister, J. M., & Krcmar, H. (2004). Trust in Virtual Healthcare Communities: Design and Implementation of Trust-Enabling Functionalities. *Journal Title: Hawaii International Conference on System Sciences 2004.*

Etzioni, A., & Etzioni, O. (1999). Face-to-face and computer-mediated communities, a comparative analysis. *The Information Society*, *15*(4), 241–248. doi:10.1080/019722499128402

Ferguson, D., Sairamesh, J., & Feldman, S. (2004). Open Frameworks for Information Cities. *Communications of the ACM*, *47*(2), 45–49. doi:10.1145/966389.966414

Ferguson, T. (1998). Digital doctoring-Opportunities and challenges in electronic patient-physician communication. *Journal of the American Medical Association*, 280.

Kane, B., & Sands, D. (1998). Guidelines for the clinical use of electronic mail with patients. Internet Working Group, Task Force on Guidelines for the use of Clinic-Patient Electronic Mail. *Journal of the American Medical Informatics Association.*

Leimeister, J. M., Arnold, Y., & Krcmar, H. (2006). Developing community-platforms for cancer patients-the COSMOS-project. *European journal of cancer care.*

Leimeister, J. M., & Krcmar, H. (2003). Engineering Virtual Communities in Healthcare: The Case of www.krebsgemeinschaft.de. *Electronic Journal of Organizational Virtualness, 5, 47-59. ISSN: 1422-9331.*

Leimeister, J. M., & Krcmar, H. (2005). Patient-oriented Design of Online Support Communities Jan Marco, Helmut. *Proceedings of the 11th International Conference on Human-Computer Interaction (HCI International 2005).*

Leimeister, J. M., & Krcmar, H. (2006). Designing and Implementing Virtual Patient Support Communities: A German Case Study. *The Internet and health care: Theory, research and practice,* M. Murero, & R.E. Rice, (eds.). Verlag: Lawrence Erlbaum Associates; Erscheinungsort. Mahwah: Erscheinungsjahr.

Loader, B., Muncer, S., Burrows, R., Pleace, N., & Nettleton, S. (2002). Medicine on the line? Computer-mediated social support and advice for people with diabetes. *International Journal of Social Welfare*, *11*, 53–65. doi:10.1111/1468-2397.00196

Malkary, G. (2005). Healthcare without Bounds: Mobile Computing for Physicians. *Journal Mobile Computing for Physicians.*

Reinhard, F., & Wolkinger, T. (2003). Customer integration with virtual communities: Case study: The online community of the largest regional newspaper in Austria. *Hawaii International Conference on System Sciences, January 6-9, 2003, Big Island, Hawaii.*

Rheingold, H. (2006). *Mobile Virtual Communities*. Retrieved from http://www.thefeaturearchives.com/topic/Culture/Mobile_Virtual_Communities.html

Ridings, C. M., Gefen, D., & Arinze, B. (2002). Some antecedents and effects of trust in virtual communities . *The Journal of Strategic Information Systems*, *11*, 271–295. doi:10.1016/S0963-8687(02)00021-5

Romm, C., Pliskin, N., & Clarke, R. (1997). Virtual communities and society: toward an integrative three phase model. *International Journal of Information Management*, *17*(4), 261–270. doi:10.1016/S0268-4012(97)00004-2

Siew, T. P. (2001). Mobile Community Computing Applications (MOCCA). *SIMTech Technical Report (MIT/01/017/OSCA).*

Turner, J. W., Grube, J. A., & Meyers, J. (2001). Developing an Optimal Match within Online Communities: An Exploration of CMC Support Communities and Traditional Support. *The Journal of Communication*, *51*, 231–251. doi:10.1111/j.1460-2466.2001.tb02879.x

KEY TERMS

Collaboration: A structured, recursive process where two or more people work together toward a common goal.

Electronic Communication: The assisted transmission of signals over a distance for the purpose of communication.

Healthcare: The prevention, treatment, and management of illness and the preservation of mental and physical well being through the services offered by the medical and allied health professions.

Mobile Services: A radiocommunication service between mobile and land stations, or between mobile stations.

Mobile Technologies: A combination of hardware, operating system, networking, and software.

Social Network: A social structuremade of nodes that are tied by one or more specific types of interdependency, such as visions, idea, friends etc.

Virtual Communities: A group of people that primarily interact via communication media such Usenet rather than face to face.

This work was previously published in Handbook of Research in Mobile Business: Technical, Methodological and Social Perspecives, Second Edition, edited by B. Unhelkar, pp. 316-327, copyright 2009 by Information Science Reference (an imprint of IGI Global).

Chapter 5.8

Understanding Computerised Information Systems Usage in Community Health

Farideh Yaghmaei
Shadeed Behesthi University of Medical Science and Health Services, Iran

ABSTRACT

This chapter introduces factors that affect computer usage. Discussions of computer systems effectiveness or system success frequently focus on questions of which factors provide better system usage. As there are many factors that affect computer system usage, measuring the influence of the factors is necessary. The objective of the current study was to gain a further understanding of some factors that affect the use of computerised information systems. Most studies have been in business and few studies have been conducted in the health sector and specifically in community health. The study measured the role of external variables on computer attitude, subjective norms, and intention to use computers based on the theory of reasoned action (TRA) (1). These external factors included: demographic characteristics, users' characteristics (computer experience), organisational support, and involvement.

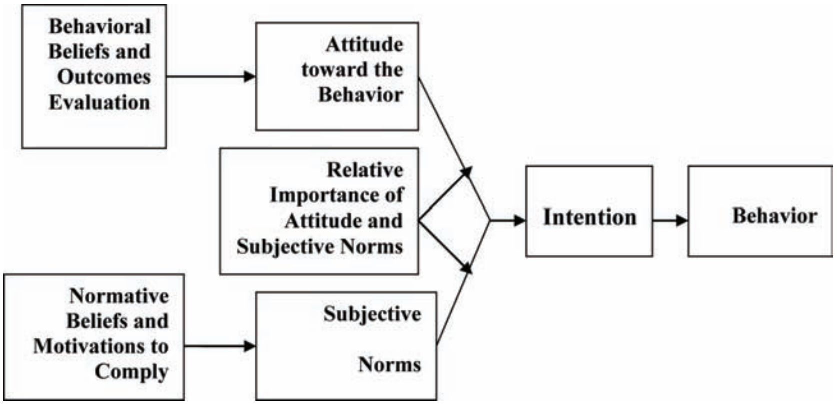
DOI: 10.4018/978-1-60566-356-2.ch030

THEORY OF REASONED ACTION (TRA)

The Theory of Reasoned Action (TRA) was developed by Fishbein and Ajzen (1975) (Figure 1). The foundation of this theory rests on the distinctions between beliefs, attitudes, intentions and behaviour. The theory shows the relationship between beliefs and behaviour through attitudes, subjective norms and behavioural intentions.

- **Beliefs:** Beliefs are formed by direct observation, outside information, or the way a person learns about an object. For example, new information from any source (such as; environment) may influence a person's beliefs.
- **Attitude:** An individual's attitude towards any object is a response to beliefs about the object so beliefs are important in determining attitude. It can be stated that attitudes are based on a person's beliefs. Attitudes may influence the formation of new beliefs about objects.

Figure 1. Theory of Reasoned Action (TRA). Source: Ajzen & Fishbein (1980)



- **Subjective norms:**Fishbein and Ajzen (1975) proposed that the formation of intention depends on the previous formation of attitude and normative beliefs.
- **Intention:** The effects of attitude (A) and subjective norms (SN) on behaviour are mediated by the behavioural intention (BI). According to the TRA, intention is the immediate determinant of behaviour and can lead to actual behaviour.

EXTERNAL VARIABLES

The external variables can influence in three ways; 1) influence on attitudes and significant amount of weight on intention, 2) influence on the subjective norms and significant amount of weight on intention and 3) influence on the relative weights of the two components (attitudes and subjective norms).

Methods

For the purpose of the present study the following hypotheses were defined (see Figure 2).

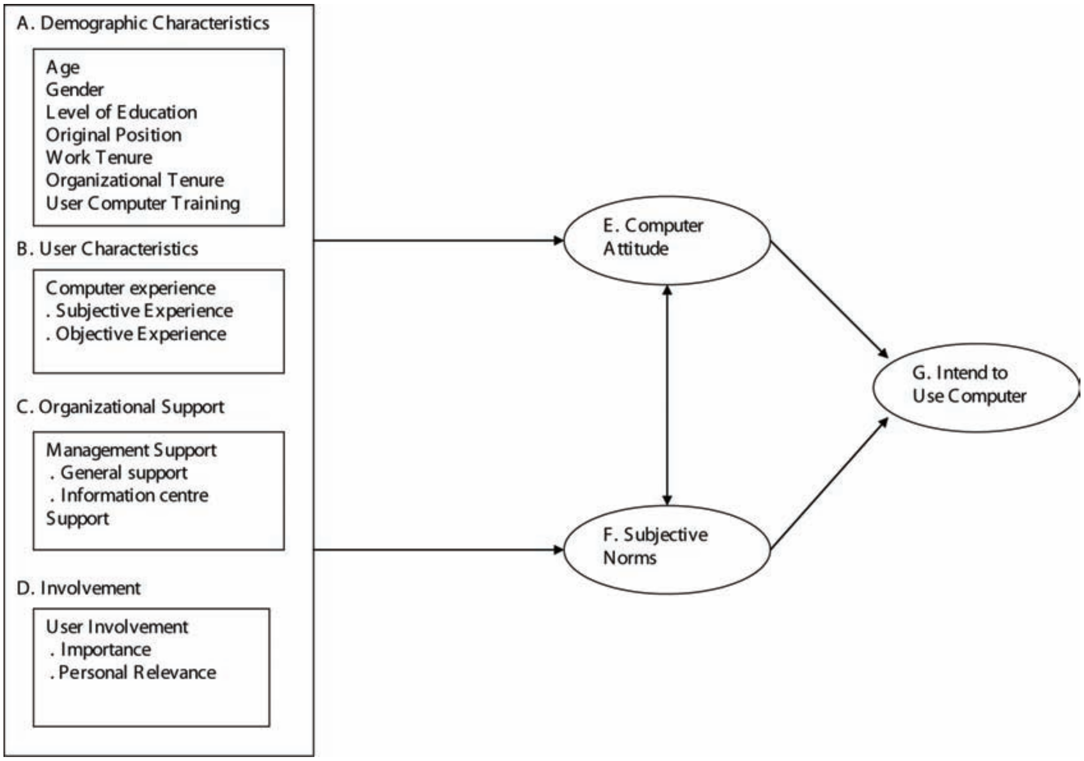
After a thorough search of the literature the researcher found valid and reliable scales for measuring the above variables. A questionnaire that consisting of 62 questions that covered users' characteristics (positive and negative subjective computer experience) (Yaghnaie 2007), management support, (general support and information centre support) (Igbaria and Chakrabarti 1990), users' involvement (importance and personal relevance) (Barki and Hartwick 1994), computer attitude (Jayasuria and Caputi 1996), subjective norms (Hebert 1994) and intention to use computers (Hebert 1994) was used.

Then study was conducted in the Community Health Services of one Area Health Service in New South Wales, Australia. The questionnaires were mailed to 430 staff (nurses and health workers) in 51 Community Health Centres in the Illawarra Area Health Service. A response rate of 70% (302) was achieved. The data was analysed using a statistical computer program (SPSS). Structural equation modelling was used to test the measurement model and the structural model. Overall, high support was found for the structural model in this study.

Results

The measurement statistics were substantially improved from the first model. The results of the revised model showed a good fit of the data, as evidence by Goodness-of-Fit (GFI = 0.9927), and the root mean square residual (RMSR = 0.0144), GFI adjusted for degree of freedom

Figure 2. The research model



(AGFI = 0.9600), and the likelihood-ratio chi-square statistic, X^2 (12, N = 302) = 12.2395, P = 0.4266. The final model accounts for the 57% of the variance in computer attitude, 26% of the variance in subjective norms, and 51% variance in intend to use computers.

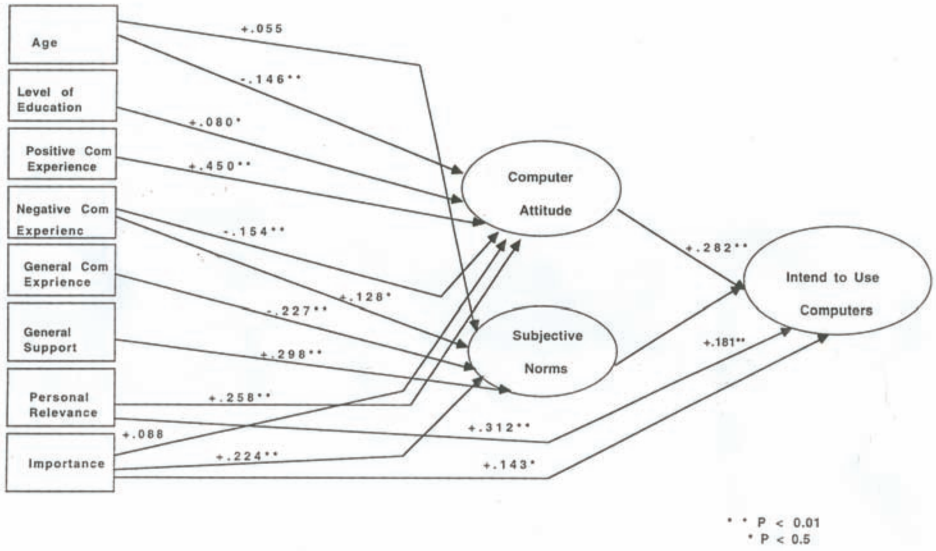
The results of the multivariate test of the structural model showed a significant direct and positive effect of level of education (ß = 0.0801, P < 0.05), positive computer experience (ß = 0.4497, P < 0.01), and personal relevance (ß = 0.2580, P < 0.01) on computer attitude. As expected, age (ß = -0.1458, P < 0.01) and negative computer experience (ß = -0.1543, P < 0.01) had significant negative and direct effect on computer attitude.

Moreover, the results showed that negative computer experience (ß = 0.1279, P < 0.05), general support (ß = 0.2980, P < 0.01) and importance (ß = 0.2241, P < 0.01) had significant positive and direct effect on subjective norms to use computers. On the other hand, general computer experience had significant negative and direct effect on subjective norms to use computers (ß = -0.2275, P < 0.01). In addition, age had a non-significant positive and direct effect on subjective norms to use computers (ß = 0.0547). The results also indicated a significant positive and direct effect of computer attitude (ß = 0.2822, P < 0.01) and subjective norms (ß = 0.1812, P < 0.01) on intention to use computers (Figure 3).

NEW FINDINGS

This study showed additional factors that predicted the intention to use computers. The results of the modified model showed that dimensions of user involvement (personal relevance and importance) affected the intention to use directly and indirectly through computer attitude and subjective norms.

Figure 3. Final model for predicting intention to use computers



While other external variables had an indirect effect on intention to use through attitude and subjective norms, personal relevance (ß = 0.3115, P < 0.01), and importance (ß = 0.1426, P < 0.01), had a significant positive and direct effect on intention to use computers. The direct effect of personal relevance was found to be stronger than importance on behavioural intention to use computers.

In total, the model explained 57 percent of the variance in computer attitude, 26 percent of the variance in subjective norms to use computers, and 51 percent of the variance in intention to use computers. Since the objective of this study was the understanding of behavioural intention, the model was acceptable in terms of explanatory power.

DISCUSSION OF RESULTS OF STRUCTURAL MODEL

The research model was found to fit the data from a sample of 300 observations. The present study investigated the specification search based on the initial model. This result provided a parsimonious model with its relationships. In general, the results showed that of the 30 direct paths tested in the structural model for the hypothesised model, 13 were found to be statistically significant in the revised model (Figure 3). The strongest effects on computer attitude were positive computer experience and weakest (but significant) was the level of education on computer attitude. Among the demographic variables, age was negatively related to computer attitude. The results also showed that the strongest significant effect on subjective norms was general support and weakest and significant was negative computer experience.

Moreover, the effect of computer attitude on intent to use was stronger than subjective norms toward intention on it.

The results of the structural model and its pattern in relation to the hypotheses of the study are as follows. Paths marked (S) are supported; paths marked (NS) are not supported; paths marked with (S√) are supported, but in the opposite direction; paths marked (SX) are supported, but were not in the hypotheses:

- **H1a:** Age will have a positive direct effect on computer attitude (S√).
- **H1b:** Gender will have a positive direct effect on computer attitude (NS).
- **H2a:** Age will have a positive direct effect on subjective norms (NS).
- **H2b:** Gender will have a positive direct effect on subjective norms (NS).
- **H3:** Demographic characteristics (organisational position, organisational tenure and work tenure) of user will have a positive direct effect on computer attitude (NS).
- **H4:** Demographic characteristics (organisational position, organisational tenure and work tenure) of user will have a positive direct effect on subjective norms (NS).
- **H5:** Level of education will have a positive direct effect on computer attitude (S).
- **H6:** Level of education will have a positive direct effect on subjective norms (NS).
- **H7a:** Positive computer experience will have a positive direct effect on computer attitude (S).
- **H7b:** Negative computer experience will have a negative direct effect on computer attitude (S).
- **H7c:** General computer experience will have a positive direct effect on computer attitude (NS).
- **H8a:** Positive computer experience will have a positive direct effect on subjective norms (NS).
- **H8b:** Negative computer experience will have a positive direct effect on subjective norms (S).
- **H8c:** General computer experience will have a positive direct effect on subjective norms (S√).
- **H9a:** General support will have a positive direct effect on computer attitude (NS)
- **H9b:** Information centre support will have a positive direct effect on computer attitude (NS).
- **H10a:** General support will have a positive direct effect on subjective norms (S).
- **H10b:** Information centre support will have a positive direct effect on subjective norms (NS).
- **H11a:** Personal relevance will have a positive direct effect on computer attitude (S).
- **H11b:** Importance will have a positive direct effect on computer attitude (NS).
- **H12a:** Personal relevance will have a positive direct effect on subjective norms (NS).
- **H12b:** Importance will have a positive direct effect on subjective norms (S).
- **H12c:** Personal relevance will have a positive direct effect on intention to use computers (SX).
- **H12d:** Importance will have a positive direct effect on intention to use computers (SX).
- **H13:** Computer attitude will have a positive direct effect on intention to use computers (S)
- **H13:** Subjective norms will have a positive direct effect on intention to use computers (S)

The most important result of this study was the finding of the strong direct and significant effect of positive computer experience on computer attitude. It seems that in the formation of computer attitude, positive computer experience has an important role. This study showed the effect of positive computer experience on computer attitude. On the other hand, as expected, negative computer experience had a negative effect on computer attitude. Thus, computer attitude can be changed by positive or negative experiences of the users with computer systems. An interesting result was that negative computer experience had positive direct effect on subjective norms to use computers. These results confirm the important role of both organisational policies and a climate to use computers, especially for users with negative experience.

A new finding of this study was that involvement not only affected intention to use indirectly but also directly. Thus, the importance of the role of involvement was confirmed in this study. It seems that user involvement is an important factor in system usage and there is a need to expand the theory in order to better understand factors that potentially influence system usage.

Future research is needed to refine the latter model (Figure 3) and improve it by removing non-significant relationships. Moreover, a study is needed into the use of some parameters that were deleted in this study, due to the insufficient sample (such as; computer training and task characteristics). In sum, it is important that research continues in this area.

DISCUSSION OF THE STUDY

There are various views toward acceptance and use of computer technology in different fields. For example, health information systems offer automated systems to assist personnel to administer patient care by increasing access to large volumes of information, improving delivery of care and decision making.

One of the interesting results of the present study was the negative effect of age on computer attitude. The result was similar that of Igbaria (1993) when he reported that older managers expressed more unfavourable attitudes towards computers than younger. Other studies also showed that younger personnel in hospitals had more positive computer attitudes than older personnel (Grann, 1984; Zoltan-Ford, 1984). The results reinforce the notion that age is a factor that can influence computer attitude. In addition, the examination of age on subjective norms indicated that there was a positive effect of age on subjective norms to use computers. It means that older users pay more attention to the policies of organisations and their peers' perspectives for using computers than younger users.

The result also showed direct positive and significant effect of the level of education on computer attitude. It seems that level of education is a factor that can affect computer attitude. This result is consistent with the study by Rapko and Adaskin (1993) who reported that nurses with high levels of educational qualification had positive attitudes toward computer systems because the level of education influenced their understanding of the systems. Moreover, Lucas (1978) argues that users' with a high level of education accept computer systems, but users with a low level of education may resist them. Therefore, the level of education influences the understanding of computer systems (Brodt and Stronge, 1986).

An important hypothesis of this study was to test whether positive computer experience affects computer attitude. The results showed a strong positive and significant effect of positive **c**omputer experience on computer attitude. This indicates that the provision of opportunities to gain positive experience, especially for new or inexperienced users would be useful for effective system usage. Furthermore, positive computer experience may help users in increasing favourable perceptions about the impact of computers on their life (Yelland, 1995). The importance of prior computer experience in promoting computer attitude and usage was highlighted by the finding of other studies. For example, Igbaria (1990) reported strong correlations between computer experience and computer attitude. The results confirm that increasing computer experience is vital for providing favourable attitude and ultimately system usage (Igbaria, 1990; Kleintop et al., 1996).

The results also indicated a direct negative and significant effect of negative computer experience on computer attitude. This finding emphasises the importance of negative computer experience as a real problem and its effects on computer attitude. Negative computer experience may cause negative perception about using computers and it can cause difficulties is being able to use computer systems. Thus, attempting to provide positive experience will help users to accept and use computer systems.

In contrast, negative computer experience had a direct, positive and significant effect on subjective norms. In those situations in which users have negative experience with computers, the role of organisational policies about information systems and their usage could assist users to accept computers in their workplaces. However, computer system usage with users who have negative computer experience is not guaranteed because usage may be ineffective or insufficient. Therefore, the needs of participants with negative computer experience should be takes into account, especially when system usage is compulsory. In this regard, managers should assess users with negative feelings about computer and help them to change their negative feelings to positive. From the results it can be concluded that the role of information system (IS) managers is crucial in providing positive computer experience or changing negative experience. Moreover, managers should be aware that psychological and subjective feelings can influence physical and mental ability. Very little experimental research has been conducted in this area and future studies are needed.

The results also showed that general support had direct, positive and significant effect on subjective norms. The participants with support from the management system paid more attention to others' expectations (managers or friends to use computer system) than those without support. The organisation with a supportive management will have a co-operative climate (Songer-Nocks, 1976). This study confirms the importance of the need for users support regarding acceptance and performance of computers.

The understanding involvement factor and its role in systems usage require examination as a factor on users' perceptions. This study examined the influence of users' involvement (importance and personal relevance) on computer attitude and subjective norms. The results showed that personal relevance and importance had directly positive effect on computer attitude, however, the effect of the importance on computer attitude was not significant. The results also indicated that importance had direct positive and significant effect on subjective norms to use computers. The participants also believed that the importance of the system can influence their attention to organisational policies and others' expectations to use systems. If the users' involvement is considered they would be satisfied with the information systems policies, consequently, the organisation would have a high quality of performance.

The results of the present study showed additional factors that influenced intention to use. Importance and personal relevance (dimensions of involvement), directly and indirectly, (through attitude and subjective norms), affected intention to use computers. In the Theory Acceptance Model (TAM), the role of perceived usefulness is similar to important and personal relevance in this study. However, these two constructs, usefulness and involvement, are different. A system may be useful but not necessary importance or personally relevant (Barki and Hartwick, 1994). Thus, this study found a different connection between importance and personal relevance to intention to use. It seems that user involvement is an important factor in system usage. Therefore, user involvement as a psychological belief (Barki and Hartwick, 1994) can increase the system's value and consequently, system usage. The study suggests that involvement of health staff can be useful for developing and implementing a new computer system. During system development, users should have a sense of perceived involvement that leads to system acceptance and usage. As mentioned earlier, involvement is a perceptual issue so if users believe that they are actively involved in system development and their inputs are valuable and worthwhile, they will be more satisfied. From the results of this study, it is indicated that an appropriate level of a user's involvement will result in a better management information system (MIS).

It seems that users' involvement is an important responsibility for managers to provide positive and open communication between users and other key groups to support the important role of users in processes of development and usage. In addition, managers should be aware of the nature of users' involvement because from these results it can be concluded that users need to have a sense of active psychological involvement.

The finding showed that computer attitude had a strong direct positive and significant effect on intention to use computers. The participants, with favourable computer attitudes, were willing to manage difficulties related to systems and were capable of improving their performance. This study confirms the results of another study in health area (Hebert, 1994). Therefore, computer attitude may affect the actual success or failure of system implementation.

By focusing on subjective norms in this study, the effects of peers, superiors, subordinates, and organisational climate on systems usage was studied (Moore, 1987). The result also showed that the users' subjective norms influenced directly and positively the intention to use computers. Hebert (1994) reported that the users' subjective norms influenced their intention to use computers and use of technology was based on the policy of the organisation. In a different study, Nederhof (1989) reported similar results: that there was a strong relationship between the participants' subjective norms and their intentions. In addition, other studies, Bentler and Speckart (1981); Igbaria et al. (1996) had similar findings. Therefore, the role of the subjective norms in information system studies is crucial for making policies in organisations. Information system (IS) managers should convey to users the purpose and the policies of computerised technology because if users accept the IS policies the organisations will have a co-operative condition (Songer-Nocks, 1976). Communication of users with their peers and also understanding the information policies can enhance computer systems usage. Therefore, in some situations behaviour of persons may be influenced by subjective norms, rather than attitude. The important findings related to subjective norms in this study suggest that more research, focusing on system usage is necessary and would be useful.

The results showed the influence of positive computer experience on computer attitude, the effect of negative computer experience negatively on attitude. The results also showed that negative experience had positive and direct affect on subjective norms. The other new finding of this study was the direct effect of importance and personal relevance on intention to use computers. The results also supported other studies on the importance of organisational support regarding intention to use systems. Moreover, computer attitude and subjective norms were also found to mediate relationships between external variables and intention to use computers. In general, the study was able to explain the variables that affected the intention to use computers directly and indirectly (Figure 3).

STRENGTHS OF THE STUDY

Method and the Research Model

This study with its multi-method approach contributes to the body of knowledge on management information system (MIS) and established a foundation for further studies.

It serves a number of purposes. It provides a tested theoretical framework for increasing and understanding factors related to use of computerised systems. Integration of the different personal and work factors in this study could be helpful for different organisations in more effective implementation of MIS.

The present findings provide evidence of the utility of the Theory of Reasoned Action (TRA), its application for understanding and predicting computerised information system usage. To the researcher's knowledge, there are only a few published studies demonstrating the applicability of the TRA (Fishbein and Ajzen, 1975) for system usage in the health area, especially in community health centres.

The model presented in this study holds important implications for practising information system managers in organisations attempting to manage system usage. It will provide guidance concerning those factors that need to be managed well in terms of system usage. Understanding how the differences in personal and organisational characteristics impacts on system usage in the model and it provides a basis for further research in this area. The framework of analysis presented in the model, will be useful for practitioners as well as researchers. Therefore, the search for other relevant factors can be facilitated in future studies. The result of this study showed factors that are important in a global environment; however, the result cannot be extended to all fields.

Furthermore, subjective norms play an important role in development process of information systems. In the early stage of implementing a new system subjective norms are important for determining acceptance of a computerised system and in later process attitude are the crucial determinant. Therefore, it is critical important for users to understand that organisational policies are in place to ensure that the computerised systems are used effectively and efficiently. Many of the findings and arguments regarding social pressure or others' expectation that developed in this study are appropriate for organisations in general.

The other strong point of this study is the number of factors as external variables in the research model that can provide more and more precise results especially in health area. In general, the findings of the current study revealed the strength of the external validity of the TRA.

From a practical stand point, the research model, as a general model of computer usage and the scales that were introduced in this study could be useful for system development and system usage.

SUGGESTIONS FOR FUTURE STUDY

Computer Experience Scale

Additional research is needed on a number of fronts. The Subjective Computer Experience Scale (SCES) that was developed for measuring computer experience should undergo further testing. Multiple studies would lead to refinement and increased generalability of this scale. The researchers might add more items (perhaps including some omitted from the original instrument), measure the reliability of those items and discard the unreliable ones. In this process any organisation could be targeted for in-depth analysis of the scale.

Due to the importance of subjective computer experience, the SCES could be used in a longitudinal study to determine; 1) how and to what extent initial computer experience influences judgement of people about their positive or negative experience? 2) how, under what conditions, what kinds of computer experience could be provided? 3) how subjective computer experience changes over time? 4) what is the characteristic of users who have positive or negative computer experience? and 5) what is the similarity and differences in their characteristics? Longitudinal studies can determine result more explicitly. This information will give new knowledge about computer experience because by more attention to human factors, usage of computer systems would be enhanced (Staggers, 1991).

Based on the previous study of Songer-Nocks (1976), some factors such as; previous experience may affect behaviour directly. It would be interesting to determine in future studies, whether factors such as; high levels of positive computer experience, lessens the moderating influence of computer attitude that found in this study.

Moreover, research could move toward clarifying under what conditions subjective norms can be effective and useful in reducing users' negative experience. This will answer many questions regarding organisational policies that most managers face today with regard to user resistance to computer systems.

As result of the training-related findings, this study suggests that computer training can reduce negative computer experience. Type of training in this regard, is an important factor (Harrington et al., 1990). Therefore, additional research on negative computer experience is needed to find how training can reduce the duration (temporary and permanent) or intensity of negative computer experience.

User Involvement

These findings suggest that future studies in this area should be careful in assessing user involvement because the perception of involvement may influence the subsequent system success or failure after implementation. One approach to minimising the impact of bias may be to use longitudinal designs.

This study measured the effects of user involvement on participants' attitude and subjective norms. Based on the involvement-related results in this study, it is suggested that the effect of involvement on computer attitude and subjective norms may be due to some user characteristics. It would be interesting to examine whether the relationship of perceived users' involvement to system success is moderated by variables such as; demographic and personality characteristics. The findings will have important implications. Organisations that follow general recommendations to obtain high levels of users' involvement may not obtain the anticipated benefits due to individuals' differences among users.

In addition, the difference of nurses' and health workers' task characteristic highlights the question of: when and who should be involved? In the process of information systems whose judgement and under what condition should it be accepted? These are important issues and require further exploration.

Other Variables in the Research Model

Since computer systems use depends on the many factors related to task environment and system characteristics, it is important to expand the model in future research to explore other potential factors which influence system usage. These factors include: organisational size, organisational age, length of computerisation of organisation, work environment variables, quality of systems, availability and accessibility of system, user participation, career opportunities, salary, job autonomy and task uncertainty.

Furthermore, a number of specific variables and their roles were discussed in the current research study (see chapter 4), such as; user self-efficacy, confidence and satisfaction. Studies regarding to satisfaction, computer experience and computer usage have shown that there are positive relationship among these variables (Rivard and Huff, 1988; Igbaria, 1990; Igbaria and Nachman, 1990). Thus, these can be examined as external variables on computer attitude and subjective norms in future study.

Moreover, based on the studies of Hill et al., (1987); Compeau and Higgins (1995), self-efficacy can influence computing skills of users and system usage. Studies in the health sector emphasised the effect of computer experience on computer self-efficacy, outcome expectancy and consequently, job performance (Henry and Stone, 1995). Mills and McQueen (1997) studied effects of self-efficacy on computer use in the health sector. The findings suggested that self-efficacy and confidence affected computer usage. The authors point out that confidence of users could assist them to use computer systems effectively and successfully. These finding indicate that to assist users in developing performance with respect to computer systems, developing positive perception and confidence for their ability are useful. The relationship between self-efficacy, computer experience and system usage requires more investigation to give more information for management of computer systems.

Extend the Research Model

This study provides a model of computer usage which further research may modify. In order to explain usage and the value of the information systems more broadly, future research is needed to explore additional issues. For instance, a research model that integrates the TRA and the TAM will provide greater insights of both the theoretical model and better understandings of the factors that influence systems usage. The ultimate model will be able to broadly predict system usage and acceptance of technology in organisations. Continued research will greatly enhance our understanding of the determinants of system usage.

REFERENCES

Barki, H., & Hartwick, J. (1994). Measuring user participation, user involvement, and user attitude. *MIS Quarterly*, *18*(1), 59–77. doi:10.2307/249610

Bentler, P. M., & Speckart, G. (1981). Attitudes ‘cause’ behaviour: A structural equation analysis. *Journal of Personality and Social Psychology*, *40*(2), 226–238. doi:10.1037/0022-3514.40.2.226

Brodt, A., & Stronge, J. H. (1986). Nurses’ attitude toward computerisation in a Midwestern community hospital. *Computers in Nursing*, *4*(2), 82–86.

Compeau, D. R., & Higgins, C. A. (1995a). Application of social cognitive theory to training for computer skills. *Information Systems Research*, *6*(2), 118–143. doi:10.1287/isre.6.2.118

Fishbein, M., & Ajzen, I. (1975). *Beliefs, attitude, intention, and behaviour: An introduction to theory and research.* Philippines: Addison-Wesley Publishing Company.

Grann, R. P. (1984). Attitude and affective use of computers among hospital personnel. *IEEE* 543-545.

Harrington, K. V., Mc Elroy, J. C., & Morrow, P. C. (1990). Computer anxiety and computer-based training: A laboratory experiment. *Journal of Educational Computing Research*, *6*(3), 343–358.

Hebert, M. (1994). Adopting information technology in hospitals: The relationship between attitudes/expectations and behaviour. *Hospital & Health Services Administration*, *39*(3), 369–383.

Henry, J. W., & Stone, R. W. (1995). A structural equation model of job performance using a computer-based order entry system. *Behaviour & Information Technology*, *14*(3), 163–173. doi:10.1080/01449299508914643

Hill, T., Smith, N. D., & Mann, M. F. (1987). Role of efficacy expectations in predicting the decision to use advanced technologies: The case of computers. *The Journal of Applied Psychology*, *72*(2), 307–313. doi:10.1037/0021-9010.72.2.307

Igbaria, M. (1990). End-user computing effectiveness: A structural equation model. *Omega*, *18*(6), 637–652. doi:10.1016/0305-0483(90)90055-E

Igbaria, M. (1993). User acceptance of microcomputer technology: An empirical test. *Omega*, *21*(1), 73–90. doi:10.1016/0305-0483(93)90040-R

Igbaria, M., & Chakrabarti, A. (1990). Computer anxiety and attitudes towards microcomputer use. *Behaviour & Information Technology*, *9*(3), 229–241. doi:10.1080/01449299008924239

Igbaria, M., & Nachman, S. A. (1990). Correlates of user satisfaction with end user computing. *Information & Management*, *19*(2), 73–82. doi:10.1016/0378-7206(90)90017-C

Igbaria, M., Parasuraman, S., & Baroudi, J. (1996). A motivational model of microcomputer usage. *Journal of Management Information Systems*, *13*(1), 127–143.

Jayasuriya, R., & Caputi, P. (1996). Computer attitude and computer anxiety in nursing: Validation of an instrument using an Australian sample. *Computers in Nursing*, *14*(5), 1–6.

Kleintop, W. A., Blau, G., & Currall, S. C. (1996). Migration to a new electronic mail system: User's attitudes and management support for achieving use. *Information Resources Management Journal*, *9*(2), 25–34.

Lucas, H. C. Jr. (1978). Empirical evidence for a descriptive model of implementation. *MIS Quarterly*, *2*(1), 27–41. doi:10.2307/248939

Mills, A. M., & McQueen, R. J. (1997, April 1-5). Developing user sophistication in the organisation: An empirical investigation. In *Proceedings of The Pacific Asia Conference on Information Systems, PACIS'97*, Brisbane, Queensland, Australia (pp. 561-572).

Moore, G. C. (1987). End-user computing and office automation: A diffusion of innovations perspectives. *INFOR*, *25*(3), 214–235.

Nederhof, A. J. (1989). Self-involvement, intention certainty, and attitude-intention consistency. *The British Journal of Social Psychology*, *28*, 123–133.

Rapko, H., & Adaskin, E. (1993). Computerised hospitals: An attractive or deterrent to recruitment in nursing*? Canadian Journal of Nursing Administration*, *6*(2), 19–21.

Rivard, S., & Huff, S. (1988). Factors of success for end-user computing. *Communications of the ACM*, *31*(5), 552–561. doi:10.1145/42411.42418

Songer-Nocks, E. (1976). Situational factors affecting the weighting of predictor components in the Fishbein model. *Journal of Experimental Social Psychology*, *12*(1), 56–69. doi:10.1016/0022-1031(76)90086-X

Staggers, N. (1991). Human factors, the missing element in computer technology. *Computers in Nursing*, *9*(2), 47–49.

Yaghmaie, F. (2007). Development of a scale for measuring user computer experience. *Journal of Research in Nursing*, *12*(2), 185–190. doi:10.1177/1744987106068353

Yelland, N. (1995). Young children's attitudes to computers and computing. *Australian Journal of Early Childhood*, *20*(2), 20–25.

Zoltan-Ford, E. (1984). Professionals person's attitudes toward computer: Comparative analysis and some suggestion. *IEEE,* 536-539.

This work was previously published in Handbook of Research on Information Technology Management and Clinical Data Administration in Healthcare, edited by A. Dwivedi, pp. 482-494, copyright 2009 by Medical Information Science Reference (an imprint of IGI Global).

Chapter 5.9

Managing E-Procurement in Public Healthcare:

A Knowledge Management Perspective

Tommaso Federici
University of Tuscia, Italy

Andrea Resca
LUISS 'Guido Carli' University, Italy

ABSTRACT

In large parts of Europe, the development of healthcare is subject to contrasting forces: explosion in spending, while governments are faced with budget constraints, and pressures to be innovative, technologically advanced in order to improve the services' quality. Even though e-procurement initatives can be seen as a solution to the first issue in this dilemma, such initiatives have not been widely deployed and have not delivered the expected benefits so far. In this perspective, as case study of an e-procurement implementation of an Italian local healthcare agency has been examined because of the comprehensive design of the e-procurement system, the differentiation of tools adopted and the multiple solutions already implemented or in progress. The aim of this work is to reconstruct, by following a knowledge management approach, the steps that led to the introduction of e-procurement as a new operating practice, by redesigning supply purchasing, supply chain and logistic processes.

INTRODUCTION

In large parts of Europe, the development of healthcare is subject to contrasting forces. On the one hand, there has been an explosion in spending and, at the same time, governments are faced with strict budget constraints. On the other hand, public healthcare is under pressure to be innovative, technologically advanced and to provide increasingly better quality of services. In this context, e-procurement can be seen as an instrument for providing solutions to the first issue of this dilemma. Two recent European directives 2004/18/EC and 2004/17/EC, according to the i2010 eGovernment Action Plan, promote e-procurement to achieve significant efficiency improvements – also in public healthcare – by reducing at the same time purchasing and administrative costs.

However, e-procurement initiatives in such area have not been widely deployed, and most of them have not fully delivered the anticipated benefits, so far. The main reason for the lack of tangible results is the traditional resistance of public institutions to IT-based process innovation and the complexity of healthcare procurement – in terms of the variety of goods, specificity, and of suppliers' numbers – that requires different supply processes and diverse competences.

In order to investigate this scenario in more detail, the case study of a large e-procurement implementation at an Italian public Local Healthcare Agency (LHA – Azienda Sanitaria Locale, ASL), considered one of the most advanced by the Central Procurement Agency (CONSIP), was explored. This case study is remarkable because of the comprehensive design of the e-procurement system, the differentiation in adopted tools, the robust testing (since 2000) and the multiple solutions already implemented and in process within the Agency. The decision to examine this case study is also due to the fact that the use of e-procurement tools is seen as only one aspect of a more profound reorganization of the entire supply process.

The purpose of this work is to reconstruct - by performing interviews with some of the most representative players and examining documents and previous studies on this case - the managerial interventions that made this innovation possible and in particular how knowledge has been managed in this innovative programme. From this perspective, it was presumed that the introduction of e-procurement and the reorganization of purchasing, supply chain and logistical processes, had required diverse knowledge which has been investigated at the cognitive level, the organizational level and the social and institutional level of knowledge, proposed by Lam (2000).

Distinguishing between individual knowledge and knowledge related to a specific social context, this approach gives a comprehensive picture of the concept of knowledge. Furthermore, this perspective is helpful to examine the realities of Public Administrations (PAs) like LHAs, which are characterized by the importance of rules and procedures and by hierarchical organizational structures. Lam's extensive references to Mintzberg's classic studies (1979) is important in this point, as the organizational forms singled out by Mintzberg fit very well in the PA area, reinforcing the accurateness of this analysis.

RESEARCH STRATEGY

The research question of this work concerns the dissemination of innovation and primarily its adoption. The focus is on the ability of a specific organization to adopt an innovation and on the elements that facilitate or hamper such adoption. In other words, the issue is the impact, at an organizational level, that the introduction of innovation produces, and its possibility to be absorbed and managed.

At the basis of this investigation there is the concept of knowledge, as the element that characterizes an organization, both before the innovation introduction and after it. Therefore, a specific aspect to take into consideration is the meeting of established knowledge and the new one enabled by innovation.

The research strategy adopted to study the dynamics between established and new knowledge is based on a case study, which concerns innovation related to the introduction of a widespread e-procurement at Viterbo's Local public Healthcare Agency. Because of its tendency towards innovation, as seen by the implementation of several e-procurement projects in recent years, the LHA of Viterbo can be considered to be an explanatory case study (Yin, 2003). The analysis of such a case study provides answers which throw light on how and why innovation dissemination has taken place, on the basis of the organizational interventions that have been introduced.

The objective of this case study is also to throw light on the effects of these interventions in order to outline the dynamics at play by the introduction of e-procurement. These dynamics will be analysed looking at a knowledge management approach and in particular Lam's model (2000). As it will be later detailed, this approach seems to be apt to investigate knowledge and its management alongside the innovation process. Actually, Lam's perspective succeeds, to a certain degree, to highlight diverse types of knowledge which arise through the introduction of innovation. Therefore, using Yin's words (2003), it is possible to draw a pattern out of the connection between this perspective and the dynamics present in the case study.

In addition, as it is detailed below, the theoretical framework based on Lam's model leads to causes of difficulty in interpreting the dissemination of adopting e-procurement and the suggestions in overcoming them. However, these results should not be generalized.

Regarding data collection, Federici's research (2005, 2006) informs the basis of this research project. It has examined, step by step, both the several projects that have led e-procurement to the present state of the art and the organizational changes introduced at Viterbo's LHA. However, this is not only a bibliographic research, further internal documents were analyzed and semi-structured interviews conducted with some of the key representative managers in charge of procurement, both operating in the traditional and more innovative areas.

THEORETICAL FRAMEWORK

The issue of e-procurement in the public sector has been, so far, a rarely discussed topic. Studies are mostly concerned with the analysis of policies and behaviour of Public Administrations (PAs) and Procurement Authorities at a national and centralized level (Hardy & Williams 2005, Somasundaram & Damsgaard 2005, Somasundaram 2004, Devadoss *et al.* 2002). Even less frequent is research on the healthcare sector, particularly at a local operating level, where e-procurement solutions must be implemented, which impacts on the structures and the knowledge already existing within the organizations, which require different approaches of intervention.

Procurement Within the Healthcare Sector

Firstly, it is necessary to take into consideration that healthcare structures deliver critical and specialized services (vs. the rest of the PA): more than in other sectors, it is paramount to safeguard high quality standards for the purchasing of goods and services (and their impact on service quality), together with the economy and timeliness of purchases, the transparency of activities in an environment in which companies are subject to market competition and its governing principles. Healthcare spending for goods and services can be classified into three sections:

- *common* for the whole PA, independent from the type of buying Administration (e.g.: phone services, office materials);
- *common-but-differentiated*, existing for all Administrations but highly differentiated through the buying sector (e.g. in the healthcare sector: maintenance and cleaning of hospital buildings);
- *healthcare-specific*, composed of drugs and medical devices (appliances and materials that, separately or jointly, are used in instances of injury, disease or surgical operation).

This diversity must be taken into account when devising innovative ways to manage procurement before choosing the most appropriate solutions, in order to improve quality and efficiency of supplies, whilst at the same time rationalizing and reducing spending. The large difference among the three spending categories indicated above and the availability of diverse electronic tools ask for a deep reflection on which solutions suit each type of good / service. This requires a segmented approach (Federici 2006).

Secondly, the term "procurement" is often used in a narrow sense, being associated with the sole purchasing phase, as can be seen in Panayioutou *et al.* (2004) or in Kim & Shunk (2004). Consequently, the term "e-procurement" becomes a synonym for a class of electronic tool that directly link buyers and suppliers on the same network to make a deal. According to other studies (Somasundaram 2004, MacManus 2002), and with the typical operation of a healthcare agency, in this work "procurement" indicates a broader process, which begins with the need for a good or service and ends with its use and the payment for its supply. It involves: purchase programming, the sourcing choice, the purchasing act, incoming material handling, warehouse logistics, inventory control and invoice processing.

An e-procurement system deals with the whole procurement process, and not just with its purchasing phase. The term "e-procurement" here consistently indicates that organizational solutions supported by ICT-based tools, which allow electronic forms of procurement and are potentially more effective and efficient than traditional ones. Such solutions involve a more or less wide-reaching and thorough redesign process to take into account the entire life-time of a product or service.

E-procurement solutions include process redesign and the use of appropriate tools in two main areas, which have to be used in a complementary way to streamline the whole procurement process:

- *e-purchasing*, includes very different tools which allows the purchasing phase to be entirely managed, from finding a product to invoicing and payment, through on-line tenders (*e-tendering*) and the use of *marketplaces* and *electronic catalogues* (*e-requisitioning*), electronic invoice exchange and processing (*e-invoice*) and liquidation activity (*e-payment*);
- *e-logistics*: which aims to optimize the management of inventories (in healthcare structures: pharmacy and the supply office) and internal goods flows, based on Intranet/Extranet technologies, integrating Supply Chain Management (SCM) solutions, linking both internal and external players.

Knowledge Management: Lam's Perspective

The knowledge management approach and, especially, Lam's (2000) interpretation of it, considers three levels (the cognitive level, the organizational level and the societal-institutional level) that could outline the e-procurement phenomenon in a comprehensive manner. The present issue is to build a bridge between an abstract concept like knowledge and an organizational process supported electronically, such as e-procurement in the Health sector. In other words, the question is how this process can be represented in terms of the concept of knowledge.

According to Lam's model, any organizational form, if seen through the lenses of the concept of knowledge, characterizes itself in terms of the three levels mentioned above. In particular, any individual, in a single or collective dimension, interacts with others on the basis of his/her background (the cognitive level of knowledge). The same individual operates in an organizational context with a low degree of autonomy, in the case of an organizational environment characterized by rigid procedures and routines, or a high degree of autonomy in case of an organizational environment loosely coupled (organizational level of knowledge). Furthermore, he/she is part of a specific labour market that rewards some profiles, but not others; moreover he/she has formed a background on the basis of a particular educational or training institution (social-institutional level of knowledge). Of course, these three levels overlap with each other and knowledge characterizing a specific organization is something unique that emerges from such an overlap. Nevertheless, Lam's approach leads to a wide-ranging perspective to investigate organizational life, and the introduction of an important innovation such as an e-procurement system.

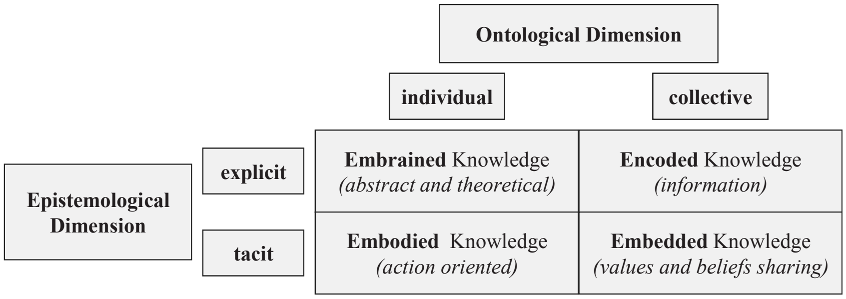
To thoroughly examine Lam's work, it requires a detailed study of each level. The double entrance matrix is the methodological instrument used in order to analyse any level of knowledge. This matrix surveys relationships between two variables but in this case they are represented by dichotomies leading to a four cell matrix. For instance, the cognitive level is exemplified by the relationship between the ontological dimension of knowledge, presented in terms of the individual-collective dichotomy, and the epistemological dimension of knowledge, explicit-tacit dichotomy (see Figure 1). The same methodology has been used to examine the remaining two levels. So, each of the three levels of analysis generates a four cell matrix each with different content.

Opposing the explicit-tacit dichotomy and the individual-collective one at the cognitive level of knowledge, four categories emerge (Collins 1993, Blackler 1995):

- Embrained knowledge (individual-explicit) can be exemplified by what is learnt at school. It is abstract, theoretical and used to solve conceptual problems such as calculations and speculations;
- Embodied knowledge (individual-tacit) is based on practical experience. It does not depend on the activity of reasoning but on action alone. The "learning-by-doing" method represents this kind of knowledge and learning to ride a bicycle is a prime demonstration of it;
- Encoded knowledge (collective-explicit) is codified and stored into rules and procedures. Therefore, it is readily transmitted through language, signs and symbols (information). Scientific management principles, for example, are an attempt to codify workers' skills and 'know-how';
- Embedded knowledge (collective-tacit) represents the shared values and beliefs that define informal rules and norms of a specific social context which contributes to govern the interaction and communication among members of a society.

Lam's work looks for organizational forms that can support the type of knowledge mentioned above. In her understanding of this point, this result can be achieved by opposing 'knowledge agent' and 'standardization of knowledge and work' in the double enter matrix. 'Knowledge agent'

Figure 1. Cognitive level: knowledge types (source: Lam, 2000)



		Ontological Dimension	
		individual	collective
Epistemological Dimension	explicit	**Embrained** Knowledge *(abstract and theoretical)*	**Encoded** Knowledge *(information)*
	tacit	**Embodied** Knowledge *(action oriented)*	**Embedded** Knowledge *(values and beliefs sharing)*

is characterized by the individual-organization dichotomy and 'standardization of knowledge and work' by the dichotomy high-low. If the 'knowledge agent' is individual, there is the possibility to enjoy a certain degree of autonomy and subjects can develop their own know-how and practical problem-solving. If the 'knowledge agent' is the organization, the managerial hierarchy becomes the engine of organizational activities transforming individual knowledge in rules and procedures. A high 'standardization of knowledge and work' suggests a scenario in which each role is strictly coordinated with others in an environment characterized by hierarchical controls. On the other hand, a low standardization outlines an organizational environment in which coordination is achieved via direct interaction and mutual adjustment and not on the basis of comprehensive design. The combination of these dichotomies results in four organizational ideal-types (see Figure 2):

- 'Professional bureaucracy' (embrained knowledge) experiences a reduced role at senior management level. Organizational activities are based on individual expertise which relates to specific professional bodies. Nevertheless, coordination and control are governed centrally through standardized and bureaucratic means. Hospitals are a typical example of this organizational form;
- in the 'machine bureaucracy' type (encoded knowledge), coordination and control are also centrally governed. Moreover, the entire organization is subject to a continuous process of formalization and codification of knowledge in which the top management tier is at the head of formulating strategies and directives;
- the 'operating adhocracy' form (embodied knowledge) sees the loss of importance of the organizational chart and coordination and control is not based on rules and procedures. In this instance, mutual adjustments among organizational actors prevail and activities are not managed vertically but left to the subjects' undertaking;
- the 'J form' (embedded knowledge) idealized characteristics in Japanese companies (Aoki 1988). Coordination is not loosely coupled as in adhocracies because of a strong corporate culture rather than hierarchical control. At the same time, horizontal coordination prevails giving rise to shared work experiences and joint problem solving amongst organizational members.

Lam maintains that knowledge outlined through organizational forms is not sufficient for investigating the entire knowledge configuration operating in organizations as they are part of a larger social context. Education and training systems (Maurice *et al.* 1986) and the nature of labour market organization (Marsden 1986) are the two elements believed to be able to enrich

Figure 2. Organizational level: organizational forms (source: Lam, 2000)

		Knowledge agent	
		individual	**organization**
Standardization of knowledge and work	**high**	Professional Bureaucracy	Machine Bureaucracy
	low	Adhocracy	J-form organization

Figure 3. Social-institutional level: education and labour market (source: Lam, 2000)

		Labour Markets *(career and mobility)*	
		OLM *(market)*	**ILM** *(firm)*
Education and training *(degree of formalization and academic bias)*	**high**	Professional model	Bureaucratic model
	low	Occupational community model	Oganizational community model

the understanding of knowledge at work in any organization leading, in this way, to the social and institutional level.

Labour market organization is interpreted according to the dichotomy occupation based labour market (OLM) and firm-based internal labour market (ILM). The former sketches a situation in which market forces govern personal careers and areas of learning. In the latter instance, expertise is internally controlled by firms causing a lower level of standardization and, thus, the difficulty of being governed by market forces. Regarding education and training systems, they can be studied according to the high or low degree of formalization and academic bias.

Again, a double entrance matrix can be built (see Figure 3): the opposition of ILM and OLM, in one dimension, and low and high degree of formalization and academic bias, in the other one, suggests four institutional configurations:

- the 'professional model' (embrained knowledge and 'professional bureaucracy') arises from a situation in which a high degree of formalization and academic bias, on the one hand, and OLM, on the other hand prevail. Here, certified expertise enables access into professional bodies and, on this basis, market forces can operate as personal careers are transparent and subject to continuous evaluation.
- in the 'bureaucratic model' (encoded knowledge and 'machine bureaucracy') there exists a high degree of formalization and academic bias. Expertise is far removed from problem-solving practices and is based upon a deductive method of reasoning. ILM characterizes this model and a narrow on-the-job training, in which careers are based on hierarchies of jobs with tiered boundaries, can contribute to establish a bureaucratic work model.
- even though the 'occupational community model' (embodied knowledge and 'operating adhocracy') characterizes itself because of OLM, inter-firm mobility is not based on certified expertise but on the 'know who' of member networks which consist of a cluster of interdependent occupations and firms. It is insides these communities that practical expertise and problem-solving can be maintained.
- the 'organizational community model' (embedded knowledge and 'J-form' organization) distinguishes itself because of a broad-based education and training system. Learning by doing and problem-solving capabilities are encouraged to the detriment of abstract theoretical knowledge in a context in which team working is seen as an instrument for connecting different workforce layers. An ILM based on a broad on-the-job training and not linked to tiered

boundaries but a common ranking system can contribute to build this community.

To sum up, a theoretical approach has been built up, with at its core the cognitive level, which constitutes the background for the organizational level that, in turn, constitutes the background for the societal-institutional level. The sum of these three levels (see Figure 4) enables a cumulative process of knowledge to be employed in organizational analysis. Nevertheless, to represent a variable through a dichotomy has some limits: on the one hand, it streamlines the analysis of a phenomenon and, on the other hand, leads to a simplified representation of reality.

E-PROCUREMENT INTRODUCTION AT THE LHA OF VITERBO

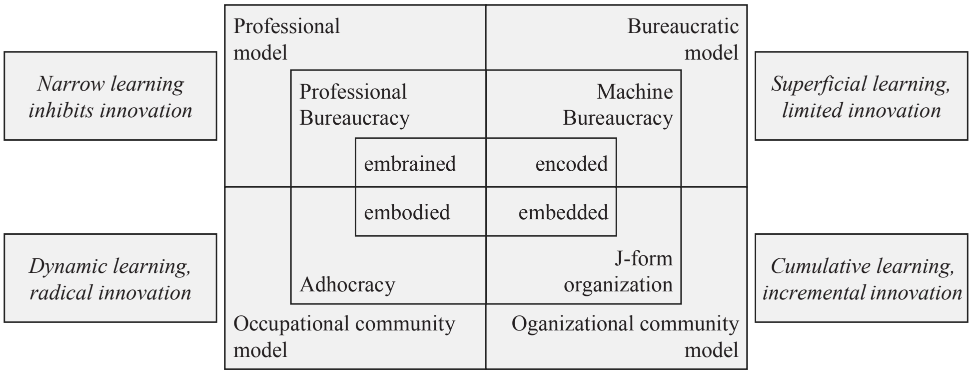
Context and E-Procurement Experiences

The Viterbo's LHA – like similar organisations (Cicchetti 2004) – is divided into three distinct areas: hospital services, territory services, administration services. With about 3.200 administrative and healthcare employees, it provides healthcare to the province of Viterbo (859 hospital beds), with a production value of about 350 €m, which is determined according to the individual spending allocated for each citizen (a total of 297,686 people since December 31, 2001).

With the aim of increasing efficiency and reducing the spending for goods and services procurement, Viterbo's LHA, since 2000, has conducted several experimental projects on e-procurement, in partnership with the Italian public as well private players (Federici 2005):

- the first initiative, in 2000, was a trial of a marketplace promoted by a private merchant: despite some positive results, this experiment ended prematurely, when the marketplace platform failed because of the low volume of transactions;
- in 2002 – when these tools were still under construction and not yet targeted to the healthcare sector – the LHA started to use the *Public Electronic Catalogue* of goods and services, which could be purchased at pre-defined conditions established in the Framework Contracts previously negotiated by the Central Procurement Agency (CONSIP 2003), and the *Marketplace for the Public Administration* (MEPA), also created and managed by CONSIP (Viterbo's LHA was one of 20 Italian PAs to take an active part in the implementation of MEPA);
- in 2003 the first platform for e-tenders was tested, which was later dismissed because of its lack of functionality; recently it has

Figure 4. Knowledge, organizations and institutions: three interlocking levels (source: Lam, 2000)



been replaced by a new one, that manages a tender electronically, providing either a complete or partial solution (this latter leaves the offer evaluation off-line);
- the LHA also carried out two distinct projects on e-logistics, both of them were promoted by private companies and based on extensive outsourcing solutions supported by extranet platforms. The first one (e-Logistics) involved central and departmental warehouse logistics for managing common goods and non specific devices used routinely in hospital wards (e.g.: gauzes, disinfectants etc.). The second project (Operating room e-procurement) coupled the supply of specific medical devices used in operating rooms to their overall logistical management: its driver was the innovative 'intervention-based' concept of linking procurement to the surgical operations performed, instead of the traditional 'stock-based' approach to purely managing the inventory levels.

These pilot projects were all driven by the Procurement and Logistics (P&L) Department of the LHA. Results were remarkable, even though they were different in nature and dimension, also taking into consideration the obstacles met (technological, organizational and also normative), as in any innovation.

Post 2004, after these pilot projects were concluded, Viterbo's LHA launched an extensive programme. Its purpose was to innovate the end-to-end procurement process (as seen above), through the adoption of diverse solutions which were coherently linked to different and specific requirements. The first step was the implementation of multiple e-procurement solutions in two segments of the broad procurement process: namely the purchasing and invoicing phases.

At present, while traditional procurement procedures are still largely used, the state-of-art of the e-procurement at Viterbo's LHA is:

- the Marketplace for PA is frequently used to buy common goods, and also some non specific medical devices (such as gauzes and alcohol etc.), but not for large orders;
- the platform for e-tenders is sometime used, also for tenders over the EU threshold, but its application is limited because the specificity of some goods, the suppliers' unreadiness in some sector and the changes introduced by recent legislation;
- the full deployment in all hospitals of the Operating room e-procurement solution is currently ending;
- the implementation of the e-Logistics outsourcing solution for common goods and non specific devices, after some difficulties caused by the suppliers, started only a few months ago and is still ongoing.

Managerial Interventions to Promote E-Procurement

Prior to starting the e-procurement introduction, the purchasing activities were divided among four Offices, on the basis of the typology of goods or services, as they are highly differentiated and specialized in healthcare. This requires the adoption of diverse procedures and connections to diverse suppliers. The subject of the four Offices is respectively: products (drugs, medical devices, consumables like paper and ink etc), general equipment (furniture, cars and elevators etc), electronic equipment (medical appliances and computers etc) and services. This division is still in existence, as such specialization is considered useful.

The traditional purchasing Office, which already existed before the e-procurement initiatives, are characterized by a knowledge oriented towards correctly applying the rigid external laws (settled by national or regional government, or by the EU) and procedures (determined by the same LHA), that regulate purchasing in a Public Administration. This sort of knowledge is strictly coded in rules and is shared within the Agency by means of official documents; for this reason, it can easily be transferred. Another important piece of knowledge concerns information about distinguishing characteristics of the product typology. To properly examine this issue, it is necessary to acquire more experience in the field, whilst the standard of education previously acquired for a position in this field had little or no relevance (actually, none of the interviewed Office supervisors had a degree, even fewer employees in law, as could be expected before). The training is entirely performed within the organization and the acquired expertise can only be used in the same Office. For this reason, career advancements and mobility are very limited. Moreover, it is important to notice that, in this context, collaborations with purchasing Offices of similar structures (e.g.: others LHAs) are occasional, hampering the development of a professional network.

The four traditional Offices – each of them, as stated above, operate separately from the others – have an average staff consisting of a supervisor and three clerks. Each role requires standardized tasks to be performed, which are typically: the sourcing of information about the product to be purchased (price, characteristics and suppliers), the writing, revising and issuing of the tender, support of the evaluation process and award notification. Despite knowledge being shared among staff in the same office, interchangeability is extremely difficult because of the tendency for staff to stay for long periods of time doing the same role. In this context the role of IT systems is to automate the traditional procedures: with office automation tools (word processing and occasionally spreadsheets) or legacy systems (accounting systems, to check fund availability and to reserve them). Consequently, a high IT literacy amongst personnel staff is not required to operate such systems. The traditional purchasing Offices have a typical form of bureaucracy: because of their culture and organizational form, they are not very flexible and not so much disposed to change. Moreover, even though they are effective in managing their duties, their activity is not efficient, as the result of the above quoted research largely demonstrates.

As the general manager of the LHA and the director of P&L Dept explored new ways to gain efficiency and to produce savings (both in terms of cost and time), they promoted a programme to introduce e-procurement. Bearing in mind the diverse issues at stake, they considered the four Offices unfit to test this innovation and decided to set up a project team, composed of new resources. To achieve this, two young economic graduates were brought in to constitute the staff that jointly operated with other private or public partners involved in the above mentioned pilot projects. The above described scenario for the development of e-procurement is the result of a series of managerial decisions made by two senior managers, which was based on the assumption that the characteristics of the two sides – the traditional and the innovative – are quite different in terms of the knowledge requested, the means of operating and the staff profiles.

The work of this team was highly experimental (because this was one of the very first attempts at e-procurement in a healthcare sector), and adopted a trial-and-error approach, whereby knowledge increased through a learning-by-doing approach.

The level of education was quite high amongst those staff involved, nevertheless it was directly spent only in some parts of the work (such as analysis of the outcomes, auditing on costs …) In addition, they were selected also because their high IT education (although they weren't IT experts) and their willingness to innovate, in comparison to workers in traditional office environment.

As parts of the constitutive platform for e-procurement, many diverse IT systems (office automation, marketplaces, platform for e-tenders, and e-logistics extranet solutions etc.) were tested in real operations over a planned period of time. The aim of each test was to model a new organizational solution, in order to provide streamlined and effective process and to employ human resources in more value-added tasks.

The Team experienced a high level of individual autonomy in an environment where informal managerial controls have prevailed, the procurement sector to test has continuously changed jointly with the related IT and organizational solutions. Team members with time have increased their knowledge about the Agency structures, ways of operating, suppliers' characteristics, purchasing rules, and so on. But they conclude that they never perceived the initial lack of knowledge to be problematic, since they turned to an 'internal expert' on a specific topic, when they needed more detailed information in that field.

As regards the use of IT tools, they were trained in some of them, particularly the more structured ones, such as MEPA or e-tender platforms. Finally, they were used to collaborate with people operating on e-procurement in other LHAs and throughout the CONSIP (Central Procurement Agency), thus creating a professional network of e-procurement experts.

At the end of the testing phase, when it was decided to promote the widespread adoption of e-procurement, two more graduates were selected, and the former informal Team became a Unit called Innovative Projects (IP) devoted to the all e-procurement processing. This Unit was integrated, with two other offices which had already moved to total paperless activity, in charge of order and invoice processing, and came under the coordination of the Director of P&L Dept. Despite this formal change, the IP Unit still works as a project team, with a high degree of delegation and informal controls. Expertise highly shared among the Unit workers, and they are fully interchangeable. They consider their knowledge easy to employ in a similar position in other administrations, but hardly worth it in other areas of the LHA. For this reason they judge their experience as exciting, but not so useful for career advancement (also because of Agency budget constraints).

The Unit in charge of e-procurement is different from the traditional purchasing office, it manages supplies regardless of the nature of the goods. In addition, even though innovative e-purchasing solutions have already been fully implemented and frequently used, this Unit is still separate from other offices, that continue to run the purchasing activity in a traditional way. Furthermore, while the traditional Offices manage the sole purchasing phase, the e-procurement Unit not only operates as a buyer (through on-line tenders or direct purchases on MEPA), but also supervises the entire procurement process (including: supply chain and logistics) being directly linked to: external providers, warehouses (for common goods and for medical devices and drugs) and internal departments who receive the supplied goods.

After being set up, the IP Unit took the lead in implementing projects to deliver new purchasing solutions and operating room e-procurement. Presently, it is leading the e-Logistics project introduction, managing the on-line purchases and supervising the go-live phase of the Operating room e-procurement.

The current goal of the P&L Dept. director is to substitute the traditional purchasing procedures with more innovative ones which are nowadays the norm at the Agency, at least at the IP Unit. The P&L Department Director wants to transfer to the four traditional purchasing offices the use of the e-purchasing tools in all of their operations: to reach this target, there must be a transferral of new knowledge solutions, and the Department Director assigned this task to the IP Unit, who will achieve this by undertaking brief courses and by having a strong supporting structure in place.

As an interesting result of the changes outlined above, the expert role, which had previously been played by the four offices, will now be played by the IP Unit. At the end of this process, the IP Unit will lose its 'buyer' role and will be responsible for controlling and auditing the broad e-procurement process and for conducting tests on other innovative solutions which sit alongside it.

KNOWLEDGE MANAGEMENT AT THE LHA ACCORDING TO LAM'S MODEL

As stated above, the objective is to study the introduction of e-procurement in the LHA using Lam's model. In other words, can this perspective interpret and evaluate the dynamics caused by this technological system in the organizational life of the Agency? In order to investigate these dynamics, the organizational setting at the LHA is investigated prior to the introduction of e-procurement.

The LHA is a typical PA and, if Lam's model is applied, this organization has a knowledge configuration which is characterized by the dominance of encoded knowledge. The reason for this is based on the prevalence of the collective-explicit dimension of knowledge at the cognitive level. Moving on to the organizational level, the 'machine bureaucracy' characterises the organizational form which represents this administration and the 'bureaucratic model' outlines the social and institutional level with references to the labour market and the education and training system.

The analysis of the e-procurement narrative at the LHA is marked by a significant number of projects, and since 2000 a project instrument has been used in order to introduce such innovation. The first question then concerns the impact of these projects. Here, it is important to notice that not only is the Agency under examination, but also a range of other actors – private IT vendors, public bodies like CNIPA (National Centre for the development of IT into the Public Administration) and CONSIP – were involved in these projects, thus affecting the knowledge configuration of the LHA.

These projects can be considered an organization in itself as, according to Daft (2003), organizations are: 1) social entities; 2) guided by objectives; 3) deliberately envisaged as coordinated and structured systems that 4) interact with an environment. E-procurement projects can surely be included in this definition. The issue is then to study if these organizational structures (pilot projects) share the same knowledge configuration as that of the LHA.

Starting with the cognitive level, in this instance encoded knowledge is of little importance. The collective dimension, in particular, seems not an appropriate to represent a context frequented by application vendors, Central Procurement Authority, university researchers and an atypical administrative unit solely dedicated to the introduction of e-procurement (IP Unit). From this perspective the individual dimension of knowledge rather than the collective dimension seems to prevail. But the cognitive level also characterizes itself because of the explicit-tacit dichotomy. At first glance, there does not seem to exist the conditions for developing tacit knowledge. However, this cannot be entirely ruled out as in specific contexts, this type of knowledge can be produced. In such conditions, embrained knowledge (individual-explicit) prevails.

Turning towards the organizational level, a 'professional bureaucracy' could represent organizational forms within e-procurement projects. This is because the 'knowledge agent' is the individual and his/her professionalism rather than the organization as in typical PAs. Civil servants, engineers, lawyers, economists etc. with their specific expertise collaborate to manage pilot projects. 'Professional bureaucracies' also distinguish themselves, because of a high 'standardization of knowledge and work'. The varied nature of actors participating in these projects renders it plausible control and coordination based on a high 'standardization of knowledge and work' although mutual adjustments and team working cannot be ruled out.

Taking into consideration the social and institutional level of knowledge, the 'professional model' emerges as the dominant model. Members seem to be in the circle of the occupation-based market (OLM) professionals with a transparent and valuable career which is subject to market forces. Concerning education and training, a high degree of formalization and academic bias seem to emerge because of the disparate figures involved; even in this case, however, forms of learning-by-doing and team building are not a remote possibility.

The comparison between knowledge configuration of the LHA and innovative projects introduced to implement e-procurement systems highlights two diverse scenarios. The LHA distinguishes itself because of encoded knowledge, the 'machine bureaucracy' and the 'bureaucratic model'. Innovative projects distinguish themselves differently because of embrained knowledge, the 'professional bureaucracy' and the 'professional model'.

A further analytical step leads us to the reshaping of knowledge configuration of the LHA due to the introduction of e-procurement projects. From an analysis of this case study, it can be seen that only part of the LHA (the e-procurement Team that later will become the IP Unit) has been deeply involved in these projects. The IP Unit is a relative small Unit in comparison with the four Offices in charge of the traditional purchasing and logistical element, even though they have recently been enlarged. So, the point, now, is to investigate the impact of this Unit on the entire P&L Dept.

In order to examine this point, it is necessary to analyse the role of the IP Unit in the P&L Dept. Interestingly, a dual role comes to the fore: that of the agent in innovative projects and that of a unit in large bureaucracies like the LHA. This ambivalence is reflected in its specific knowledge configuration. A configuration in which, as time passes by, has developed embodied knowledge (individual-tacit): individual because, as has been stressed, of the personal backgrounds of Unit members, and tacit because of the possibility of developing specific operational skills and know-how. Moving from the cognitive level to the organizational level, a situation arises in which the 'knowledge agent' becomes the individual member rather than the organization, and in such situations members are not subject to or bound by to specific rules and procedures that would ordinarily affect the rest of the LHA. As far as it concerns issues of coordination and control, mutual adjustment prevails suggesting a low 'standardization of knowledge and work'. Therefore, the IP Unit turns to adhocracy as organizational form, rather than distinguishing itself because of the 'machine bureaucracy' as seen in the rest of the LHA.

Regarding the social and institutional level, it can be noticed the establishment of a low degree of formalization and academic bias, due to the importance of problem-solving and practical expertise, on the one hand, and of the occupation based labour market (OLM), on the other hand. Members of the IP Unit are not only employees of a large bureaucracy but are, at the same time, part of an inter-firm network formed by project partners. Therefore, it is the 'occupational community model' that defines the social-institutional level due to the connections established and the shared experiences of members.

Results of the cohabitation between the IP Unit and the P&L Dept. were taken into consideration, principally, in section 4.2. However, drawing further conclusions, the organizational solution to constitute a specific unit like the IP one to introduce e-procurement can considered successful, since the organizational forms like adhocracies lend themselves extremely well to innovative projects. Knowledge configuration mobilized in this way adapts itself in order to cooperate in a context where various actors exist. The good results reached by pilot projects bear witness to this fact. However, more problematic is the dissemination of innovation to the rest of the P&L Dept. Here, a knowledge configuration characterized by embodied knowledge, operating adhocracy and the 'occupational community model' is highly inadequate. This knowledge configuration responds to the idiosyncratic situations and tasks that exist in turbulent environments. On the other hand, this knowledge is inherently instable. Consequently, the organizational chart loses its importance, roles are no longer designed in order to establish a comprehensive system and coordination and organizational members are no longer part of a general design that predetermines organizational objectives and the execution of task standards. The IP Unit can be considered, in some sense, isolated from the rest of the organization hampering the possibility of spreading an innovation like e-procurement to the entire P&L Dept.

CONCLUSION

In conclusion, it is evident that the configuration of knowledge mobilized by the IP Unit is not entirely effective in supporting the introduction of e-procurement. This innovation is, on the one hand, so pervasive and complex to adopt but on the other hand, the normal configuration of knowledge in PAs (such as the LHA) are able to support only superficial learning and limited innovation. Consequently, diverse dissemination solutions are required.

From this perspective, we can question whether Lam's model is helpful to envisage possible interventions for extending e-procurement adoption. It is believed that knowledge configuration characterized by embedded knowledge, a 'J-form' organization and an 'organizational community model' could be a point of reference to follow. For example, as far as it concerns the organizational level, the 'knowledge agent' organization seems more appropriate than the individual one which exists in an adhocracy. However, the solution proposed is not the same as the 'machine bureaucracy' perspective, in which everything is centralized and in the hands of senior management which governs through standardized and bureaucratic means. Instead, the solution emphasizes the role of working teams and, in particular, of cross-functional teams. Due to their positions, they are at the junction of knowledge flows and act as a nexus among teams.

Actually, the P&L Dept.'s senior management is moving in this direction, and it has not been ruled out that the IP Unit will play this role in future organizational charts. Finally, concerning the social and institutional levels, the 'organizational community model' could represent a solution for overcoming limitations concerning the high degree of formalization and academic bias that typifies public administration careers, and the risk of focusing excessively on the so-called 'on-the-job' training that tends to neglect practical experiences and problem solving exercises.

ACKNOWLEDGMENT

The authors wish to acknowledge the correspondent persons of the LHA of Viterbo, whose willingness and contributions have been considerable and decisive for this research: Andrea Bianchini (Director of P&L Dept.), Silvia Dari and Tania Morano (in charge of IP Unit).

REFERENCES

Aoki, M. (1988), Information, incentives and bargaining in the Japanese economy, Cambridge, Cambridge University Press.

Blackler, F. (1995), Knowledge, knowledge work and organizations: an overview and interpretation, Organization Studies, 16/6: 1021-1046.

Cicchetti, A. (2004). La progettazione organizzativa. FrancoAngeli, Milano.

Collins, H.M. (1993), The structure of knowledge, Social Research, 60/1: 95-116.

CONSIP (2003). Il Programma di razionalizzazione della spesa per beni e servizi della Pubblica Amministrazione. CONSIP Annual Report (*house journal*), Rome.

Daft, R.L. (2003), Organization Theory and Design, Chula Vista CA, South-Western College Pub.

Devadoss, P.R., Pan, S.L. and Huang, J.C. (2002). Structurational Analysis of e-Government initiatives: a case study of SCO. Decision Support System, 34, 253-269.

Federici, T. (2006). Public Healthcare: changes introduced when implementing e-procurement. In Proceedings of the: Mediterranean Conference on Information Systems, MCIS 2006, Venice, Italy, October 2006.

Federici, T. (2005). An Integrated Approach in Healthcare e-procurement: The Case-Study of the ASL of Viterbo. In Proceedings of E-Government: Towards Electronic Democracy, TCGOV 2005 (Böhlen, M. et al., eds.), p. 298, LNAI 3416, Springer, Berlin.

Hardy, C. and Williams, S.P. (2005). Public eProcurement in Action: Policies, Practice and Technologies. In Proceedings of E-Government: Towards Electronic Democracy, TCGOV 2005 (Böhlen, M. et al., eds.), p. 286, LNAI 3416, Springer, Berlin.

Kim, J. and Shunk, D.L. (2004). Matching indirect procurement process with different B2B e-procurement systems. Computers in Industry, 53, 153-164.

Lam, A. (2000), Tacit knowledge, organizational learning and societal institutions: an integrated framework, Organization Studies, 21/3: 487-513.

MacManus, S.A. (2002). Understanding the Incremental Nature of E-procurement. Implementation at the State and Local levels. Journal Public Procurement, 2, p. 5-28.

Marsden, D. (1986), The end of economic man, New York, St. Martin's Press.

Maurice, M., Sellier, F. and Silvestre, J.J. (1986), The social foundation of industrial power: a comparison of France and Germany, Cambridge, MA: The MIT Press.

Mintzberg, H. (1979), The structure of organizations, Englewood Cliffs, NJ: Prentice Hall.

Panayiotou, N.A., Gayialis, S.P. and Tatsiopoulos, I.P. (2004). An e-procurement system for governmental purchasing. International Journal of Production Economics, 90, 79-102.

Somasundaram, R. (2004). Diffusion of eProcurement in the Public Sector: Revisiting Centralization versus Decentralization Debates as a Twist in the Tale. European Conference on Information Systems.

Somasundaram, R. and Damsgaard, J. (2005). Policy Recommendations for Electronic Public Procurement. The Electronic Journal of e-Government, Vol. 3, p. 147-156.

Yin, R.K. (2003). Case Study Research (3rd edition), Thousand Oaks, CA: Sage.

This work was previously published in International Journal of Healthcare Delivery Reform Initiatives, Vol. 1, Issue 1, edited by M. Guah, pp. 1-15, copyright 2009 by IGI Publishing (an imprint of IGI Global).

Chapter 5.10

Information Management in a Grid-Based E-Health Business Environment:

A Technical-Business Analysis

Vassiliki Andronikou
National Technical University of Athens, Greece

Gabriel Sideras
National Technical University of Athens, Greece

Dimitrios Halkos
National Technical University of Athens, Greece

Michael Firopoulos
Intracom IT Services, Greece

Theodora Varvarigou
National Technical University of Athens, Greece

ABSTRACT

E-business today has moved focus to information sharing and integration across organisational boundaries in an effort to transform business processes throughout the value chain and standardize collaboration among communicating entities. Healthcare comprises a strongly collaborative distributed business environment in which information value plays a strategic role and informational privacy comprises a great concern. This new era in e-business, however, is followed by a series of issues that need to be addressed both at application and infrastructural level, such as information heterogeneity, system interoperability, security and privacy. The Grid as a technology enables sharing, selection, and aggregation of a wide variety of distributed resources comes to fill these gaps. In this chapter, the communication of information among healthcare organisations operating over a Grid infrastructure will be presented and analysed both from a technical and a business perspective.

DOI: 10.4018/978-1-60566-890-1.ch006

INTRODUCTION

Healthcare provision organisations (hospitals, clinics, etc), pharmacies as well as insurance organisations typically perform their operations from keeping and tracking patients' records and billing records to exchanging and retrieving e-health information through various computer systems. The efficient, reliable and effective operation of these intra- and inter-organisational collaborations requires the communication of these trusted systems. In fact, in such a strongly collaborative distributed business environment information comprises a valuable resource that requires cost-effective and efficient management. Yet, the variety of the systems and the data and message formats involved in such collaborations lead to serious interoperability and standardisation problems concerning the exchange, integration, sharing and retrieval of e-health information. Moreover, great differences are met across these entities in terms of data collected, database and file structures, software systems, politics, payment structures, business models; in other words each entity and even each department of theirs (such as doctor's office, out-patient clinics, imaging center, microbiological laboratories and so on) has specific requirements related to data queried and collected and interaction with patients. These issues combined with the reluctance of organisations to share their data due to lack of trust and/or security concerns lead to limitations to the successful operation of the collaborations. Moreover, given the nature of the data exchanged crucial privacy issues rise that pose even stricter requirements for prudent management of information flows, access and storage within the collaborations.

From a technical point of view these interoperability and performance issues in the healthcare environment can be distinguished into infrastructure-related and application-related. In the infrastructural level, organisations in the extended healthcare environment, including not only hospitals, clinics and doctors but also insurance organisations and pharmacies among others, use a variety of computers, networks, topologies, operating systems, configurations and data management systems offering and supporting various levels of reliability, performance, availability and security depending on their needs, budget and management policies. The existing systems improve internal processes of organisations but are not robust and secure enough to efficiently support the load of information and transactions and enable the efficient and effective cooperation, communication and sharing of information across organisational borders among the participating entities in the collaborative healthcare environment from start to finish.

At the application level, current limitations of health information systems to a specific department or healthcare organisation in the environment comprise an important obstacle to the interoperability of these systems beyond organisational boundaries. The lack of a universally accepted encoding for representing information about drugs, diseases and Electronic Health Records (EHRs) and a globally adopted message protocol for the exchange and sharing of information among the different entities in the collaborative healthcare environment pose serious restrictions to the interoperability of their systems and the efficient communication of information among them. Significant delays of information communication, when the latter is required, are posed and more importantly great inconsistencies in the EHR of the patient across healthcare providers are met leading to significant implications in care provisioning, quality of treatment and related costs.

BACKGROUND

There are several ongoing development efforts on health care standards globally aiming at information sharing and processing among healthcare stakeholders in a uniform and consistent manner. An important effort towards the treatment of the interoperability and standardisation issues mentioned above is HL7 (Health Level Seven) (HL7 Organisation, 2009), which provides messaging standards that improve care delivery, optimize workflow, reduce ambiguity and enhance knowledge transfer among stakeholders and collaborates with other standards development organisations both in the healthcare and the information systems domain so that compatible standards are produced and promoted. However, the financial cost and the great technical effort related to the transition of the currently used message mechanisms to HL7-based ones, as well as the rather slow adoption rate which stems from the reluctance of the various entities in adopting new technology and changing their perennially followed processes pose tremendous obstacles towards the adoption of the standard.

In the meanwhile, as mentioned in the previous paragraphs, the distributed nature of the intra- and inter- organisational collaborations in healthcare and the strategic role of information in these environments pose strict infrastructural requirements as well. In fact, in many cases real or 'near' real-time data integration and delivery across heterogeneous data sources as well as real-time analysis of business data and fast end-user access to key business data for decision-making acceleration are required. And what is more, issues of data consistency and privacy as well as system flexibility and robustness need to be dealt with in a cost-effective way – with security, reliability, interoperability and scalability climbing the higher stairs in the hierarchy. Such advanced infrastructural requirements combined with the innate business goal for lowering costs have driven key business sectors such as healthcare towards adopting Grid solutions into their business.

Although initially designed to cover the computational needs of high performance applications, Grid (Foster, 2002) technology of nowadays aims at providing the infrastructure for the general business domain. In fact, Data Grids (Chervenak, Foster, Kesselman, Salisbury, & Tuecke, 2001) – as a specialisation and extension of the Grid - are regarded to be the next generation inter-organisational data management systems for coordinated sharing and exchange of data as well as distributed, heterogeneous storage resources among organisations. Thus, a well-defined Grid-based solution combined with evolving international standardization efforts in healthcare comprises a new approach to information economics and can eliminate the myth of most weaknesses mentioned above and this will be the main focus of the respective paragraph.

THE MEDICAL INFORMATICS BUSINESS ENVIRONMENT

E-Health Scenario

Overview

Nowadays, e-health management and administration systems are mainly tailored to the needs and focus of the healthcare institution and the insurance organisation they serve. However, recent advances in infrastructure technologies combined with the general tendency of the population for mobility and the need for and the proven value of minimisation of communication overhead among collaborating entities within the broad healthcare domain bring to front a new era; *collaborative e-health*. A scenario of a futuristic collaborative e-health environment will be presented in this section aiming to provide the basis for analysing the technical requirements of such an environment in which inter-organisational communication is supported.

Entities and Roles

In this collaborative e-health scenario the main entities and roles involved include:

- Healthcare Provider: the term encapsulates hospitals, clinics, private doctors registered to the collaboration. Provision of healthcare services may be offered by public, private and non-public health care institutions. The roles interacting with this collaborative environment include doctors, nurses, the logistics department, among others.
- Health Insurance Organisation: it may be a government-sponsored social insurance organisation or a private insurance company. The covered individual pays (directly themselves or through stoppages) premiums or taxes to the Health Insurance Organisation it has registered to in order to help avoid high or unexpected healthcare expenses. Health Insurance Organisations closely cooperate with the Healthcare Providers in order to proceed with transaction clearing of the healthcare-related expenses of the covered individual. Quite often this process does not only involve the communication of the receipts and the appropriate supporting documents but also a negotiation process between the two parties due to their conflicting interests, leading to slow cycles of information exchange.
- Pharmacy: it provides the prescribed medication to the patient and based on the Health Insurance Organisation the patient is registered to as well as the related policies requests for a specific percentage of the total amount of money or even the whole sum.
- Patient: it involved every insured person visiting a Healthcare Provider. The individual may be covered by a public or a private health insurance, whereas it is not unusual that the person may have both types of health insurance and thus be registered to more than one Health Insurance Organisations (one public and one private).

Scenario Description

Patient X insured at Insurance Organisation A in Greece is traveling quite often in his country for business purposes. After a long meeting at his enterprise headquarters in Salonica he felt intense discomfort and took his heart pills. However, the pills didn't manage to ease his pain and based on his doctor's advice he took after calling him, he went to Hospital B that his insurance organisation cooperates with in Salonica to be examined. The doctor at Hospital B requests for the patient's e-health record (EHR) from the system. He gets information about his medical history, examination reports and list of medication he receives or has taken in the past as well as his allergy list. After examining him, he decides to proceed with the admission of the patient to the hospital for one day in order to monitor carefully the status of the patient.

After the patient is officially admitted to the hospital, his e-health record is updated with the admission information (hour, hospital section, floor, room, supervising doctor, cause for admission, expected duration of staying). After the results of the cardiogram, the doctor decides to increase for a few days the dosage of his medication and orders the nurse to give him another pill that will relax him and ease the pain on his chest. The next day the patient is ready to leave the hospital. The doctor prescribes him another set of pills, while he advices him not to forget to increase for a few days the dosage of his previous medication. The doctor proceeds with updating the patient's e-health record with the examination performed and the results as well as the temporary change in the patient's medication. Patient X goes to the accounting department where they access his e-health record to proceed with the final billing of his exams. The employee is able to view the list of examinations the patient took only that day at the specific Healthcare Provider as well as the related cost. The information displayed concerns the patient's exams performed within

Hospital B followed by their cost. Patient X is worried about his health status after this episode and decides to visit his personal doctor in Athens. For this reason, he calls him and arranges an appointment with him for the following day. The doctor's secretary updates the patient EHR with the upcoming appointment.

The patient gets a receipt for these exams and pays 20% of the total cost based on his insurance organisation policy. The list of pending operations for Insurance organisation A that patient X is insured at is updated with the current examinations the patient took. The insurance organisation accesses the billing record and the list of examinations the patient took as well as the patient's demographic information and the Hospital B information. In the meanwhile, patient X will be soon out of pills after the increase in his medication dosage and thus goes to a pharmacy the doctor at Hospital B suggested based on the list of cooperating pharmacies with his insurance organisation. The patient pays 25% of the total cost of the pills while his EHR is updated with this information. The insurance organisation receives the request through the system and is displayed with the medication the patient bought followed by the justification and the related billing information as well as the pharmacy's details. In the meanwhile, the Statistics company S is performing an anonymous resource management survey on European Hospitals and requests data from the EHR system including examination records per hospital and city.

Technical Requirements

Based on the scenario described above a set of technical requirements can be identified:

- As the information managed through such a system contains *sensitive data*, enhanced *data protection mechanisms* need to be established. In fact, *dataprivacy* and *security* constitute important issues that need to be carefully dealt with. Different levels of access to e-health medical records need to be defined and developed, secure data storage and transfer must be offered, advanced identity management needs to be supported, traceability, end-to-end message security and message integrity checks must be offered, identity theft occurrences need to be predicted and eliminated, whereas the content of the e-health medical record must be relevant, accurate but not excessive.
- Given that information comprises the most valuable resource within a collaborative e-health environment, the cost deriving from information loss (due to system attacks or network, application or hardware problems or even due to the human factor) can have great impact on the proper and successful operation of the system as well as the relations among collaborating parties (e.g., loss of medical subscription or patient history medical data) and thus a reliable and robust infrastructure is required. For this reason, *fault-tolerant mechanisms* need to be integrated to the system with the main priority being on *data reliability*.
- *Scalability* comprises an important non-functional requirement as the system must be able to serve a continuously growing number of users who are geographically dispersed.
- It should be noted that fluctuating factors affect the e-health environment, such as epidemic and a new flue among others. Hence, *efficient load balancing* techniques are required combined with enhanced dynamic data replication mechanisms must be supported by the underlying infrastructure so that the system is able to operate efficiently during rush hours and increased seasonal demand.
- In such a collaborative data-oriented system, strong needs for *efficient and real-time data management* are posed. Information is continuously updated, data

may be heterogeneous, distributed to many sites and each requiring different levels of authorisation.

- Given the current state in the e-health sector, information exchange focusing not only on e-health medical records but also on financial and billing information is required in order for non-affiliated healthcare organisations to be able to interact and exchange information. In other words, *interoperability* comprises one of the most important issues that need extensive work to be done. The IEEE (Institute of Electrical and Electronics Engineers, 1990) defines interoperability as follows: the ability of two or more systems or components to exchange information and to use the information that has been exchanged. In other words, interoperability is a term that refers both to the functional level regarding the exchange of messages and information, i.e., the physical communication among components and systems and to semantic level, i.e., interpreting operations, messages and information with a common language. In this example, interoperability issues rise due to the different encodings each healthcare actor may have adopted (regarding encoding for drugs, diseases, EHR, etc) as well the messages exchanged (e.g., different versions of HL7, etc) as it can be easily seen in figure 1.
- As already mentioned security, privacy and trust are of paramount importance. Moreover, as it can be easily deduced from the scenario described in the previous section, *effective and flexible SLA (Service Level Agreement) mechanisms* need to be established among the collaborating parties within the e-health environment monitoring and evaluating different SLAs established between the varying parties in the collaboration and handling unexpected occurrences during operation.

TECHNICAL ANALYSIS OF THE MEDICAL INFORMATICS BUSINESS ENVIRONMENT

As it can be easily deduced from the analysis of the technical requirements of an e-health collaborative environment presented above, secure, dynamic, privacy-preserving, *efficient and reliable information management* as well as interoperability comprise two of the major challenges and poses string infrastructural requirements. In the following paragraphs, it is presented how Grid technologies and the HL-7 initiative aim at addressing these issues respectively.

Information Management and the Grid

The Grid infrastructure comes to offer dynamic, on-demand provisioning of resources (storage, data, applications, processing units, bandwidth, etc) and interoperability. For this reason the use of Grid technology in this environment for sharing and integrating heterogeneous resources seems more than beneficial and gives the opportunity for meeting the demands of such a dynamic and complex collaborative environment.

As it has been mentioned, Data Grids comprise an extension of the Grid and aim to be the next generation inter-organisational data management systems for coordinated sharing and exchange of data as well as distributed, heterogeneous storage resources among organisations. Chervenak et al (2001) identify four main principles for the Data Grid architecture: mechanism, neutrality, policy neutrality, compatibility with Grid infrastructure and uniformity of information infrastructure. Mechanism neutrality refers to the independence of the architecture from the underlying low-level mechanisms which are used for data management, such as storing, transfering, etc. With the term policy neutrality they point out that apart from the basic operations, the implementation of the policies should be via high-level procedures so that the end user can adjust them to their needs. The third principle denotes that Data Grid must be an extension of the Grid inheriting the mechanisms relating to authentication, resource management, and so on. Uniformity of information infrastructure refers to using a common data model and interface to the data.

Based on this brief analysis of the Data Grid concept, applying the Data Grid mechanisms within the e-healthcare collaborative environment (i.e., *Grid-enabling*) can enable the sharing of information across organisational boundaries through an extended list of operations and services it offers. Among others, data state information including audit trails, file versions, validation data (size, checksum, validation date), locks, can be managed as well as interactions with storage systems, metadata can be assigned, efficient data replication techniques can be applied, owners to data and access controls can be assigned. Thus, what the Data Grid infrastructure offers is a set of mechanisms and technologies that provide efficient and reliable data management.

In an effort to enable trust among collaborating parties Service Level Agreements (SLAs) are established between them. An SLA (Wustenhoff, 2002) helps in the definition of the relationship between two parties by allowing the setting of the expectations between the *consumer* and the *provider*. In the case of the healthcare collaborative environment the main aim is to ensure that the overall need for timely, secure, efficient and reliable information communication is offered according to predefined Quality of Service (QoS) parameters. Thus, an SLA in this environment would for example include terms such as, the message broker service technical team will respond to service unavailability during rush hours (Monday to Friday) within 5 minutes and resolve the problem within 30 minutes or response time of 99% of drug database transactions from clinic A will be less than 1 second, with response time being the time interval between the time the user from clinic A sends the transaction request and the time he receives confirmation of successful transaction completion, whereas any deviation from these figures comprises a *violation*.

However, an SLA itself does not offer much to the participating parties if not managed appropriately. For this reason feverish research is taking place in Service Level Agreement Management (SLAM). In (Rosenberg and Juan, 2009), the authors present the SLA lifecycle including (i) SLA template specification, (ii) publication and discovery, (iii) negotiation, (iv) optimisation of resource selection, (v) monitoring, (vi) evaluation, (vii) re-negotiation and (viii) accounting. This way, after an SLA is defined and accepted by both parties (steps i-iv), the metrics (e.g., memory and disk space, transaction response time, network bandwidth, etc) related to the terms in the agreed-upon SLA are being monitored (v). The evaluation step (vi) includes the comparison of these terms with the metrics being monitored so that violations are detected and the respective pre-agreed action is taken by the system and upcoming violations of the term are prevented. Hence, for example, if more than 1% of the drug database transactions take more than 1 second, then this comprises a violation and specific action needs to be taken according to the pre-agreed policy (e.g., the technical support team needs to take action or requests are redirected automatically to another replica of the database).

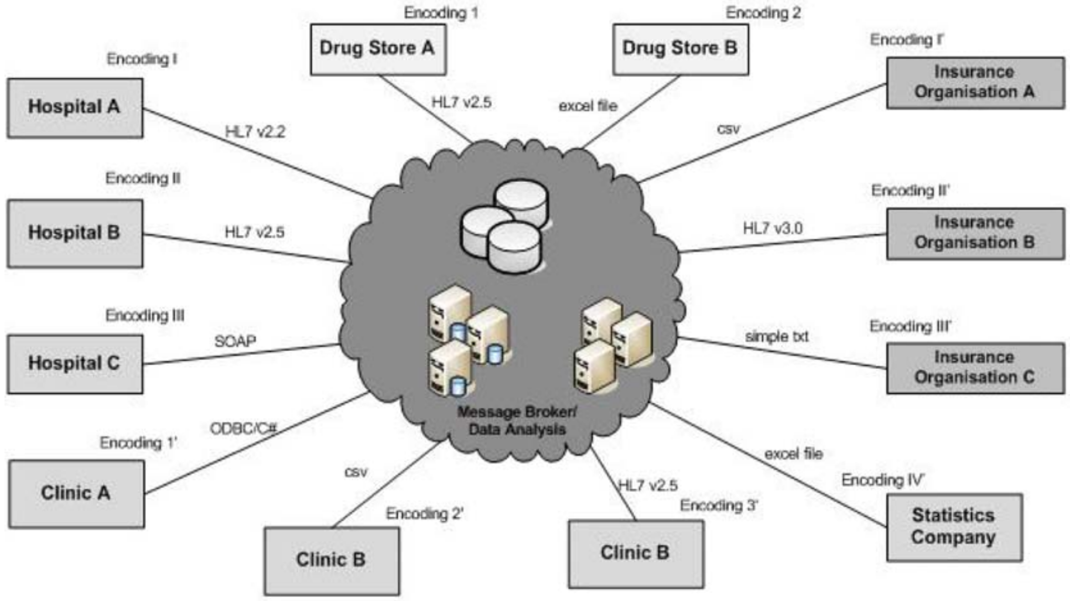
The reliability aspects of data management within a Grid environment are mainly dealt with through data replication techniques. The major topics that the task of data replication covers include the replica creation, placement, relocation and retirement, replica consistency and replica access (Venugopal, Buyya, & Ramamohanarao, 2006). In real-world environments, constraints that the system imposes need to be taken into account such as available storage space, computational resources, network bandwidth, maintenance, access and storage costs, energy consumption, etc.

The Grid provides an environment suitable for solving the problem of storage and most importantly management of such data sets and for making them available over wide geographical areas. Data replication techniques that can be employed by the Grid imply the creation of exact copies of data sets. In other words a data set or just a part of it can be located at many different storage nodes at the same time, thus making possible the redirection of requests made for the data set by a client application to the most ‘appropriate’ storage node. When developing a data replication management set of services within the e-healthcare environment, certain features of the environment must be taken into account; the *great volume of information exchanged* on a daily basis, the *variety of roles* and the *various levels of authorization*, the *significant number of users* of the e-healthcare services, the *geographical dispersion* of the entities and resources in the e-healthcare environment, the need for *real-time operations* (especially related to the synchronization of the e-health records).

An important decision to make in such an environment is the number of replicas to be created as well as the location of these new replicas in order to meet a performance goal. In the e-healthcare environment, this decision strongly depends on the Quality of Service (QoS) requested (e.g., level of reliability the participating entity is willing to pay for or the law poses), whereas minimal infrastructure cost is targeted for from the Service Provider’s side. In fact, in the case of the e-healthcare environment in which a significant portion of the data exchanged and stored comprises sensitive data, a perfect balance between achieving the desired QoS and reducing the number of instances of the data to the minimum so that the possibility of data abuse, disclosure and attack is reduced is required. Based on the replication scheme followed a replica persists until the authorised entity deletes it based on a predefined policy or its lifetime expires (static replication), or replicas are automatically created and deleted based on system or entity-related parameters (dynamic replication), such as current workload, network bandwidth, cost, expected demand. Though the latter incurs additional costs and network overhead, it allows for workload balancing, fault-tolerance and more efficient handling of the dynamicity of the Grid environment.

Concerning the user management and the authorisation assignment and monitoring aspects, Role-Based Access Control (RBAC) (Chakrabarti et al, 2008) and/or Process-Based Access Control (PBAC) mechanisms (GRIA, 2009) are used. The first one requires accurate directories of the healthcare provider’s and health insurance organisation’s staff based on their position in the respective organisations as well as careful listing and description of the different roles having access to the information and their authorisation levels. This process will actually form the privacy levels of the information in the environment. Thus, doctors will be granted access to different pieces of information (including historical data, medication, examinations, surgeries, allergies, symptoms, signs) of a patient’s e-health record than the nurses or the logistic department within the same healthcare Organisation, whereas the information exposed to different roles in a health insurance organisation will involve a different perspective focusing on pending payments and thus including billing information linked to the specific healthcare provider’s details as well as supporting documents related to the billing data. PBAC 2 comprises a dynamic access control mechanism. In brief, each web service has a list of operations that it can perform and PBAC determines which user can perform which actions in which context. The core component is a Policy Decision Point (PDP), which responds to the question “Can <this user> perform <this operation> on <this resource>?”. The response depends on the roles the user belongs to that are bound with the resource and policy related to the resource. Although these mechanisms are met individually on various systems serving from healthcare to surveillance and defence, hybrid models also exist.

Figure 1. Conceptual View of Interoperability among healthcare domains



Application Interoperability: The HL7

Apart from the infrastructural demands at resource level, current limitations of health information systems to a specific department or healthcare organisation in the environment comprise an important obstacle to the interoperability of these systems beyond organisational boundaries. These interoperability issues mainly stem from the various encodings used by each healthcare organisation for describing information about drugs, diseases, EHR as well as the different messaging mechanisms used for the communication of information, including different versions of HL7, simple text files, CSV (Comma Separated Values) and so on (see Figure 1). This results in significant delays of communication when required and more importantly in great inconsistencies in the EHR of the patient across healthcare providers leading to significant implications in care provisioning, quality of treatment and related costs. Hence, application interoperability is also required; a need that is tightly coupled with standardisation of the terms and the interaction in the healthcare environment while maintaining flexibility and cost-effectiveness. The "Health Level-7" initiative aims at producing specifications for bringing these gaps, just like a common language gives the opportunity to people of different native tongues to communicate with each other.

What is unique about HL7 (HL7 Organisation, 2009) is the fact that it deals with specifying flexible standards and guidelines of the entire healthcare organisation and is not limited to specific departments and is continuously adjusted and extended in an effort to support the varying requirements and needs of the different users, roles and entities within the e-healthcare domain. By defining a set of rules allowing for information exchange and processing while achieving uniformity and consistency, HL-7 specification aims at enabling interoperability among different healthcare entities and thus minimising delays in the information flow as well as geographical isolation and great variations in medical care. Healthcare providers are thus given the opportunity to standardise their daily operations and procedures. Based on common events taking place in healthcare organisations with clear focus among others in the patient administration domain, the HL-7 initiative has been developing message structures, Web services among others, able to carry HL7 messages. An example comprises the HL7 ADT (Admission, Discharge and Transfer) set of messages for exchanging information about the patient's state and status of their demographic data (Spronk, 2008). Thus, using the patient data (e.g., demographic data, next of kin, diagnosis, insurance information and so on) collected by the ADT application and transmitted via the related messages, the healthcare providers' Patient Billing System (PBS) will then create a billing record for this patient. The analysis of the HL-7 specification goes beyond the scope of this book chapter.

The implementation of the e-healthcare collaborative environment can, thus, be realised in two ways: either through the wide adoption of an HL7-based messaging architecture able to use different messaging and transports, including web services over a Grid infrastructure or through the integration of a *message broker* able to "translate" the exchanged messages to the standard each organisation is currently using. There are ongoing efforts for achieving the wide adoption of HL7 as a messaging standard for communicating information within and across the various entities in the healthcare environment. According to Rowland (2007) until 2007 HL7 had already 27 recognised International Affiliates with negotiations with 5 other countries in process, whereas the latest list of HL7 Affiliates includes more than 30 countries worldwide (HL7Australia, 2009).

As already mentioned however, the realisation of these standards in the healthcare environment comprises a time-consuming process requiring tremendous effort. For this reason, during this transitional stage the incorporation of a message broker responsible for translating the messages from one entity using a specific messaging protocol to another entity using a different one can enable the interoperability among the various systems. As a prerequisite each collaborating entity should have registered in advance the message protocol as well as the encodings for drugs, diseases and EHR it is currently using to the message broker, whereas a mapping from one messaging protocol to other and from one encoding to the other will be required. Thus, for example if clinic A is using X-based messages for communication of information, Y-based encoding for EHR and Z-based encoding for drugs and wants to communicate with clinic B using H-based messages for information communication, T-based encoding for EHR and W-based encoding for drugs, then, when receiving a request from clinic A to clinic B, the message broker should "translate" the messages from clinic A to clinic B based on the pre-defined mapping { X ↔ H, Y ↔ T, Z ↔ W).

Use of standard web services makes the incorporation of the services into the different entities in the domain relatively easy and cost-efficient, whereas the Grid infrastructure, as a standard-based infrastructure offering security, reliability, policy definition and monitoring and efficient content management, proves to be the proper enabling technology. Currently efforts on Grid-enabling application within the healthcare domain have mainly focused on exploiting the computational capabilities of the Grid or Data Grid within the healthcare providers' domain. Jin et al (2006) presented MIGP (*Medical Image Grid Platform*) which performed information retrieval and integration in distributed medical information systems focusing on combining HL7 and Grid infrastructure into the WSRF-compliant HL7 (Health Level 7) Grid middleware to enable medical data and image retrieval within Healthcare Providers. Another approach for the medical information integration as well as content-based image diagnosis of emphysema disease based on the Grid infrastructure was presented by Zheng et al (2008). However, the presented medical informatics collaborative environment goes beyond the organisational boundaries integrating healthcare providers', health insurance organisations' and pharmacies' systems through the introduction of *a reliable and robust Grid infrastructure* enabling *message brokering*, *encoding mapping* and *data analysis and aggregation*.

BUSINESS ANALYSIS OF THE E-HEALTH BUSINESS ENVIRONMENT

The healthcare domain comprises one of the strongest business environments as it is tightly coupled with "inevitability" in people's life; health problems. During the latest national conference held some months ago in Florida USA, Senator Tom Coburn mentioned that "*administrative costs in account for $700 billion of the $2.3 trillion spent on health care annually in the U.S.",* indicating that about 30% of the healthcare budget is actually put on non-healthcare provision tasks. These figures lead to great cost concerns which make ICT-enabled information management and communication as well as interoperability and general infrastructural changes a crying need.

The presented scenario indicates the frequency of the interactions with the system as well as the complexity of the information flow. Currently however, it is quite often that even within a healthcare provider specialized systems serving different departments are not integrated, forcing staff in search of a patient's medical or administrative data to enter another department's system in order to obtain a full clinical picture. Given the lack of standardization and the resource-poor infrastructures which are unable to meet the overwhelming demands of these information flows ICT solutions climb the highest stairs of the next steps hierarchy within the e-healthcare collaborative environment. Through the integration of Grid technologies in the resource infrastructure level and the implementation of the HL7 specifications in the application infrastructure level significant steps towards the efficient and privacy-aware information management and exchange will be made. Taking a closer look to this collaborative environment these infrastructural changes allow for a set of benefits to be realized.

In the technical analysis of the proposed e-health collaborative environment HL7 is presented as a set of specifications working towards enabling interoperability in the healthcare domain through developing standards for the management and integration of e-healthcare information. Standards comprise the most efficient path towards enabling interoperability between systems in a cost-effective manner, allowing for the sharing of health-related information among healthcare providers as well as healthcare providers and pharmacies with health insurance organisations. In fact, through standardization waiting times across the transaction cycle within the full healthcare environment (including not only healthcare providers but also pharmacies and public and private health insurance organisations) are minimized, errors mainly due to the human factor are significantly reduced and the road to large-scale e-health realization can finally open. In other words, the quality of healthcare provision can improve significantly while the overall costs within the healthcare domain can in fact be lowered and/or transferred for the improvement of the healthcare services offered to the patients, such as better medical devices, lower queues to doctor's office and timely management and communication of information to the interested parties.

As it has been quite obvious from the previous analysis of the e-health collaborative environment information comprises the most valuable resource. Within this domain information can be distinguished between medical information and administrative data. Medical information includes symptoms, signs, medication, diagnoses, family history, surgeries, examinations (from blood measurement to amniocentesis and cervical smear test), whereas patient demographic information, health insurance, billing information, health plan are regarded administrative data. It is quite evident that within a large-scale e-healthcare collaborative environment constant updating of information is required in order to achieve information synchronization, the size of the information collected and continuously being updated is tremendous whereas the nature of much of this information requires proper handling and management since it encapsulates sensitive data.

Efficient organisation of information and timely communication of administrative data not only between the medical departments and the logistic department of a healthcare provider but also between healthcare providers and health insurance organisations (public or private) offers a significant reduction in the billing process. Nowadays, especially the lack of standardization in the communication between healthcare providers and health insurance organisations and of integration of the various systems (medical system, record system, billing system, etc) causes tremendous delays in the billing cycle. Many records are still in paper format whereas those electronically kept are still incompatible across systems – even within the same organisation. Before the finalisation of the process health insurance organisations quite often request for additional supporting documents from the healthcare providers and a negotiation process begins in order for both parties to meet their interests. More specifically, the first ones want to ensure that the amount of money claimed by the healthcare provider is not greater than the expected cost of the medical examinations, the treatment and facilities use due to possible admission, the medication provided and the equipment of materials used. At the same time, the second ones want to reassure the full settlement of their patient's billing. For this reason, it is a common phenomenon that people or healthcare providers – based on the policy of the health insurance organisation – experience long delays before the final financial settlement.

Efficient information sharing and communica-

Table 1. E-health collaborative environment SWOT analysis

Strengths	Weaknesses
• Reduced operating expenses • Operations performance improvement • Increased efficiency, availability and reliability of the offered services • Interoperability among the players within the e-health environment • More timely communication of information both among healthcare providers as well as between healthcare providers and health insurance organisations • Reduction of the delays related to the fulfillment of the transactions cycle among the involved entities and thus of the finalization of the payment procedure • Access to important, quite often critical information related to their e-health medical record by the healthcare provider serving them	• The different players are unfamiliar with Grid technology • Unwillingness of patients as well as healthcare providers and health insurance organisations to share their data externally • Ownership of e-health medical records • Aggregation of massive data requiring long-term preservation and maintenance
Opportunities	**Threats**
• Increasing market maturity • Generally accepted need for standardization and interoperability of e-health systems • International market • Growing and improved networks • Continuously advancing information technologies	• Security, profiling and privacy concerns for individual's confidential as well as sensitive data being exposed through an extended network of collaboration. • Reluctance of healthcare providers and health insurance organisations to proceed with the adoption of new technology • Vague presence of Grid applications in large-scale collaborative environments

tion along with interoperability among systems of these entities comes to make the billing process a less tedious task and a more accurate and cost-effective process.

Efficient privacy-aware information management through a scalable and interoperable infrastructure based on Grid technologies and HL7 specification leads the way towards the implementation of a large-scale multi-institutional international platform offering consistent and secure linking of e-health records and providing privacy-preserving access to the latter to different departments and organisations at the same time. Such an implementation offers a helping hand to doctors who frequently lack access to updated and complete patient medical information allowing for the improvement of the quality of patient treatment as well as the reduction of the duplication of examinations occurrences. In fact enabling inter-linked e-health records can accelerate the diagnosis and treatment processes and thus through its wealth of important – often critical - information proves to provide valuable input during the doctor's decision making process. However, apart from the personal treatment of patients, e-health records implemented and exposed within a large-scale e-healthcare collaborative environment, it also offers great benefits related to clinical trials. In fact, the collection and processing of medical information from e-health records while ensuring the anonymity of the patients, allows for researchers to exploit this informational wealth for examining the effects of medication on a certain disease, the relation of demographic data to a specific health problem, the regular progress of a certain illness and so on.

ISSUES, CONTROVERSIES, PROBLEMS

Following the business-technical analysis of the e-health collaborative environment this section presents the related concerns and challenges of the proposed Grid- and HL7-enabled environment as well the expected future trends. Initially a common SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis for the proposed environment is presented in the following table.

Businesses are slow at and quite reluctant in adopting new ICT solutions. Especially when it comes to the healthcare domain in which traditional processes are more than commonly rooted within, the barriers for integrating new ICT solutions become greater. For this reason a significant transition period will be required starting from intra-organisational changes and followed by inter-organisations ICT-enabled collaborations establishment. The lack of successful implementation and operation of large-scale collaborative environments with quantifiable benefits poses even greater obstacles towards this direction.

Data privacy comprises also an important issue. Entities within the e-healthcare collaboration are really concerned about the exposure of the medical and administrative data to other parties over the network or even their disclosure to other parties. The Electronic Privacy Information Centre (EPIC) identifies 4 main concepts of privacy (Electronic Privacy Information Center, 2002): (1) bodily privacy, (2) territorial privacy, (3) information privacy and (4) informational privacy. Informational privacy which incorporates a more descriptive definition and constitutes the main privacy aspect within an e-healthcare collaborative environment, comprises the establishment of rules governing the collection and handling of personal data such as credit information, medical and government records (also known as "data protection") with any secondary uses of that information constituting violation of the person's right to control it (Banisar, 2000). In the e-healthcare domain, informational privacy is almost equal to medical privacy, with the latter referring to the right of the person to manage their medical records at their desire. Common concerns include disposal of medical information to their insurance company, their employer, the media or even their acquaintances for different reasons per occasion, such as financial, social or even personal ones.

From the legal perspective, apart from informational privacy, ownership of the e-health records comprises an important issue. In such a large-scale distributed medical informatics environment the most potential scenario would include a company serving e-health record preservation and maintenance. In this case, trust establishment through legal means as well as close watch by an appointed authority would be required to ensure proper data handling according to predefined policies and standards avoiding data disclosure or illegal processing, as well as provision in case of company closing down.

From the technological aspect, information within the e-healthcare collaborative environment currently is stored and exchanged in many different forms; printed, written on paper, electronically stored in different formats (such as files, databases), displayed with slides or films, spoken, sent by mail or through electronic means. In order for a Grid- and HL7-enabled solution to be applicable within this environment however the transformation of this information initially into an interoperable electronic form is required, which is a time-consuming and tedious task.

FUTURE RESEARCH DIRECTIONS

Grid technologies – although a set of technologies feverishly researched for years – still retain open issues that need to be tackled with. In fact, as they were initially inspired from and designed for enabling and improving computationally intensive applications, support for large-scale collaborative environments and their resulting shifting of non-functional requirements priorities from performance to reliability, scalability, trust and security poses stricter requirements related to efficient and cost-effective data management, informational privacy, dynamic SLA establishment and flexible user management. Taking into consideration the e-healthcare – and more specifically the medical informatics - sector-specific features, developing reliable, cost-effective, robust, privacy-aware data management techniques which address the heterogeneity, the dynamicity and the great volume of information is of great importance. When it comes to the privacy preservation aspect of the data management techniques, it should be noted that its successful development satisfying the strict requirement for informational privacy requires a *multidisciplinary* approach integrating considerations and joint effort from the legal, medical, technical and social domain. Hence, when implementing such a collaborative environment, the legal framework covering data protection (leading to data minimization and requiring special handling of *sensitive data*) along with the specific informational needs from each entity (doctors, hospital's billing department, different departments in insurance organization, etc) should be taken into account.

A great challenge also met concerns the maintenance of the Electronic Health Records. As the vision for the e-healthcare collaborative environment incorporates their long-term preservation, special provision needs to be made on the lifetime of the information stored so that information included is not out-dated while no obsolete or unnecessary information is kept in the system.

Aiming at providing an evolvable and flexible platform for the e-healthcare collaborative environment, mobility should also be taken into account. According to Litke et al (2004) Mobile Grid comprises a full inheritor of Grid with its additional trait being its ability to support mobile resources (with the latter serving either as a service provider or a service consumer) in a seamless, transparent, secure and efficient way. Hence, our environment can be extended providing m-health services through allowing for real-time access and update of the e-health record of a patient could by using 3G-enabled PDA devices in cases that the doctors perform examinations out of the healthcare providers premises, e.g., medical visit at the patients' home, if required. Moreover, mobile telemedicine can be integrated to the system allowing for real-time monitoring of patients health status, communication of information to their personal doctors and automatic updating of their e-health records.

CONCLUSIONS

This book chapter showed that it will not be long before e-healthcare collaborative environments become commonplace for the broader healthcare domain, including healthcare professionals, health insurance organisations, pharmacies, patients and citizens. Medical informatics comprises a rising interdisciplinary field that promises substantial benefits within the healthcare provision area. In this book chapter we analysed the technical and business requirements of the e-healthcare collaborative environment. Given the nature, the variety, the volume and the importance of the information in the e-healthcare collaborative environment as well as the complexity of the information flows current techniques applied within this domain prove to be obsolete or inadequate. With efficient, reliable and privacy-aware data management and interoperability climbing the highest stairs in the hierarchy of the technical and business requirements, the integration of Grid technologies followed by the implementation of the HL-7 specifications paves the way towards the successful realization of a large-scale international e-healthcare collaborative environment allowing for the continuous, timely and reliable communication of medical and administrative information across organisational boundaries. The SWOT analysis presented showed that the potential of this integration is promising although quite a few barriers need to be overcome; reluctance in the adoption of new technology and the transformation of the currently followed operations, data privacy concerns, current technological insufficiency in meeting the strict requirements for efficient, reliable, privacy-aware data management and interoperability. However, these deterring factors can be translated into interesting research fields that require feverish work and a multidisciplinary approach.

REFERENCES

Banisar, D. (2000). *Privacy and human rights: An international survey on privacy laws and developments*. Washington: Electronic Privacy Information Centre.

Chakrabarti, A., Damodaran, A., & Sengupta, S. (2008). Grid computing security: A taxonomy. *IEEE Security and Privacy*, *6*(1), 44–51. doi:10.1109/MSP.2008.12

Chervenak, A., Foster, I., Kesselman, C., Salisbury, C., & Tuecke, S. (2001). The data grid: Towards an architecture for the distributed management and analysis of large scientific datasets. *Journal of Network and Computer Applications*, *23*, 187–200. doi:10.1006/jnca.2000.0110

Electronic Privacy Information Center. (2002). *Privacy and human rights: An international survey of privacy laws and developments*. EPIC.org.

Foster, I. (2002). What is the Grid? A three point checklist. *GRID Today*.

GRIA. (2009). *GRIA - PBAC 2 Manual*. Retrieved February 10, 2009, from http://www.gria.org/documentation/5.1/manual/pbac-2-manual

HL7 Organisation. (2009). *Health Level 7*. Retrieved Februart 10, 2009, from http://www.hl7.org

HL7Australia. (2009). HL7 Affiliates Links. Retrieved February 10, 2009, from http://www.hl7.org.au/HL7-Links.htm

Institute of Electrical and Electronics Engineers. (1990). *IEEE standard computer dictionary: A compilation of IEEE standard computer glossaries*. New York.

Jin, H., Sun, A., Zhang, Q., Zheng, R., & He, R. (2006). MIGP: Medical Image Grid Platform based on HL7 Grid middleware. In *Advances in Information Systems* (pp. 254-263). Berlin/Heidelberg: Springer.

Litke, A., Skoutas, D., & Varvarigou, T. (2004). *Mobile Grid computing: Changes and challenges of resource management in a mobile Grid environment*. Access to Knowledge through Grid in a Mobile World, PAKM 2004 Conference. Vienna.

Report, K. D. H. P. Coverage & Access (2008, September 22). *U.S. residents cut back on health care spending as economy worsens*. Available at http://www.kaisernetwork.org/daily_reports/rep_index.cfm?DR_ID=54579

Rosenberg, I., & Juan, A. (2009). *Integrating an SLA architecture based on components* [BEinGRID White Paper].

Rowlands, D. (2007). *Report on the HL7 Working Group Meeting held in Cologne, Germany*. Retrieved February 10, 2009, from http://www.hl7.org.au/docs/HL7%20Mtg.%202007-04%20Koln%20-%20Combined%20WGM%20Report.pdf

Spronk, R. (2008, August 21). *HL7 ADT Messages*. Retrieved October 28, 2008, from http://www.ringholm.de/docs/00210_en_HL7_ADT_messages.htm

Venugopal, S., Buyya, R., & Ramamohanarao, K. (2006). A taxonomy of data Grids for distributed data sharing, management, and processing. *ACM Computing Surveys*, *38*(1). doi:10.1145/1132952.1132955

Wustenhoff, E. (2002). *Service level agreement in the data center*. Retrieved February 10, 2009, from http://www.sun.com/blueprints/0402/sla.pdf

Zheng, R., Jin, H., Zhang, Q., Liu, Y., & Chu, P. (2008). Heterogeneous medical data share and integration on Grid. *International Conference on BioMedical Engineering and Informatics. 1* (pp. 905-909). Sanya: IEEE.

This work was previously published in Infonomics for Distributed Business and Decision-Making Environments: Creating Information System Ecology, edited by M. Pankowska, pp. 81-96, copyright 2010 by Business Science Reference (an imprint of IGI Global).

Chapter 5.11

Projecting Health Care Factors into Future Outcomes with Agent-Based Modeling

Georgiy Bobashev
RTI International, Russia

Andrei Borshchev
XJ Technologies, Russia

ABSTRACT

Human behavior is dynamic; it changes and adapts. In this chapter, we describe modeling approaches that consider human behavior as it relates to health care. We present examples the demonstrate how accounting for the social network structure changes the dynamics of infectious disease, how social hierarchy affects the chances of getting HIV, how the use of low dead-space syringe reduces the risk of HIV transmission, and how emergency departments could function more efficiently when real-time activities are simulated. The examples we use build from simple to more complex models and illustrate how agent-based modeling opens new horizons for providing descriptions of complex phenomena that were not possible with traditional statistical or even system dynamics methods. Agent-based modeling can use behavioral data from a cross-sectional representative study and project the behavior into the future so that the risks can be studied in a dynamical/temporal sense, thus combining the advantages of representative cross-sectional and longitudinal studies for the price of increased uncertainty. The authors also discuss data needs and potential future applications for this method.

DOI: 10.4018/978-1-60566-772-0.ch013

INTRODUCTION

Risk Factors and Predicted Dynamic Risks

Predicting the future of health outcomes is always a challenge. Almost all specific health outcomes can depend on hard-to-predict factors. For example, the number of new influenza cases in a town depends on the random contacts among its residents. At the same time, some stable causal dependencies can provide robust background for ballpark estimates, qualitative analysis, and often quantitative assessment of relative risks. In the same example, children at school have a much higher chance of getting the flu than a single adult working on a construction site. The challenge of modeling is to differentiate between the actual critical factors that shape the outcome and the uncertainty surrounding the prediction. In a few instances it is possible to combine the two approaches (Bobashev et al., 2000) so that a mathematical model part captures the robust dynamics and a statistical part accounts for the unexplained variation.

Naturally, modeling strategy depends on the objectives. Beyond that, a clear understanding of the scales on which the outcome resides drives the modeling approach such as system dynamics, agent-based, process (Colizza, 2007 Riley, 2007).

Often global patterns and relationships are the results of the interactions of many local behaviors and decisions (Epstein, 2007). Thus, the description of these local factors becomes critical for understanding how interventions should be structured and which sub-population is the most responsive to an intervention.

Stable and reliable global patterns of the spread of communicable disease could arise dynamically from local and seemingly unpredictable behavior; for example, random network contacts could lead to exponential growth of HIV prevalence. Thus, the studies of local behavior and contact structure could be critical for the description of global outcomes.

In order to project the outcome into the future, one usually needs the following:

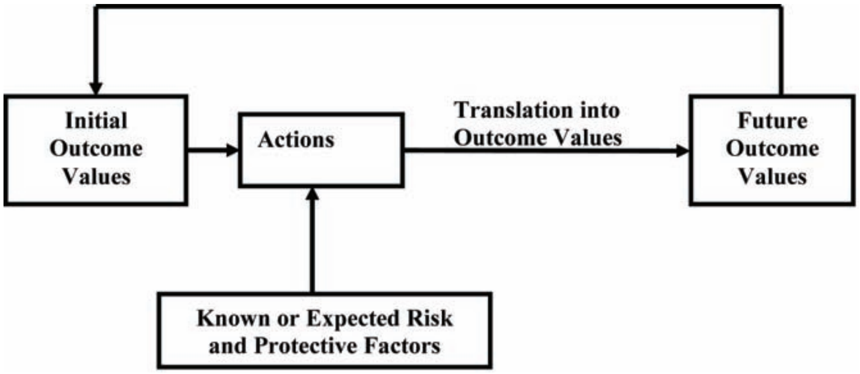
- A clear definition of the initial outcome values and risk factors (i.e., the values of the outcomes at the starting (initial) time point. For example, an individual at the baseline could be either HIV positive or negative;
- A description of the actions that individuals may take in the future (e.g., attending a ball game during a flu epidemic season);
- The collection of factors determining the actions, which could relate to a number of independent variables as well as the past actions or past states simultaneously (e.g., mixing matrices, which probabilistically describe a choice of a sexual partner, reflect that individuals are more likely to seek partners with some similar and dissimilar qualities to themselves so that, as some studies have shown, individuals who have many sexual partners are likely to have sex with those who themselves have many sexual partners [Turner et al., 2006]); and
- The translator of the behaviors into the outcomes (e.g., HIV is transmitted per direct syringe-sharing with a certain probability, which is lower if the syringe is rinsed in bleach).

Simulation models put the ingredients together and, by iterating behavior over time, provide updated outcome values as the events occur (see Figure 1).

Agent-Based Models as Tools for Projecting Behavior into the Future

Agent-based modeling is a method of developing simulation models that suggests that the modeler focuses on describing the behavior of individual entities (e.g., patients, staff, households, companies). Such entities—agents—are put into a certain environment where they interact, change their state, move, or are created or destroyed. The system level (aggregate) behavior emerges as a result of simulation of multiple individual behaviors (Borshchev & Filippov, 2004). Agents in agent-based models (ABMs) are typically acting under control of a simulation engine on a computer and in virtual (model) time. The agent-based approach is particularly helpful when a researcher

Figure 1. A process diagram of the iterative behavior projecting into the future



considers interaction between the individuals and emerging behavioral patterns.

In many health care applications, ABMs can capture reality in a more natural way and often are easier to develop than models based on differential or difference equations, which require aggregated parameter estimates. Because of recent developments in computational hardware and software, realistic agent-based modeling has become quite feasible and thus its popularity has grown in many areas of application.

In this chapter, we consider applications of agent-based modeling in two different health care areas: containment strategies in the spread of infectious diseases and interaction of staff and patients in a hospital.

Examples of Problems that Agent-Based Models can Solve

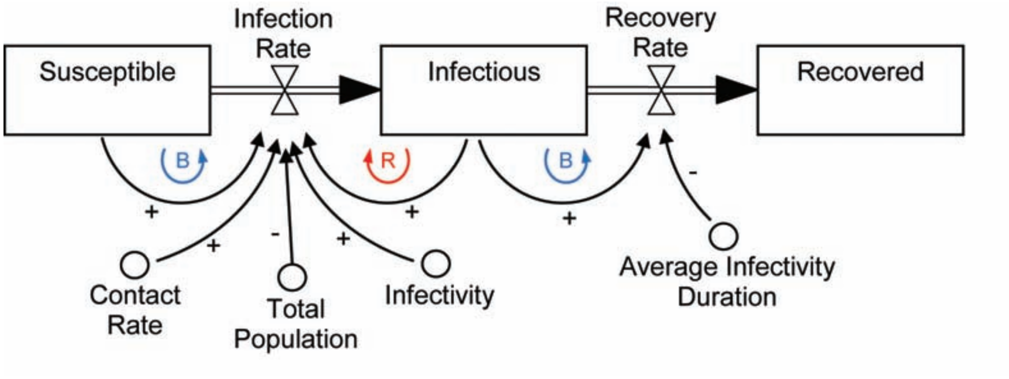
We start with the system dynamics (differential equations) description of a simple Susceptible-Infectious-Recovered (SIR) model of disease diffusion and show the limitations of such an approach in realistic populations. We then re-conceptualize the model using the agent-based method and demonstrate the basic patterns for specifying behavior of individuals (agents). We then compare the simulation results of system dynamics and agent-based models.

Next we extend an ABM to capture the social network contact structure and illustrate how different network types and parameters affect the results. The further enhancements of the model can include households, working environments, travel, and health interventions such as self-isolation and quarantine.

Another application of network-related behavior is a model of HIV diffusion in a network of drug users with a hierarchy of syringe-sharing and the use of different syringe types. We show which groups of individuals have the highest chance of being infected in the future and thus need the most attention of the public health interventions. We show that even a small percentage of high dead-space syringes could be enough to sustain a high level of HIV in the population.

The last model in this chapter is a model of an emergency department (ED) where patients and staff interact with one another. We use a process modeling method for this model, which can be considered as intermediate between system dynamics and agent ABM. We show that such a model allows ED administrators to optimize the use of the staff and the utilization of other ED resources, and outline how ABMs can help to further enhance the model.

Figure 2. The stock and flow diagram of the SIR model



The Modeling Language

Throughout the chapter we use the modeling language of AnyLogic (a software tool for agent-based and mixed-method simulation modeling), which includes several commonly adopted visual notations: stock and flow diagrams, statecharts, and process flow diagrams. All models described in this chapter are available as runnable applets at the AnyLogic Web site (AnyLogic 2008).

How Do Social Networks Affect the Disease Dynamics?

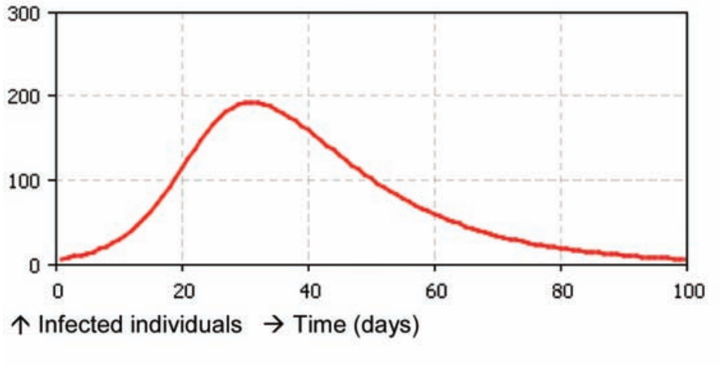
When one gets the flu during a winter epidemic, does one always know who has given them the disease? Probably not. Most people would say that they picked it up "randomly" from "someone" at work, in school, etc. Of course, most people don't want to get sick and do not specifically target a hazardous contact, so there might be an impression that infectious disease are spreading "randomly." However, when it comes to a sexual encounter, could it be considered "random"? Do people randomly pick a sexual partner, or drug-injecting partner, or even a person with whom to socialize at work? A recent study has shown that sexual partnerships are quite different among teenagers than among mature adults, and these structures can dramatically affect the spread of sexually transmitted diseases among these sub-populations. Similarly, among drug injectors, some networks have almost no HIV, while in others the prevalence can reach 80%.

One of the answers is hidden in the network structure of social, sexual, and drug-injecting contacts. In the next section, we show how to explore the impact of such a structure on the disease dynamics using ABMs. Because different diseases have different infectivity, course of disease, mortality, etc., we illustrate the impact of the networks on a generic disease where individuals can be susceptible to, infected with, or recovered from the disease.

A System Dynamics Model

In a "classic" system dynamics model of a disease diffusion (Anderson and May, 1991; Sterman, 2000) we divide the total population into three compartments (categories) with respect to their disease status: Susceptible to the disease, Infectious, and Recovered, hence the three compartments that could be modeled as stocks in the stock and flow diagram used in system dynamics science (see Figure 2). As people are infected they move from the Susceptible category to the Infectious category, and then, as they recover, to the Recovered category. The disease spreads as those who are infectious contact and pass the

Figure 3. The dynamics of infectious population (disease prevalence) in the system dynamics SIR model



disease to those who are Susceptible (the positive feedback loop) while at the same time depleting the pool of susceptible (the negative loop). The recovery from the disease creates another negative feedback loop.

Mathematically, the system dynamics model is a system of differential and algebraic equations, in the case of SIR they are:

Initially a fraction of the total population (PercentInitiallyInfected) are Infectious and the rest are Susceptible.

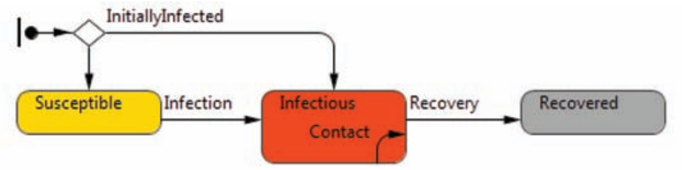
The simulation of the system dynamics SIR model produces a bell-shaped curve of the Infectious population (see Figure 3). However, this model makes a number of simplifying assumptions. One of the strongest assumptions is the homogeneity and perfect mixing of individuals in each compartment (stock): for example, all infectious people are assumed to behave in exactly the same way regardless of their individual history, properties, etc. This assumption implies that any person in the population can contact anyone else with the same probability. This simplification could sometimes be justified when the disease of interest is spread through airborne particles like influenza and the population of interest resides in a large well-connected metropolitan area such as New York or London. However, for structured populations and diseases where the transmission depends on the type of contact, such simplification could be misleading. In the ABM of the same problem, such an assumption can be dropped completely.

An Agent-Based Model

In a completely disaggregated ABM, each person is modeled as a separate object with his own parameters, state variables, and behavior rules. The agent's behavior may be continuous over time, discrete (based on events), or hybrid. In this particular model, we distinguish between three different states of a person (Susceptible, Infectious, and Recovered) and assume that state transitions are instantaneous and there are no continuous changes.

A statechart with a sequence of three states naturally describes this behavior. Note that the states of an agent mirror the three stocks in the system dynamics model; however, here the states are mutually exclusive: the agent can be in only one state at a time (see Figure 4). To reflect the fact that some people are already infected at the beginning of the simulation, the statechart entry point has a branch InitiallyInfected. The choice of the initial state can be probabilistic (e.g., based on a global model parameter PercentInitiallyInfected) or deterministic (e.g., with infected people placed

Figure 4. The statechart of a person in the agent-based SIR model



in particular locations).

The transition to the Infectious state models the event of a disease being passed to the agent from a sick person. In the model terms, the trigger of that transition is the message "Infection." Once in the Infectious state, the agent is able to pass the disease to others; thus, we are interested in his contacts. We assume that ContactRate (a global parameter) is constant while in the Infectious state, and we can use internal transition Contact that will be repeatedly taken until the agent recovers. In the action of that transition, the agent will choose another agent from the people that he knows (this is defined by the social network, which we consider below) and send him the message "Infection." However, we know that not every contact results in infection being passed, so the message should be sent with the probability InfectionProbability, which is yet another global parameter. If the message reaches an agent who is already Infectious or Recovered, it is ignored because there is no transition from those states triggered by such a message. Finally, the transition Recovery is a timeout that defines the illness duration. In the system dynamics model, the timeout is often modeled as exponentially distributed with the mean AverageIllnessDuration. Here we can use the same assumption for the sake of comparison; however, the more realistic approach would be to use a real distribution of the length of the infectious period as was done in Rvachev and Longini (1985) to compare the simulation results with the output of the system dynamics model. However, the ABM gives you absolute freedom in modeling durations of agent states: for example, you can easily use a uniform distribution between 5 and 15 days.

At the top level of the model, we define the population, the social network type, and the global parameters, which are the same as in the system dynamics model. In this particular model, the agents are homogeneous, i.e., they share the same parameter values and have identical behavior. Again, one is free to add any degree of heterogeneity to agent-based models: from individual parameters with different values to different behavior patterns (e.g., different ContactRate of different people).

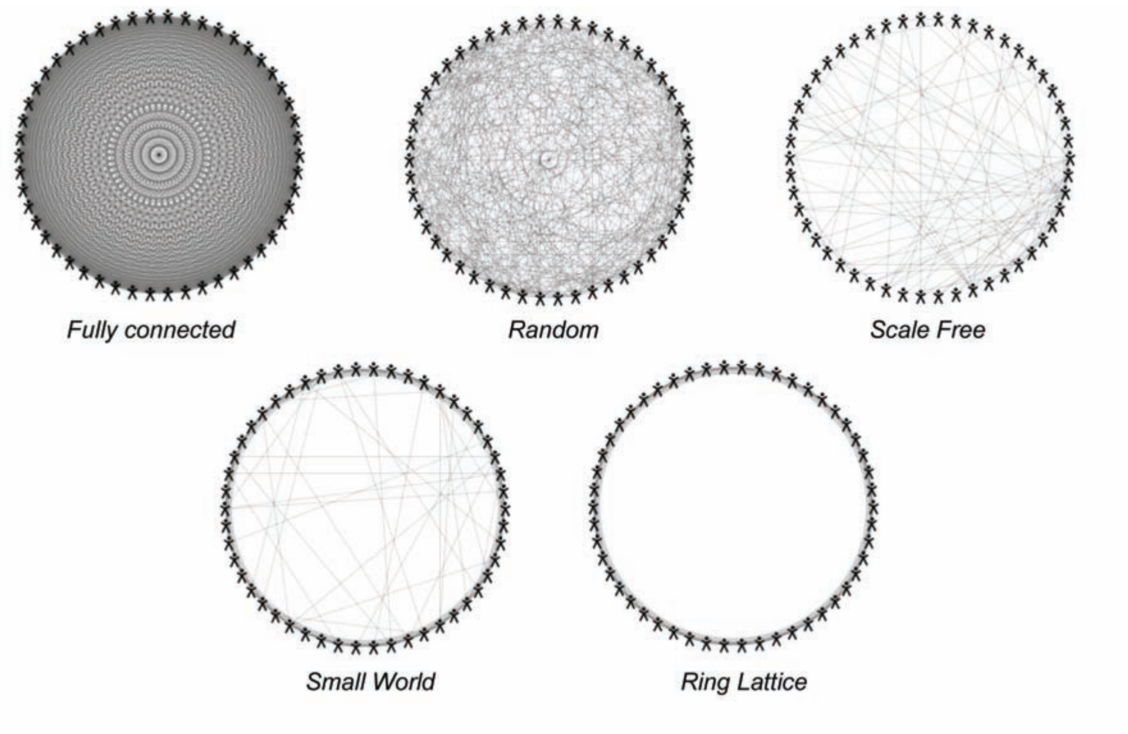
We also need to define simulation outcome variables on which to collect the statistics of interest such as the maximum size of the infectious population and the time from initial exposure to the maximum size of the infectious population.

The Network Types

The experiment design for this model follows the pattern suggested in Rahmandad and Sterman (2008). We explore the dynamics of disease diffusion in the following types of networks:

- Fully Connected: Anybody can contact anybody else. This network type fully corresponds to the perfect mixing assumption of the system dynamics model.
- Random: An agent is linked to a random subset of the agent population.
- Scale Free (Barabasi & Albert, 1999): Some people are "hubs" with lots of connections and some are "hermits" with few connections. This type of network is built using a preferential attachment algorithm where the probability of a new person

Figure 5. Schematic diagrams of different network structures



linking to the existing people is proportional to the number of links those people already have.

- Small World (Watts, 1999): Most agents are linked to their close neighbors, but there is a certain percentage of long-range links, i.e., links to distant agents. One of the ways to describe such arrangement is to arrange the agents in a circle (ring structure) and define neighbors as agents closest to the left and to the right.
- Ring Lattice: Each person is linked to a fixed number of his closest neighbors on a ring. This type of network is most distant from the fully connected network.

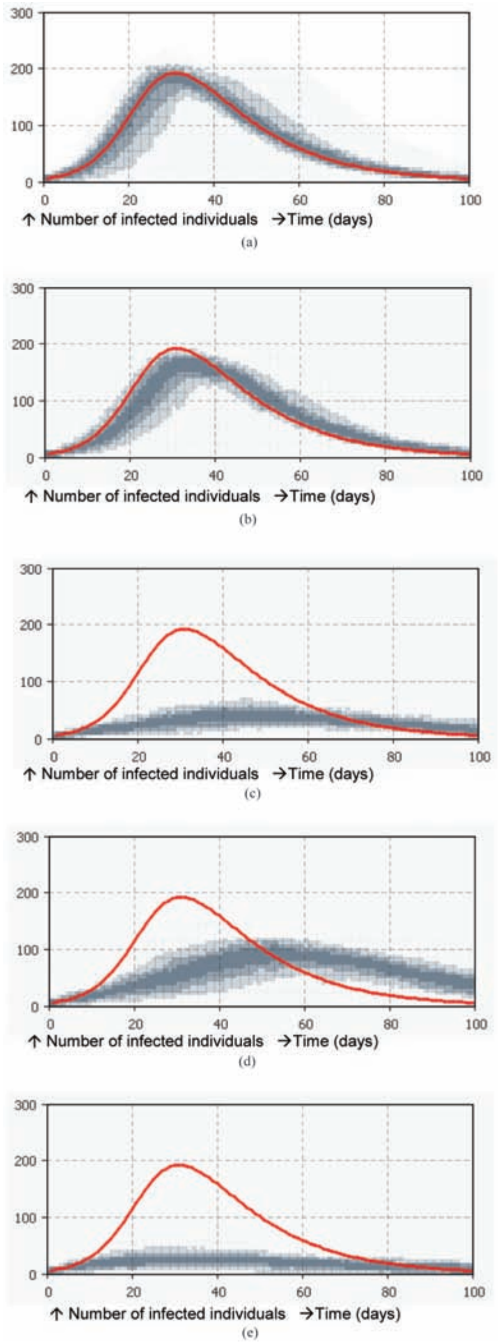
The network structures are illustrated in Figure 5 for a population of 50 agents.

The Simulation Results

Unlike the system dynamics model, which is deterministic and generates a single trajectory, the ABM is stochastic (in this case due to the contact occurrences, the probability of infection being passed during a contact, the illness duration, and the network structure). Therefore, each simulation run will give different results. We will perform a number of runs for each network structure and assemble the distribution of results in a two-dimensional histogram with highlighted envelopes to indicate the mean realization and variation around it. The solid curve is the number of infected individuals calculated from the base case system dynamics model. The results are qualitatively the same as in Rahmandad and Sterman (2008).

As one can see from the plots in Figure 6, the less a network resembles a well mixed structure, the stronger the discrepancy in the disease dynam-

Figure 6. (a) Disease diffusion in a fully connected network. (b) Disease diffusion in a random network with 10 links per node. (c) Disease diffusion in a scale free network with parameter = 2. (d) Disease diffusion in a small world network with 10 links per node and 5% of long distant links. (e) Disease diffusion in a ring lattice with 10 links per node.



(a)

(b)

(c)

(d)

(e)

ics on the networks. This effect is best explained by looking at the extreme setting. When all people are completely connected (Figure 6a), the ABM performs the same as the homogeneously mixed system dynamics model by construction. The epidemic quickly rises and then tails out. Not all people get infected. A percentage of individuals remain susceptible. When the subjects are connected randomly, the epidemic is smaller and spreads more slowly than the completely connected case, because each individual has only a limited number of connections. When all subjects are arranged in a circle, the disease is spread only to the nearest neighbors, and thus the speed of the transmission is much slower, and the epidemic could last for a much longer time and eventually produce an even greater number of infected individuals than under the random mixing case. Small world epidemic shapes could be viewed as a combination of the random mixing and the ring lattice cases, because the small world populations are structured as nearest neighbors with random connections to the rest of the population. One of the main features of the scale free populations is that they have potential "superspreaders" who, if they become infectious, can quickly infect large numbers of people. Although these networks may appear somewhat artificial, they have a direct application to disease prevention programs. Not long ago, Bearman et al. (2004) showed that sexual networks in adolescents and young adults are very different from those among older adults. Most older adults have stable monogamous partnerships, with a small fraction of very active individuals who have a large number of partners concurrently (i.e., network structure with superspreaders). If a sexually transmitted disease enters the population, it could cause a large outbreak (or outbreaks) when people connected to the superspreaders get infected in a short period of time. The rest of the population remains protected because of their monogamous relationships. While the structure of adolescent sexual network is mostly monogamous with no concurrency, the rate of partner change is relatively high. If a sexually transmitted disease enters such a population, it would not cause a quick outburst but would travel slowly from one partnership to another similar to a ring lattice or a small world network with sparse links across the population.

In these examples, we have illustrated the advantage of the ABMs in capturing the network structure. The further enhancements of the agent-based SIR model may include introduction of households, working environments, travel, and self-quarantine.

However, in the SIR example the agents are homogeneous, that is, they do not differ from each other by any specific features. In our next example, we increase the complexity of the agents to illustrate how individual features make a difference in disease dynamics.

How can Being on the Top of Social Hierarchy among Drug Injectors Protect One from HIV?

At the beginning of the HIV epidemic in the United States, heroin users who had been injecting for a longer period of time had a lower prevalence of HIV than drug users with a shorter history of injecting. The answer was unexpectedly simple. Those who had used heroin longer were likely to be higher on the social hierarchy of users and were more likely to procure heroin. Thus they were more likely to inject before others, and an infected syringe would be less likely to reach them (Bourgois, 1998, 2004). Such an effect is difficult to model using conventional methods, but agent-based modeling allows us to incorporate such a modification easily. Below we describe how this could be done in a model of injecting drug users in a single U.S. county.

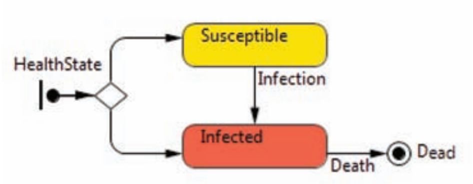
A Model of HIV Transmission among Injecting Drug Users

An ABM consists of two major structural components: the agents who are performing all the action and the top-level "container" object that defines the structure of the networks, describes the distribution of buddies, prior experiences, etc. In other words, the top-level defines the initial conditions and the global structure for the model.

We first consider a model of a drug user (an agent). To distinguish between the Susceptible and Infected states of the drug user, we use a statechart with two states (note that, in contrast with the previous SIR model, there is no Recovered state for HIV). A certain percentage of drug users are initially HIV infected; they start in the Infected state. Otherwise, the drug user begins in the Susceptible state and transitions to Infected in the event of using an infected syringe during an InjectingActivity with a certain probability. The corresponding transition Infection is triggered by the message "Infection" coming from the InjectingActivity organizer (the injection behavior is described below). If we plan to run the model for a longer period of time, we can also model the reduced life duration of an infected user. This can be done by adding a transition from Infected to a final state: Dead, triggered by a timeout. The timeout is a draw from the (known) distribution of life duration of an HIV-infected person, and the action of the transition is deleting this user from the model.

The central part of the drug user model is the injection behavior. Each user has a number of "buddies" who periodically get together to use drugs. The number of buddies is defined by the network. Occasionally, an injector would use with a "stranger" who is a random person from the entire population of injectors (Blower et al., 1991). We use a statechart with two states—Idle and InjectingActivity—to model the drug usage behavior. There are two ways to get to the InjectingActivity state: organize an activity or be invited. We assume that anybody can organize an InjectingActivity and invite others. The transition Organize from the Idle state to the InjectingActivity state occurs after a period of inactivity (in the Idle state) that can be between 1 and 3 days. When this transition is taken, the organizer of the InjectingActivity invites his buddies with a certain probability (FractionInvited) by sending them the message "Invitation." If the user being invited is in the Idle state, he will take the transition Invitation, confirm participation (by sending back the "Confirm" message) and proceed to the InjectingActivity state. The other possibility is that the invited drug user is already at another InjectingActivity, in which case the invitation will be ignored.

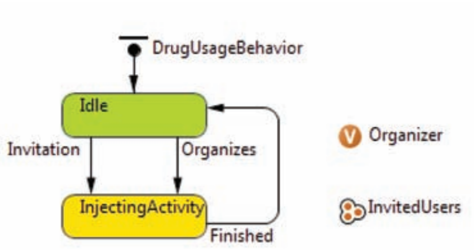
Figure 7. The HealthState statechart for an injecting agent



The duration of the InjectingActivity itself is not relevant here (we only need to know the participants), but we can set it to 1 hour deterministically for animation purposes. Therefore, the transition InjectingActivityIsOver that brings the drug user back to the Idle state has a constant timeout of 1 hour. The actual injection sequence is modeled in the exit action of the state InjectingActivity of the organizer. The organizer iterates through the list of participants (sorted by the experience, most experienced users at the beginning), starting with the clean syringe. If a user is already infected, the syringe is marked as infected and the subsequent users will get infected with the probability InfectionProbability (in the model terms, the message "Infection" is sent to the user).

An agent can receive three types of messages: "Invitation," "Confirm," and "Infection." The

Figure 8. The DrugUsageBehavior statechart and the related drug InjectingActivity data for an injecting agent



"Invitation" message is forwarded to the DrugUsageBehavior statechart, the "Infection" message is forwarded to the HealthState statechart, and the "Confirm" message causes its sender to be added to the collection InvitedUsers according to his experience. Experience is a parameter that indicates how long the user has been injecting and defines his rank in the social hierarchy of users. The initial value of Experience for a particular user can be set up as a draw from the distribution of experience throughout the drug user population (which, in this case, is the required input data for the model) or deterministically. Note that Experience is the only source of agent heterogeneity in this model.

The Top Level of the Model

At the top level of the model, we need to define the population of injecting drug users, their network of contacts, and some global parameters, namely the following:

- InitialNumberOfUsers: the initial number of agents in the model;
- PercentInitiallyInfected: the percentage of users who are initially HIV positive (for simplicity, we can assume this is not correlated with Experience);
- FractionInvited: the probability that a drug user who is known to the InjectingActivity organizer will be invited;
- InfectionProbability: the probability of getting infected after injection with an infected syringe; and
- ExperiencePDF: the distribution of experience among the drug user population used to initialize the Experience parameter of individual drug users.

For illustration purposes, here we use a small world network; however, in practical models of HIV transmission, the network structure should be estimated from the data or at least by using a mixing matrix (who injects with whom) as described in the data section below.

Note that if we wish to model the new drug users that join the network during the model runtime, we need to dynamically connect them to the existing users while preserving the network parameters.

The other important model elements that are defined at the top level are various statistics, output visualization, and animation. The following outputs are important in our case:

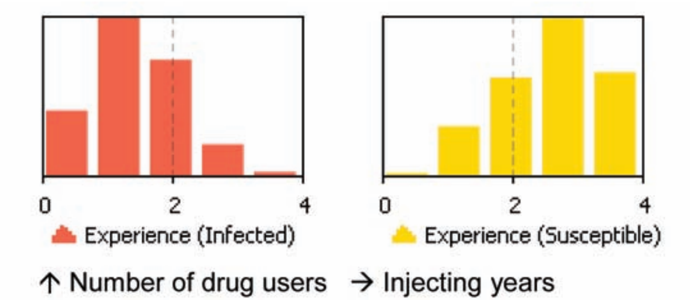
- the dynamics of the drug user population (if we do not add new users during the simulation),
- the dynamics of the fraction of HIV-infected drug users, and
- the distribution of experience among the users who are infected and not infected at the end of the simulation.

After the model is set up, one can use it to answer important policy and research questions.

The Simulation Results

One of the first illustrations of model application results is estimation of the effects that the drug-using experience has on the chances of HIV infection. Because we can track each individual agent in the model, we can make comparisons based on their behavior. After using the simulations

Figure 9. Distribution of Experience among Susceptible and Infected users at the end of simulation.



to project the behavior over the 3 years ahead, we can compare the distribution of experience among users who are HIV positive and HIV negative (see Figure 9). By running the model many times (e.g., 100) we can collect the necessary statistics and estimate the difference in survival from HIV between those who had more than 2 years of drug-using experience and those who had less (see Figure 10). As both figures show, the survival is indeed better among those who had used drug for a longer period of time. One could use a variety of statistical methods to estimate odds ratios, relative risk, hazard, etc., by applying appropriate statistical methods to the simulated data in the same manner as it would be applied to the real data. However, the main difference is in the interpretation of the variation. In simulation modes, the variation is composed of two sources: uncertainty in the parameters and variation due to the stochasticity of the simulation. We discuss these sources in the discussion section.

This model could be expanded to represent a number of comparisons when agents are supplied with individual characteristics such as demography, disease status, behavior, etc. The next example illustrates how such models can help evaluate the impact of high dead-space syringes on HIV transmission.

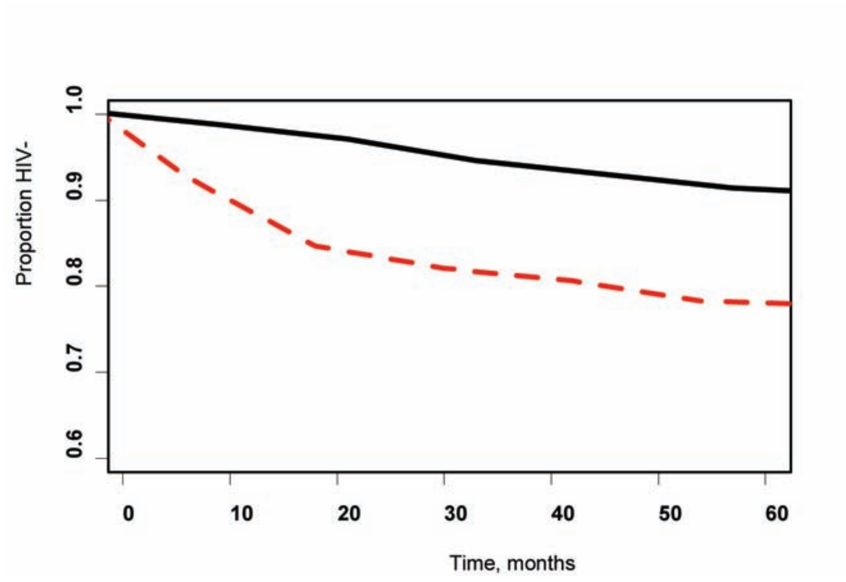
Do All Syringes Pose Equal Risk for HIV Transmission?

William Zule and his coauthors have pointed out the fact that different syringes have different amounts of so-called "dead space," which is a small space in a syringe barrel between the fully depressed piston and the needle (Zule & Bobashev, 2008). This dead space in syringes with detachable needles can retain 50 times more blood after the injection than insulin syringes with built-in needles. While injecting the drug, a user often draws back some blood to fill up the barrel and then injects the drug back into the vein. The syringe could then be passed to the next user, with some blood retained in the barrel. After a couple of rinses, which the injector usually does to prevent the needle from clogging and to reduce the risk of HIV, the relative amount of the virus in the dead space becomes more than 1,000 times higher in the detachable needle syringes compared to insulin syringes. If the concentration of the virus has an impact on the probability of HIV infection, then switching to insulin syringes could reduce the incidence and consequently the prevalence of HIV. But what percentage of injectors would need to switch to more expensive insulin syringes in order to reverse the course of HIV epidemic? Below we demonstrate how to incorporate the use of different syringes into the model of injectors.

Changes to the Injection Drug Users Model

We assume each drug user always uses a particular type of syringe (safe or unsafe), so we add a Boolean parameter UsesSafeSyringe to the model of the drug user. At the top level of the model we add SafeSyringeUsersFraction—a probability

Figure 10. Survival curves among the highly experienced (solid line) and low experienced (dashed line) injectors



needed to initialize UsesSafeSyringe for each user. We also need another top-level parameter InfectionProbabilitySafe—the probability of getting infected after injection with an infected safe syringe, which is obviously lower than InfectionProbability for a regular (unsafe) syringe.

Another assumption we make is about injection behavior. We assume that if at least one user at the InjectingActivity uses a safe syringe, then that syringe will be used by everyone. Therefore, in the model of the injection sequence in the exit action of the state InjectingActivity of the organizer, we should first check if anyone has a safe syringe and, if so, use InfectionProbabilitySafe instead of InfectionProbability.

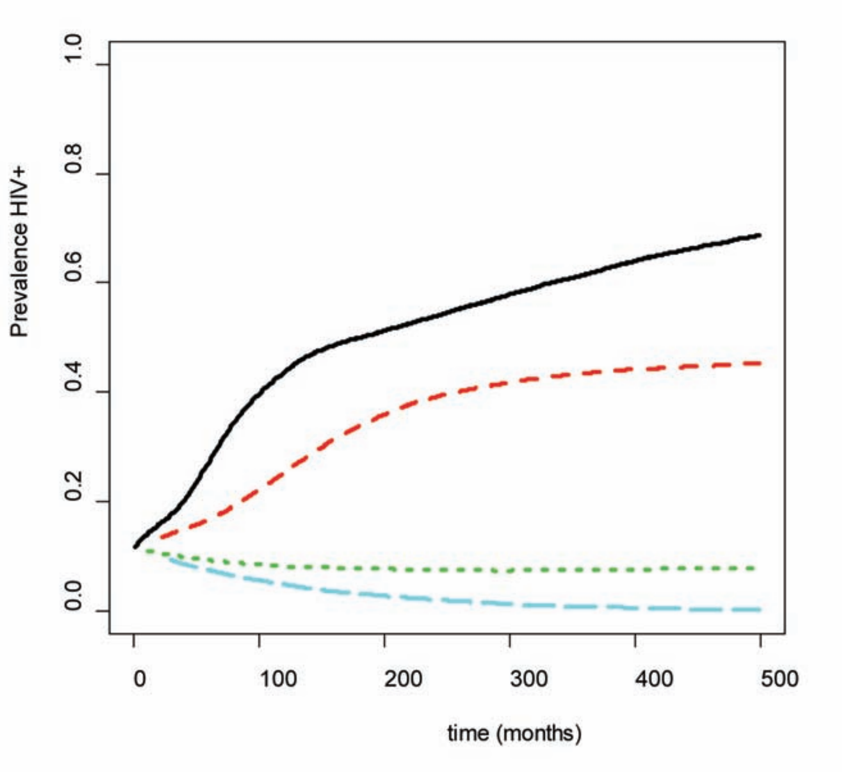
The Simulation Results

Once again, when the model is run a number of times (e.g., 100) we can accumulate the data about the outcomes and summarize it in a form of a statistical analysis or a graph.

Figure 11 shows that even a small percentage of high dead-space syringes can lead to a high prevalence of HIV, which implies that in order for the intervention to be successful, it is necessary to replace the vast majority (>90%) of high dead–space syringes.

By giving the researcher the possibility to track an individual agent, ABMs have the advantage of adding an explicit spatial component. Knowing the location of the individual, it is possible to place them on a Geographical Information System (GIS) map; conduct spatial statistics; and assign various environmental information such as poverty, crime, and education indexes (see Figure 12). This option could have the risk of producing potentially identifiable personal information. However, there are a number of safeguards to protect individual privacy. Some common methods include perturbing the actual location by random spatial noise, aggregating spatial locations up to large spatial areas (from individual addresses to a block group), and using synthetic populations, which are populations of virtual agents that have comparable demographic characteristics to the census at some aggregate level such as county or census tract (Wheaton et

Figure 11. Dynamics of HIV prevalence in a population of injecting drug users. Solid line corresponds to 100% of high dead-space syringes, dashed line to 50%, dotted line to 10%, and long dashed line to 0%.



al., 2006). The use of virtual populations is thus advantageous because the agents' characteristics are not the characteristics of real people, but at the statistically aggregated level the results of the analysis are similar to what they would be for the real population.

Can ABMs Help to Efficiently Manage the Emergency Department?

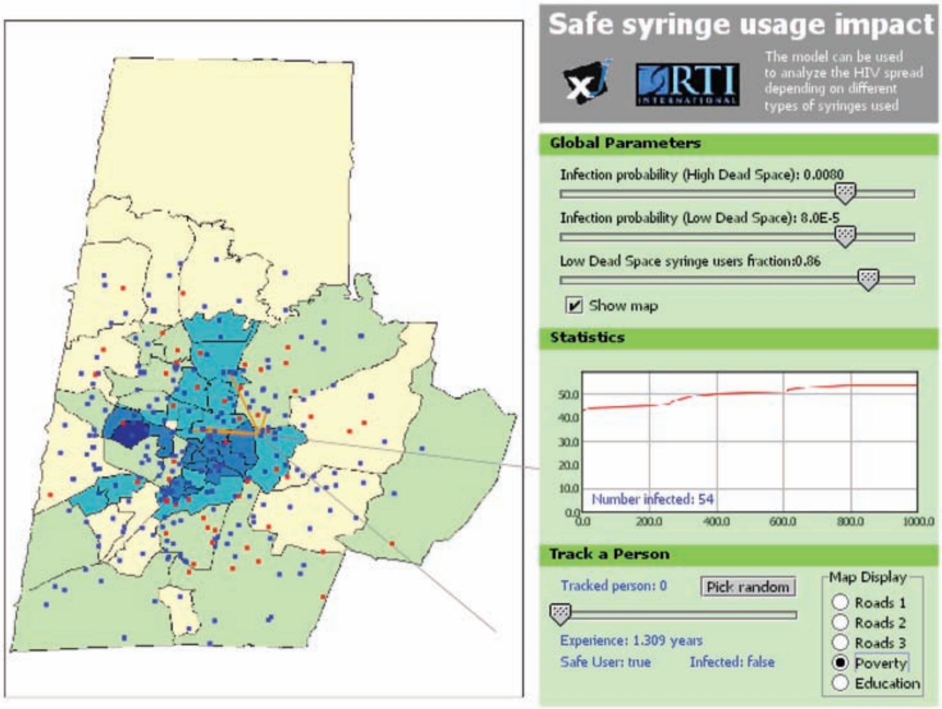
The workload in emergency departments is notorious for being extremely high at times. "Physician patient load patterns and ED demand patterns should be taken into consideration when physician shift times are scheduled so that patient load may be balanced among a team. Real-time monitoring of physician patient load may reduce stress and prevent physicians from exceeding their safe capacity for workload" (Levin et al., 2007). The same is true for a number of health care departments that are not EDs.

Because the functioning of an ED is quite complex and the patient cases range widely in the type of care they need, it is often difficult for the management to process the bulk of the information needed for optimization. A strategy to ease workload in one place can create a bottleneck elsewhere in the process (Miró et al., 2004). Below we demonstrate how ABMs allow one to summarize the processes in the ED and evaluate different strategies to ease the workload.

The Model

Compared to other parts of a hospital, the ED has more clearly defined sequences of operations.

Figure 12. Example of using GIS to map the poverty index and the locations of the injecting drug users in Durham County, North Carolina. The actual locations of the responders have been stochastically scrambled.



Safe syringe usage impact

The model can be used to analyze the HIV spread depending on different types of syringes used

Infection probability (High Dead Space): 0.0080

Infection probability (Low Dead Space): 8.0E-5

Low Dead Space syringe users fraction:0.86

☑ Show map

Number infected: 54

Tracked person: 0

Experience: 1.309 years

Safe User: true Infected: false

Map Display

○ Roads 1

○ Roads 2

○ Roads 3

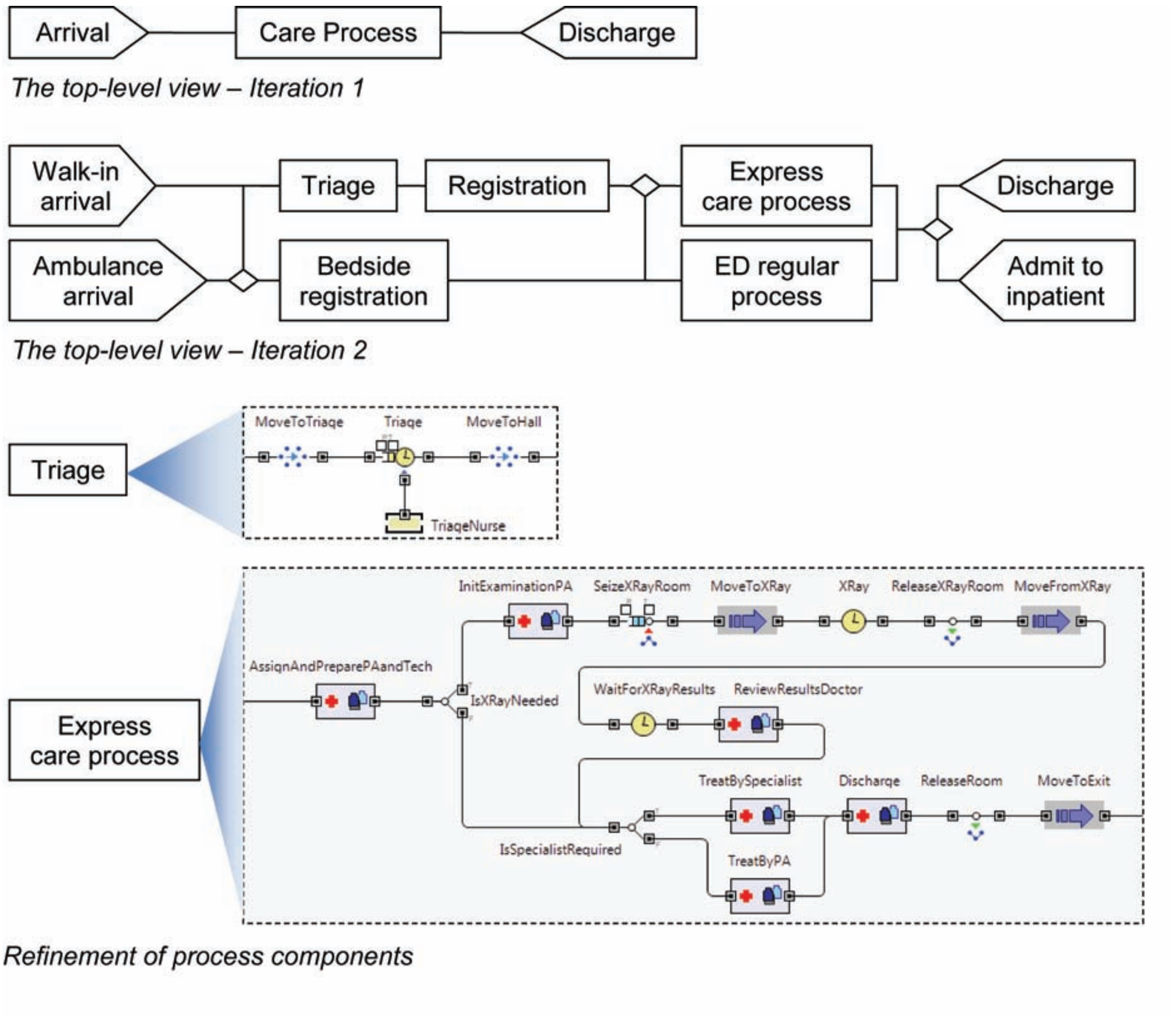
● Poverty

○ Education

Therefore, we can start with a modeling technique that can be considered to be intermediate between system dynamics and agent-based modeling: process modeling, also known as “discrete event” modeling. This modeling method has been known for decades; is well developed; and is widely used in manufacturing, business processes, the service sector, etc. Process modeling suggests that the modeler view the system as a process—a sequence of operations, perhaps with branches and loops—where entities (in this case patients) interact with (and compete for) resources (staff, rooms, equipment). The entities and resource units are modeled as individual objects and may have individual parameter values. Therefore, process models are disaggregated like agent-based ones. However, these objects are passive. They have no independent behavior and thus are completely controlled by the process; and here the process models are fundamentally different from ABMs. We begin by modeling the operations of the ED as a process and then we outline how the model can be extended by adding the agents.

Process models can be designed both bottom up and top down. For this example, we chose the top-down method. The top level of the ED operation model is a sequence of patient admittance, care process, and discharge (see Figure 13). In the next design iteration, we distinguish between walk-in patients and patients brought by ambulance. The walk-in patients go through triage and registration and are then placed into an emergency care room. The ambulance patients are put into a room first and are then registered. There are two types of care process in our ED model: Express Care (open 11AM–11PM) and Regular Care (open 24 hours). These two types have different steps and require different resources. The internals of the

Figure 13. The process model of an emergency department



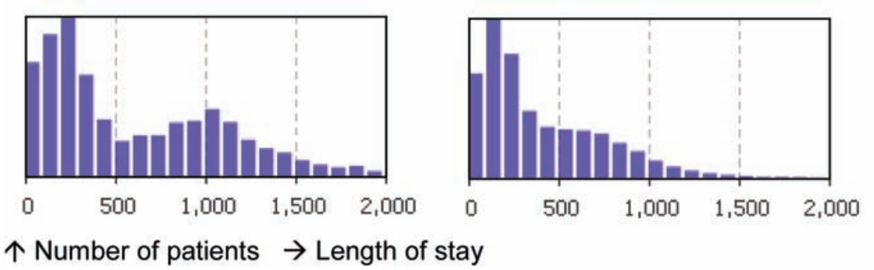
Express Care process are shown at the bottom of Figure 13. First, a personal assistant and technician examine and prepare the patient. Then, if X-rays are needed, they are taken and the results are reviewed by a doctor. After that (or directly after initial examination if X-rays are not needed), a specialist may be needed to treat the patient. After treatment, the express care room is released and the patient is discharged, or, alternatively, admitted to inpatient.

At the bottom level, the process components are built of primitive library objects such as Seize, Delay, Release, MoveTo, ResourcePool, Decision, etc. The properties of patients that flow through the process may affect the branches taken, the duration of operations, the type of resources needed, etc.

The Simulation Results

During the simulation of the process model, we are able to collect various kinds of statistics related to patients, staff, rooms, and equipment. Typically, we are interested in the following:

Figure 14. Distribution of patients' length of stay in the emergency room for two different working hours options of Express Care process



- the length of stay of patients in the ED;
- staff, room, and equipment utilization; and
- locations of bottlenecks in the process, particularly the sizes of queues.

These outputs are used to compare different process improvement strategies, to choose optimal staff levels, and to set working hours. Figure 14 shows the distribution of patients' length of stay in the ED for two different working hours options of the Express Care process.

Another kind of output is animation of the ED operation. Animation can be used to verify the model behavior and to perform rapid what-if experiments. For example, the animation of the ED model could be viewed on a floor plan of the actual ED (applet is available for viewing at the Web site: http://www.xjtek.com/anylogic/demo_models/healthcare/).

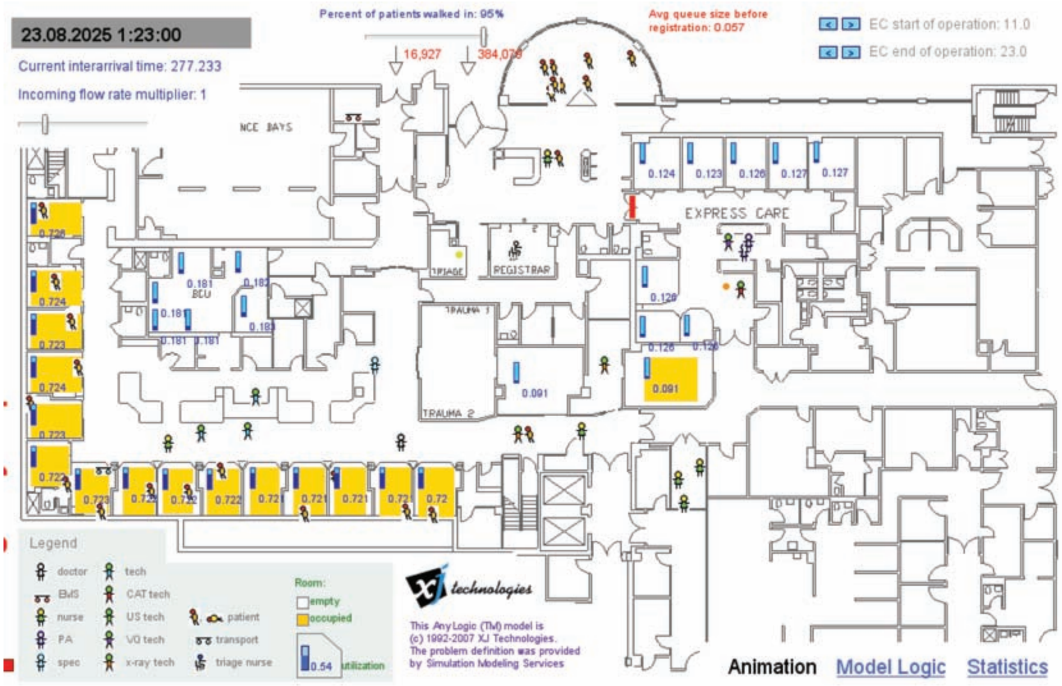
Extending the Model with Agents

Although process models are capable of capturing diversity in individual parameters of both entities and resources, the inability to define individual behavior puts a natural restriction on how far the model can go in reflecting reality. In particular, ABMs can help in modeling the longer-term behavior of ED staff. We can associate an agent with each staff resource unit in the process model (a specialist, a technician, a nurse, etc.) and make it persistent throughout the model run, so that the agent exists even when the corresponding resource is not present in the process model. We can then efficiently model the staff knowledge development, trainings, vacations, and even interaction of individual staff members at work, which can affect the ED process. For example, the staff performance and error rates when treating patients may depend on the individual states and properties of the corresponding agents.

FUTURE TRENDS IN DATA COLLECTION

One of the main challenges in the construction of ABMs is obtaining the right data to calibrate and validate the model. It is often *the* main challenge. When conducting health surveys, the focus of the sampling is usually to collect a representative sample of the studied population. The cornerstone of sampling methods and the resulting models is an assumption of independent and identically distributed subjects where one subject could well be a representative of many other similar subjects. Is this assumption true in the case of sexually transmitted diseases? If sexual partners are seldom picked at random, does the selected partner represent hundreds or thousands of other potential partners? Could a number of partners be averaged for the sake of simplified assumptions? If, over the past month, one person had one sexual partner and another had 9, does that mean that between

Figure 15. Animation of the emergency department model



them they had on average five sexual partners? Similar questions could be asked about a number of other types of contacts, such as injecting drug use contacts and contacts within hospitals and workplaces.

Most often, survey data focused on static and individual estimates is not suitable for the estimations of transition probabilities and network interactions, which are at the center of ABMs. Instead, the surveys for ABMs should focus on collecting data for dynamic and network estimates. Of course, such data pose very serious challenges.

Obtaining network information carries with it the issue of privacy. For example, in order to collect accurate data on sexual networks, one has to ask for identifiable information about sexual partners, which many respondents are reluctant to provide and sometimes do not even have. One compromise between the ease of data collection under the representativeness assumption and the need to obtain partnership information is to collect information about the *types* of partners. For example, sexual partners could be classified into long-term and short-term; their demographics could include age, race, gender, education, and socioeconomic status; and their behavior could include drug use and number of sexual partners as assessed by the respondent. Such information could be then be used to construct a mixing matrix, indicating the probabilities of having a sexual partnership between the representatives of particular categories (Morris, 2004).

Another challenge in obtaining network information is the adequate type of sampling design. Probability surveys are not helpful in identifying target populations, especially if part of the population of interest can be "hidden," such as in the case of injecting drug users. There is no practical way to enumerate all the users to develop a sampling frame. On the other hand, respondent-driven sampling (Heckathorn, 2002) allow one to obtain a representative sample of connected individuals. In this sense, respondent-driven sampling sample links rather than individuals, and following the links combined with the information on the mixing matrices could potentially allow one to reconstruct the network structure.

One critical component that distinguishes ABMs from other types of models is a dynamic scheduling of the events. After the respondents are enrolled, they are usually asked questions regarding their behavior. Some of the typical survey questions deal with the initiation of the behavior ("When was the first time you…?"), recency ("When was the last time you …?"), and frequency ("How often do you…?"). Although these questions somewhat help to schedule the events by estimating the periodicity of particular behavior, they do not help to establish transitions between the types of behavior and its consistency. ABMs often require questions of the type "For how long have you been… ?" or "In what other activities were you involved while…?" Concurrency and the rate of partner change are critical for the transmission of many sexually transmitted diseases. However, such questions are seldom asked in the surveys. For example, knowing how many sexual partners a person had over the last 6 month does not help a researcher to establish how many are stable partners and how many are short-term or occasional.

Nevertheless, a number of tools have been used to collect important behavior data suitable for ABMs. One is a "timeline fall back" where a subject is asked retrospectively about particular events. Prospective ethnographic tools have also been developed to follow-up with respondents and collect information on the scheduling of events (Vahabzadeh et al., 2007). However, these tools were not developed specifically for use in ABMs, and some adaptation might be needed. The use of blogs became very useful in collecting scheduling information. For example, a very sophisticated model of influenza spread in a city, EpiSims (Eubank et al., 2004), used blogs to validate individual movements and contact information.

Additional information that impacts transitions and interactions requires even more detailed ethnographic description. That is why development of ABMs highlights the need for close collaboration with ethnographers and for adapting the old ways of data collection to the new levels of formalizing and using them to project dynamic risk factors into the future.

DISCUSSION

We have presented several simple examples of the uses of ABMs and showed how they could be useful for understanding and projecting risk factors into the future. These models, although quite simplistic, uncover some of the relationships that should be considered when developing health services policy. Because the actual behavior and health-related outcomes could be very complex (detailed, nonlinear, evolutionary, and multiscale), the modes focusing on any specific areas of research are likely to be of a much higher complexity level. In the discussion, we reexamine the utility of agent-based modeling, and modeling in general, to provide some means of safeguarding against misuse and misinterpretation of the models.

Agent-based modeling is a fast-developing area of research, and while numerous models have been developed and utilized, there is not much theory for evaluating ABMs as rigorously as can be done for most system dynamics models. ABMs have a larger number of parameters, each of which has to be evaluated; the stochastic nature of micro-simulation often leads to a broad variety of solutions. Reality, in turn, could be viewed within a similar paradigm: the observed events and behavior are only a single realization of what could have happened out of millions of potential outcomes. The function of ABMs is thus not to reproduce actual observations but rather to capture more general features of the phenomenon. Thus, we would like to warn about a temptation to treat the outcome of an ABM as an imitation of an observed real-life situation. Another application of ABMs is identification of the results that could be rare or unusual. These applications are especially important in risk management, when the objective is to estimate the risks of rare but potentially damaging outcomes. Before the conclusions can be made about ABMs, the outcomes from a large number of realizations should first be processed to reveal the trends and relationships that are general enough to guide future decisions. The same argument applies to modeling in general; however, system dynamics models are often already operating in terms of the aggregated measures such as rates, odds ratios, and risk factors, while ABMs evaluate individual trajectories and thus require an additional aggregation step.

What makes ABMs advantageous in specific cases is the ability to describe local non-linearity and self-organization resulting from a sequence of local events. There is one more important utility of ABMs that makes them attractive to modern modeling: the natural manner in which events are described. ABMs allow the description of events without using sophisticated mathematical apparatus. While system dynamics models require that the aggregated dynamic equations are developed first and then the solution of these equations projects the outcome into the future, in ABMs the behavior is project into the future first and then the results are aggregated. This process is often easier and more natural to formalize and thus more appealing to a researcher. For example, when describing health-related processes in a complex world, one might start with a simple equation-based model and then increase the description of disease transmission by adding more and more compartments corresponding to various population subgroups. For a simple system of four differential equations described here it is possible to derive important analytical solutions that have a strong impact on health policy (Bailey, 1975; Anderson & May, 1991). When the number of equations becomes too high, the model loses its analytic appeal but becomes more useful as a numeric simulator. An ABM is designed as an efficient numeric simulator from the very beginning. By design, ABMs are naturally expandable to accommodate increasing levels of complexity such as heterogeneity in contacts, variations between individuals, and combinations of processes across physical scales such as molecular, cellular, organ, individual, group, and population.

ABMs also have a number of specific challenges, including the following:

- *Challenge to populate the model with parameter values.* Populating an ABM often requires knowledge of detailed individual decision-making and/or scheduling patterns. For example, in a model of different types of syringes, we did not consider the fact that many drug users change their behavior after they learn about their seroconversion. It takes different lengths of time for different categories of people to admit to the testing clinic and then change the behavior (often depending on the local intervention programs and insurance status). Also, knowledge of the actual network structure would change the actual numerical values of the results. However, the qualitative assessment might remain very similar. Depending on the purpose of the models and the results of sensitivity analysis, one should make decisions about spending large amounts of money to improve the model's numerical values, as opposed to conducting inexpensive qualitative assessment of a simple model.
- *Challenge to validate the model.* Validating ABMs is a topic of numerous discussions. With the large amounts of data that would be available in the industrial setting with repeated processes, validation is not as big a challenge as in the health care environment. The lack of validation data that was discussed in the data collection section prohibits the models from being fully validated. In the presented models we used simplified parameterization when the

values of parameters were obtained from published literature and educated guesses. This was done to illustrate that even simple models can provide additional insight into important health-related problems. There is a large body of models and peer-reviewed literature that describes more detailed models that have been calibrated and validated to different degrees (Law, 2007), but the assessment of these much more complex models is not the purpose of this chapter.
- *Challenge to obtain an analytical solution.* Although for equation-based models it is possible in many cases to obtain an analytical solution or an approximation, little has been done yet to obtain an analytical solution for an ABM that could be used instead of numerical simulations. Few exceptions occur when agents are simple, i.e., when they are not involved in complex interactions and do not evolve during the course of the simulation. In such simplified case, the model is reduced to the analysis of the networks that have a more advanced theory behind them (Snijders et al., 2007, Newman, 2002).
- *Computational challenge*. The advantage of system dynamics models is that they deal with aggregated populations and thus do not depend as dramatically on the population size they describe. Conversely, ABMs increase computational demands as the population size increases. The more complex are the agents the stronger becomes the limitation. For example, when agents are organized in a large network, each agent contains information about the individuals that they are likely to meet in the households, workplace, common areas, etc. Advanced computational methods are needed to program such arrangements in an efficient way. The options for conducting large simulation experiments are to use large computational facilities such as supercomputers, distributed computational clusters, and computational networks such as TeraGrid. However, for the purposes of evaluating the impact of policies in smaller locations such as hospitals and health care facilities, user-friendly software packages, such as AnyLogic, which create manageable models, are often sufficient.

Finally, we would like to bring clarity into the "explanatory" and "predictive" sides of modeling. In different subject areas, these terms would have different meanings. For example, in economics, a "predictive" model would produce a predicted value for disease prevalence with a confidence interval, and the same would apply for the estimated forecast of monetary burden. In behavioral and neuroscience, predictive would often indicate a more qualitative way of uncovering a mechanism that governs behavior. Regardless of definitions, we argue that explanatory and predictive are not necessarily conflicting objectives, but rather parts of a larger logical process. For example, the prediction of the national level of HIV prevalence for the next year might be based on a statistical regression trend model. It would probably be the same as this year with small variation that could be explained by the amount of funding spent on prevention and treatment. The linkage between cost and effectiveness could be done with some empirical algebraic equation. What such a model would not be able to tell is why some regions, communities, and individuals are at a higher risk and what would be a better way to change people's behavior. In this sense, a dynamical model powered by ethnographic knowledge may describe the phenomenon qualitatively and thus could be considered "explanatory" or "educational." However, the result of such models would be a qualitative "prediction" aimed at making a suggestion to public health as to which intervention direction is more promising for societal well-being. Thus, explanatory models become useful when their intent and focus is future practical prediction and application. Otherwise, purely explanatory models would have little practical value beyond the casual appeal of computer games.

ACKNOWLEDGMENT

The authors would like to thank Dr. Joshua Epstein for his valuable discussions.

REFERENCES

Anderson, R. M., & May, R. M. (1991). *Infectious disease of humans: Dynamics and control*. Oxford: Oxford Sciences Publications.

AnyLogic. (2008). XJ Technologies and AnyLogic Web site: www.anylogic.com

Bailey, N. J. T. (1975). *The mathematical theory of infectious diseases and its applications*. London: Oxford University Press.

Barabasi, A. L., & Albert, R. (1999). Emergence of scaling in random networks. *Science*, *286*(5439), 509–512. doi:10.1126/science.286.5439.509

Bearman, P. S., Moody, J., & Stovel, K. (2004). Chains of affection: The structure of adolescent romantic and sexual networks. *American Journal of Sociology*, *110*(1), 44–91. doi:10.1086/386272

Blower, S. M., Hartel, D., Dowlatabadi, H., Andersen, R. M., & May, R. M. (1991). Drugs, sex & HIV: A mathematical model for New York City. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, *331*, 171–187. doi:10.1098/rstb.1991.0006

Bobashev, G. V., Ellner, S., Nychka, D. W., & Grenfell, B. (2000). Reconstruction of susceptible and recruitment dynamics from measles epidemic data. *Mathematical Population Studies*, *8*(1), 1–29.

Borshchev, A., & Filippov, A. (2004, July 25–29). From system dynamics and discrete event to practical agent based modeling: Reasons, techniques, tools. *Proceedings of the 22nd International Conference of the System Dynamics Society,* Oxford, England.

Bourgois, P. (1998). The moral economies of homeless heroin addicts: confronting ethnography, HIV risk and everyday violence in San Francisco shooting encampments. *Substance Use & Misuse*, *33*(11), 2323–2351. doi:10.3109/10826089809056260

Bourgois, P., Price, B., & Moss, A. (2004). Everyday violence and the gender of Hepatitis C among homeless drug-injecting youth in San Francisco. *Human Organization*, *63*(3), 253–264.

Colizza, V., Barthelemy, M., Barrat, A., & Vespignani, A. (2007). Epidemic modeling in complex realities *CR Biologies, 330*, 364-374

Epstein, J. M. (2007). *Generative social science: Studies in agent-based computational modeling*. Princeton, NJ: Princeton University Press.

Eubank, S., Guclu, H., Kumar, V. S. A., Marathe, M. V., Srinivasan, A., Toroczkai, Z., & Wang, N. (2004). Modelling disease outbreaks in realistic urban social networks. *Nature*, *429*, 180–184. doi:10.1038/nature02541

Heckathorn, D. D. (2002). Respondent-driven sampling ii: Deriving valid population estimates from chain-referral samples of hidden populations . *Social Problems*, *49*(1), 11–34. doi:10.1525/sp.2002.49.1.11

Law, A. M. (2007). *Simulation modeling and analysis* (4th Edition) McGraw-Hill.

Levin, S., Aronsky, D., Hemphill, R., Han, J., Slagle, J., & France, D. (2007). Shifting toward balance: Measuring the distribution of workload among emergency physician teams. *Annals of Emergency Medicine*, *50*(4), 419–423. doi:10.1016/j.annemergmed.2007.04.007

Miró, O., Sánchez, M., & Millá, J. (2004). Hospital mortality and staff workload. *Lancet*, *356*(9238), 1356–1357. doi:10.1016/S0140-6736(05)74269-0

Morris, M. (2004). Overview of network survey designs. In M. Morris (Ed.), *Network epidemiology: A handbook for survey design and data collection* (pp. 8-24). London: Oxford University Press.

Newman, M. E. J. (2002). The spread of epidemic disease on networks . *Physical Review E: Statistical, Nonlinear, and Soft Matter Physics*, *66*, 016128. doi:10.1103/PhysRevE.66.016128

Rahmandad, H., & Sterman, J. (2008). Heterogeneity and network structure in the dynamics of diffusion: Comparing agent-based and system dynamics models. *Management Science*, *54*(5), 998–1014. doi:10.1287/mnsc.1070.0787

Riley, S. (2007). Large-scale spatial-transmission models of infectious diseases . *Science*, *316*, 1298–1301. doi:10.1126/science.1134695

Rvachev, L. A., & Longini, I. M. (1985). A mathematical model for the global spread of influenza. *Mathematical Biosciences*, *75*, 3–22. doi:10.1016/0025-5564(85)90064-1

Snijders, T. A. B., Steglich, C. E. G., & Schweinberger, M. (2007). Modeling the co-evolution of networks and behavior. In K. van Montfort, H. Oud, & A. Satorra (Eds.), *Longitudinal models in the behavioral and related sciences* (pp. 41-71). Mahwah, NJ: Lawrence Erlbaum.

Sterman, J. (2000). Business Dynamics. Systems Thinking and Modeling for a Complex World. Irwin/McGraw-Hill, New York.

Turner, K. M. E., Adams, E. J., Gay, N., Ghani, A. C., Mercer, C., & Edmunds, W. J. (2006). Developing a realistic sexual network model of chlamydia transmission in Britain. *Theoretical Biology & Medical Modelling*, *3*(3), 1–11.

Vahabzadeh, M., Jia-Ling, L., Epstein, D. H., Mezghanni, M., Schmittner, J., & Preston, K. L. (2007). Computerized contingency management for motivating behavior change: automated tracking and dynamic reward reinforcement management computer-based medical systems. CBMS ‘07. Twentieth IEEE International Symposium on June 20–22. Pages: 85-90. Digital Object Identifier 10.1109/CBMS.2007.35

Watts, D. (1999). *Small worlds*. Princeton, NJ: Princeton University Press.

Wheaton, W. D., Allpress, J. L., Chasteen, B. M., Cajka, J. C., Wagener, D. K., Cooley, P. C., & Roberts, D. J. (2006). *Nationwide geographically-explicit synthetic populations using public use microdata.* Presented at Congress of Epidemiology, Seattle, WA, June 21–24, 2006.

Zule, W. A., & Bobashev, G. V. (in press, 2008). High dead-space syringes and the risk of HIV and HCV infection among injecting drug users. *Drug and Alcohol Dependence.*

This work was previously published in Multi-Agent Systems for Healthcare Simulation and Modeling: Applications for System Improvement, edited by R. Paranjape; A. Sadanand, pp. 234-256, copyright 2010 by Medical Information Science Reference (an imprint of IGI Global).

Chapter 5.12

Practical Action and Mindfulness in Health Information Security

Jeff Collmann
Georgetown University Medical Center, USA

Ted Cooper
Stanford University Medical Center, USA

ABSTRACT

Although it is sometimes tempting to treat information security as a domain of its own, this approach will inevitably yield failures of information security and failures for the organization. This occurs because serious breaches may originate from organizational conditions not obviously related to information security policies, procedures or practices and because information security practices operate in, and are affected by the context of their parent organization. For these reasons, healthcare leaders must comply with but look beyond good industry practices alone while planning, implementing, and evaluating information security programs. In this chapter, we demonstrate that a consensus exists on key good information security measures that all healthcare leaders should, and often do use in designing their information security programs. We follow this analysis with two case studies that demonstrate the limitations of focusing only on good information security practices. These case studies help explain the mutual interaction between health information security programs and their wider organizational context by introducing key concepts about organizational performance, including "practical action," "practical resistance," "sponsored social movement," and "mindfulness" and examining them at the individual, group, organizational, and cross domain levels of organizational life.

DOI: 10.4018/978-1-60566-356-2.ch022

INTRODUCTION

Health care leaders and staff members have spent several years now designing, implementing and evaluating programs for complying with the privacy and security regulations of the Health Insurance Portability and Accountability Act (HIPAA) of 1996 (Department of Health and Human Services

[HHS], 2000, 2003; Gostin, Turekbrezina, Powers et al 1993; Mandl, Kohane and Brandt 1993). This work typically entails deploying traditional safeguards for information privacy and security on which wide consensus exists. As health care leaders reflect upon their work, however, they should begin looking beyond the boundaries of the traditional information security domain to include insights from the social science literature on High Reliability Organizations (HROs) and organizational failure. Two concepts, practical action and mindfulness may offer particular help in better understanding and trying to learn from their experiences with HIPAA compliance. Scott Snook introduces the concept of "practical action" in his explanation of the friendly fire shoot down of two American helicopters by two American F-15 jets over Northern Iraq during Operation Provide Comfort. According to Snook (2000), "practical action" operates as a ubiquitous feature of organizational life and refers to "behavior that is locally efficient, acquired in practice and legitimized through unremarkable repetition" (p. 182). Weick and Sutcliffe (2001) describe mindfulness in their analysis of avoiding failure in complex organizations faced with the high possibility of unexpected, catastrophic events. From the perspective of Weick, Sutcliffe and Obstefeld (1999), organizations that develop and sustain a state of collective mindfulness create "a rich awareness of discriminatory detail and (facilitate) the discovery and correction of errors capable of escalation into catastrophe." (p.81) Expanding their focus beyond the domain of information security alone will help healthcare executives identify potential vulnerabilities and sources of failure that standard approaches to information protection ignore.

RESEARCH DESIGN AND METHODS

We designed this project to illustrate the necessity for evaluating broad organizational conditions as well as industrial guidelines for good practice in information security planning. Thus, we begin by analyzing current surveys in English of information security practice and comparing them with two important information security initiatives of the United States (US), the Federal Information Security Management Act (FISMA) of 2002 and Security Standard of the Health Insurance Portability and Accountability Act (HIPAA)of 1996 (HHS 2003). This analysis demonstrates that a consensus exists on key good information security measures that all healthcare leaders should, and often do use in designing their information security programs. We follow this analysis with two case studies in the design and implementation of good information security practices across two large organizations, the United Kingdom National Health Service and the US Military Health System. These case studies introduce concepts for and demonstrate the importance of understanding the organizational context for implementing good information security practice. Drawing from the work of Scott Snook (2000), we consider efforts to reform healthcare information security practice at the individual, group and organizational levels of action as well as across levels in the case studies.

TRADITIONAL INFORMATION PROTECTION SAFEGUARDS

With the wide-spread use and integration of information technology into the operations of most organizations, failures in information security have commonly compromised operations, resulted in financial losses and besmirched reputations. To improve information technology security, a body of knowledge has developed that includes policies, procedures, best practices and administrative, physical and technical controls. This body of knowledge has been codified in a number of places including: 1. *An Introduction to Computer Security: The NIST Handbook* (National Institute of Technology and Standards [NIST] 1995), 2.

ISO/IEC 27002 *Information technology - Security techniques - Code of practice for information security management* (2005), 3. Information Security Forum *The Standard for Good Practice for Information Security* (2007) and in Federal regulations such as the Federal Information Security Management Act (FISMA) (2002) and HIPAA Security Standard (HHS 2003).

To improve the performance of information technology security, it is essential to understand what impacts performance in this area. A search of the World Wide Web and information technology literature yields surveys that attempt to identify and assess issues of information security. Prominent surveys in English include:

a. UK Department of Trade and Industry (2006) Information Security Breaches Survey 2006 – PWC
b. National Association of States (2006) Chief Information Officers Strategic Cyber Security Survey 2006
c. Information Technology Association (2006) Survey of American Federal Chief Information Officers 2006
d. Deloitte (2006) Global Security Survey of Global Financial Services Industry 2006
e. Computer Security Institute (2002, 2003, 2004, 2005, 2006, and 2007) Annual Computer Crime and Security Survey 2002-2007

These surveys asked questions about implementing technology, best practices, physical security, security controls, security training and awareness, adequacy of budgets, staff skills and the attitudes of corporate senior management towards information security. While each survey varied considerably in its level of detail, all asked questions in certain areas of information security. None of the surveys appeared to have been designed to be comprehensive or to cover the complete set of practices as codified in any of the cited bodies of knowledge. Rather, they tended to be based on a limited set of categories and often focused on those areas commonly reported in the media with a sensational impact. They often sought to determine the most commonly experienced types and costs incurred with exploited vulnerabilities rather than elucidating their root causes. (See Table 1)

The categories of survey question can be separated into three groups that represent a rough rank order of consensus about concern: Group I (High Consensus) - topics investigated by four or five of the surveys; Group II (Medium Consensus) – topics investigated by three of the surveys, and; Group III (Low Consensus) – topics investigated by only one or two of the surveys.

High consensus of concern was found in the surveys that organizations must allocate resources for security as a necessary business expense. Organizations must develop plans to protect and recover from damage to their information and information management systems using administrative, physical and technical safeguards. At the operational level, organizational staff must learn about their information security roles and responsibilities. The IT program must monitor, interpret, document and report on the flow of events in their systems as the first line of enforcement defense. These activities all require staff, time, money and, thus, an information security budget.

Medium consensus of concern was found in the surveys that organizations should implement three types of good information security practice: Risk Assessment, Incident Management, and Technical Control Mechanisms. All organizations should examine threats to the privacy and security of information, vulnerabilities in information security defenses, and the consequences of an information security breach for customers and business. They should identify what administrative and technical mechanisms exist to prevent security breaches as well as how organizations recognize, document, report and manage incidents. The surveys also express moderate consensus about Compliance with Laws and Insurance Policies, two areas of traditional and important corporate risk manage-

Table 1. Question asked by prominent surveys in English

Question Categories	Surveys				
High Consensus	**A**	**B**	**C**	**D**	**E**
Security Budget	X	X	X	X	X
Training & Awareness	X	X	X	X	X
Security Plans	X	X	X	X	
Business Continuity Plans	X	X	X	X	
Audits	X		X	X	X
Physical Controls	X	X	X		X
Medium Consensus					
Compliance with Laws	X	X			X
Insurance Policies	X		X		X
Incident Management	X	X			X
Risk Assessment & Management	X	X		X	
Technical Controls	X	X			X
Low Consensus					
Security in IT Architecture		X	X		
Plan Supports Organization Mission		X	X		
Effectiveness Evaluations		X		X	
Inventory of Systems				X	
Security Standards	X				

ment. Relative to the other ten topics: Security in IT Architecture, Evaluation of Effectiveness Security Standards, Maintaining Inventory of IT Systems and Plans Support the Organizational Mission warranted low consensus of concern.

The HIPAA security rules include thirteen of the sixteen topics meriting investigation by any of these surveys, including all of the topics in Group I (Security Budget, Training and Awareness, Security Plans, Business Continuity Plans, Audits and Physical Security); four of the five topics in Group II (Compliance with Laws, Incident Management, Risk Assessment, Control Mechanisms) and three of five topics in Group III (Effectiveness Evaluations, Inventory of Systems, and Security Standards). HIPAA does not reference insurance policies, security in IT architecture or plan supports organizational mission. HIPAA does impose several requirements not included in these surveys, including most critically, requirements about sharing patient information with third parties (a "privacy-related" topic). HIPAA also assigns a higher priority than the survey consensus of concern rankings to risk assessment and risk management, two standards that constitute the foundation of overall HIPAA security compliance and health information protection.

Under FISMA, agencies of the United States Federal government must annually report their performance according to a set of criteria released by the Office of Management and Budget (OMB). Although OMB issues specific reporting instructions each year, a core set of criteria has emerged with updates to reflect current issues such as the physical security of laptops. For FISMA, the reports have included eleven of the sixteen survey topics, including four of the five topics in Group I (Security Budget, Training and

Awareness, Security Plans, and Business Continuity Plans); three of the five topics in Group II (Incident Management, Risk Assessment, Control Mechanisms) and four of five topics in Group III (IT Architecture, Effectiveness Evaluations, Inventory of Systems, and Security Standards). During the five years of reporting, FISMA has not requested measures of Auditing, Compliance with Laws, Insurance Policies or Plan Supports the Mission. FISMA does require agencies to report on their Plans of Action and Milestones, a document meant to guide and mark correction of deficiencies in their security plan implementation as well as security of contractors' operations, Privacy Reports and agency plans for emerging technologies and threats. FISMA requires all non-security systems in US agencies to comply with Federal Information Processing Standards and to use as guides for program development the special publications on information security of the National Institute of Standards and Technology (see http://csrc.nist.gov/).

Taken as a group, these surveys indicate an overall consensus on topics of concern with more than half of all surveys as well as HIPAA and FISMA agreeing on ten of the sixteen topics. Most of the survey questions derive from regulatory requirements or authoritative guidance about the actual performance of information security in various commercial or governmental domains. Although highly relevant to their purpose of surveying compliance with specific regulations or good information security practice, these surveys ignore a range of questions about the organizational context of information security practice. They also take for granted how organizations mobilize to implement reforms. Yet, from the perspective of healthcare leaders, these issues are critical for successful performance. On the one hand, organizational conditions outside the narrow domain of information security potentially threaten the confidentiality, integrity or availability of information. On the other hand, reforming established practices of information security to comply with new mandates requires vibrant leadership and extensive work at all levels of an organization. How should we think about these two issues?

BEYOND TRADITIONAL INFORMATION PRIVACY AND SECURITY SAFEGUARDS

Since Charles Perrow's (1999) classic study of "normal accidents", social scientists have been debating the feasibility and methods for designing and safely operating complex technological systems. While acknowledging the structural difficulties of managing complex systems, "High Reliability" or "High Resiliency" theorists (HRT) argue that strong leadership, continuous training and practice, redundant safety mechanisms, and organizational mindfulness create cultures of safety that prevent catastrophic accidents and allow organizations to learn from their mistakes (Wildavsky 1988; Weick and Sutcliffe 2001; Collmann and Cooper 2007; Cooper, Collmann and Niedermeyer, in press). Normal Accident Theorists (NAT) argues that complex, tightly coupled systems inevitably produce system accidents that are difficult if not impossible for human operators to manage (Sagan 1993; Rochlin 1997; Snook 2000). Complex systems include many diverse components interconnected in multiple ways. Tightly coupled systems exhibit few gaps enabling rapid system operation and process flow, and, in the event of error, allowing local human and technical failures to escalate into larger-scale accidents with implications for the system as a whole. Thus, complex, tightly coupled systems often preclude even well-trained operators from effectively tracking and preventing system accidents with catastrophic consequences. These analyses converge in recognizing our contemporary dependence on complex technological systems and the need for great care in their management. Scott Snook (2001), who has drawn extensively from both approaches, recasts the problem in the form of an important question: "What are the critical design features of a hyper-complex, multi-level, multi-task, organizational system that will increase the likelihood of accomplishing the "total task" consistently?" (p. 235). All these questions may be asked of electronic healthcare record systems because they function as complex and tightly coupled technological systems and require highly reliable management systems to avoid and recover from accidents (Collmann, Alaoui, Nguyen, and Lindisch 2005; Collmann and Cooper 2007; Cooper, Collmann and Neidermeyer, in press).

Much guidance has emerged for healthcare organizations about what new policies, procedures and practices they should adopt (Cooper, Collmann and Demster 2007). From a strategic perspective, however, this guidance does not address how healthcare organizations should envision the mobilization effort itself. For this question, the literature on social movements provides some guidance, particularly its focus on fostering novel or reformed activities, knowledge and social relationships. Sociologists typically describe "social movements" as activities that seek to create new ways of behaving and new relationships, including such examples as the American Civil Rights Movement or the global environmental movement. Although they may create new organizations to help accomplish their aims, people engaging in social movement action typically work "in the street" and outside the boundaries of the specific organizations they seek to change. From a sociological perspective, social movements represent examples of "collective behavior" rather than "formal organization". In contrast to much of the social movement literature, analyzing health information security reform requires describing the conditions under which formal organizations with established routines, bodies of knowledge and organizational relationships intentionally and effectively change in response to new mandates. Although a minority of thought leaders in healthcare recognized the need for effective health information security programs as part of computerizing patient records, many others required the motivation of Federal regulations as embodied in the privacy and security rules of the HIPAA to act. Thus, once the HIPAA regulations were published and compliance dates set, many healthcare organizations faced the problem of mobilizing their compliance effort and, beyond that, achieving genuine changes in the activities, knowledge and social relationships through which they protected the privacy and security of patient information. We have developed the concept of "sponsored social movement" to aid in interpreting this paradoxical situation that seems to require "top-down" as well as "grassroots" action.

Case 1: Group Logon with a Smartcard in the UK EHR

Scott Snook (2000) developed a set of core concepts about organizational performance in his analysis of the incident in which two US Army Blackhawk helicopters were shot down by US Air Force jets during Operation Provide Comfort (OPC) over northern Iraq on 14 April 1994. After analyzing specific reasons for this incident at the individual, group and organizational level, Snook introduces the core concept of "practical action" to describe a process that operated across all levels of OPC. By practical action, Snook (2001) means "behavior that is locally efficient, acquired in practice and legitimized through unremarkable repetition" (p. 182). This concept helps explain how the original design of OPC changed from its inception in the Pentagon through three years of implementation in Iraq to the day the helicopters were shot down. As the American service personnel attempted to do their jobs in OPC, they gradually adapted the policies and procedures required by the multi-layered OPC plan to "life in the real world". For example, the OPC plan required Air Force jets to enter the protected air space over northern Iraq in the morning before any other allied aircraft. It also required all aircraft entering the airspace to file a flight plan indicating their schedule as well as points of origin and destination. An Air Force Airborne Warning and Control Systems plane (AWAC) was supposed to track all these events and maintain situational awareness of the airspace. Army helicopters functioned as airborne taxicabs for high profile customers such as the United Nations personnel killed during the shoot down. In order to meet their customers' needs, the helicopters came and went as they pleased without regard for the policies and procedures of the OPC plan. Indeed, by the time of the accident, several generations of Army helicopter pilots had cycled through northern Iraq. Over the generations they developed their "customer-focus", trained new pilots in their adapted procedures and satisfied their customers without incident, at least until 14 April 1994. Snook (2001) coins the term "practical drift" to refer to this "slow steady uncoupling of practice from written procedure" (p. 194). Instead of being tightly-coupled and rule-driven as specified in the OPC plan, daily life in Northern Iraq became loosely-coupled and task-driven. The shoot down occurred on a day when certain personnel invoked a design rule (jets first in protected space) at the expense of personnel who were acting according to locally efficient practices (take care of your customers) under the gaze of a distracted AWAC crew.

Snook's case study refers to an event that occurred in a social system that was designed and implemented from scratch, Operation Provide Comfort. In such circumstances, change occurs with reference to a formal design and clear implementation starting point. Organizational leaders attempting to implement a reform in current practice face a different situation: "behavior that is locally efficient, acquired in practice and legitimized through unremarkable repetition" (Snook 2001, p. 182) already exists and dominates the reform target area. In Snook's terms, they are attempting to modify institutionalized task-driven, loosely-coupled activities to comply with a new design. The reform designs often envision a developmental cycle of events with the intention of reconfiguring daily practice in line with explicit new laws, rules or regulations such as HIPAA. "Compliance" means following the designed rules and, often, abandoning "behavior that is locally efficient, acquired in practice and legitimized through unremarkable repetition." (Snook 2001, p. 182) We have developed two concepts to help interpret the dynamics of this confrontation between the reform design and existing, locally-efficient behaviors, "practical resistance" and "sponsored social movement".

"Practical resistance" or the unwillingness to change established task-based, loosely coupled practices in response to reform programs potentially emerges when a reform design encounters the practical action already dominating the target area. Adapting Snook's explanation of practical action to this different context, we observe that practical resistance may emerge as local actors resist changing locally efficient practices developed with experience, potentially subvert compliance efforts in daily practice, and tacitly or explicitly protest against proposed changes. We observe such practical resistance widely in attempts to improve information security policies, including but not limited to the healthcare industry.

The House of Commons (2007) 2007 Report on the Electronic Health Record (EHR) of the British National Health System (NHS) describes a clear example of practical resistance in the implementation of smartcard access. The South Warwickshire General Hospitals NHS Trust (2007) decided to permit its staff in the Accident and Emergency (A&E) Department to logon to the hospital's EHR as a unit for an entire shift using a single smartcard. Although officially permitted by the hospital leadership, it violated the NHS EHR principle of a unique smart card for each user. From the perspective of practical resistance, the hospital justified its decision on the fact that logging on with the smartcard required 60-90 seconds per logon, an unacceptable delay in the context of a busy emergency room. The EHR

Report (House of Commons 2007) presents the terms of the debate nicely in report paragraphs 217-219 as follows:

217. The Assistant Information Commissioner acknowledged that local security breaches of this type had occurred and stated clearly that the sharing of smartcards represented an unacceptable breach of operational security systems: …there have been some graphic examples where perhaps security precautions have been circumvented by people logging on for a whole shift, using one card rather than their own cards. That must be stamped out; there cannot be any of that.

218. But other witnesses argued that the misuse of smartcards would prove inevitable unless they could provide immediate access to systems. Dr Paul Cundy commented that unless "instantaneous" access to DCR systems could be achieved, smartcards would inevitably be seen as an "obstacle" to clinical processes, particularly in a busy, multidisciplinary environment such as A&E. It is notable that the justification given for sharing smartcards by the acute trust board in Warwickshire was that access to the new PAS application could take between 60 and 90 seconds.

219. CSC (Computer Sciences Corporation), the LSP (local service provider) for the West Midlands area, acknowledged that smartcard sharing had resulted from slow access times. Guy Hains commented: The sharing of smart cards was really about the fact that the system did not provide a sufficiently immediate log on for people who wanted to use the system quickly…we recognize the need for a smart card log on procedure of 10 seconds. (p. 75)

A better example of the issues at stake in practical resistance does not exist. Throughout the world, smartcards are accepted as an effective, relatively easy-to-use means for controlling access to electronic information systems. Yet, in this context, because of the extended time necessary to logon, the smartcard obviously interfered with "behavior that is locally efficient, acquired in practice and legitimized through unremarkable repetition" (Snook 2001, p. 182); that is, rapid access to the computer workstation for processing high volumes of patients in an emergency room. This case appears particularly interesting because the practical resistance to the formal procedure occurred at all levels of the hospital from the Board that approved the policy to the A&E staff who had to use the smartcards to the IT staff who helped install the new system. In spite of this evident consensus at the local level, the Assistant Information Commissioner, a high official in the NHS far removed from the scene, highly disapproved and insisted that such practices "must be stamped out; there cannot be any of that." (House of Commons, 2007, p.75)

Case 2: Lessons Learned from HIPAA in the American Military Health System

The concept of bureaucratic reform as "sponsored social movement" seems paradoxical. In some respects, it implies "top down" reform with senior leadership attempting to mobilize change from within. In other respects, it implies "grassroots" activity with local groups organizing demands and means for organizational change. For example, many healthcare organizations experienced the HIPAA privacy and security rules as unfunded mandates. In an already tight financial situation, the Federal government imposed new requirements that necessitated assigning people, time and money to work for which nobody necessarily planned or budgeted. Moreover, HIPAA compliance work could not easily be assigned to existing organizational structures such as the information technology department because it entailed changes in policy and procedures as well as technology, changes that required review and discussion by the many different constituencies composing modern healthcare organizations, including patients and vendors as well as employees and consultants. Thus, organizations had to "sponsor" HIPAA.

Mobilizing such efforts, however, bear many of the hallmarks of "social movements." Social movements generally press for changes in ways of thinking, social practices and social structures but emanate from the grassroots. For example, the American Civil Rights Movement attempted, among other things, to undermine racial prejudice, promote racial integration in public institutions, and eliminate all forms of legal segregation. Demand for these changes emerged from multiple sources within both the black and white communities, including churches, labor unions and other forms of formal organization. The Civil Rights Movement produced national, regional and local champions who targeted certain social practices and institutions for focused attention and mobilized new social groupings through which they sought a generalized change in the American way of life. Social conflict emerged, often in brutally physical forms, and over a long period, major changes occurred in relations among black and white Americans. In the context of bureaucratic change, even "sponsored" reforms require champions working at all levels of the organization to translate the requirements into practice and overcome practical resistance. HIPAA compliance encounters practical resistance because it competes with the routine business of healthcare, engenders conflict, and thus, fights for its bureaucratic life. Without concerted "grassroots" effort by champions at many levels of the organization, the HIPAA reforms cannot survive or may become mere compliance efforts that change little in the structure or practice of health information security.

In large, complex organizations, bureaucratic reforms such as HIPAA depend upon changes at multiple levels of the organization including individual, group and organizational levels. The concepts of practical resistance and sponsored social movement apply across the levels, to each level and to segments within levels as well as the organization as a whole. In a fundamental sense, practical resistance to bureaucratic reforms necessitates mobilizing reforms through sponsored social movements. The interaction of practical resistance and sponsored social movement yields a complex political field marked by reform sponsors, reform resisters, reformed practices, and residual, now deviant practices. The long term fate of specific reforms depends on how the interaction of practical resistance and sponsored social movement among all these different activities, actors, interests and organizational levels evolves over time.

We observe this complexity in the successful effort to change health information security policies, procedures and practices for the US Department of Defense (DoD) Military Health System (MHS) to comply with the HIPAA privacy and security regulations. (US Air Force Medical Service 2003)

Organizational Level

The MHS officially sponsored and coordinated the defense HIPAA reforms using a common format known as the HIPAA Integrated Project Team or HIPAA IPT. (Kelly 2002) The HIPAA IPT received an official charter with requirements and formally appointed members representing key stakeholders, including the Army, Navy and Air Force Surgeons General and key components of the Office of the Assistant Secretary of Defense (Health Affairs). As each set of rules under the HIPAA Administrative Simplification provisions emerged, the HIPAA IPT spawned Working IPTs (WIPTs) to devote specialized attention to each one, including transactions and code sets, privacy and security. Again the WIPTs included a charter with requirements and officially appointed members representing key stakeholders, many of whom served on all four teams. These teams met monthly.

In addition to the officially appointed members, supporting staff and consultants attended the monthly meetings and performed much of the background work. Occasionally, representatives of stakeholders potentially affected by but not directly implicated in HIPAA would also attend. The HIPAA IPT and three WIPTs established the strategic direction as well as specific lines of work in sponsoring the MHS HIPAA compliance effort, such as drafting and coordinating HIPAA-related DoD policies, implementation guides and training materials. The HIPAA IPT coordinated major investments in enterprise capabilities such as computerized HIPAA training and compliance management systems. The HIPAA IPT funneled centrally-provided funds to MHS and service HIPAA efforts. The HIPAA IPT and the three WIPTs also functioned as platforms for presenting, discussing and sponsoring tools, meetings, and educational efforts funded by other MHS or service agencies. As the primary forums for addressing strategic compliance efforts, the HIPAA IPT and WIPT meetings created conditions and opportunities for conflict among participating constituencies but, from a global perspective, accomplished their objectives in planning and implementing the MHS HIPAA compliance effort.

As a Federally-mandated requirement, none of the military medical services could ignore HIPAA. Thus, each service formulated its own HIPAA-compliance effort that included sending representatives to the HIPAA IPT and WIPT meetings. Yet, depending on the specific HIPAA rule set, to different degrees they did or did not follow the lead of the HIPAA IPT and WIPTS. Each was subject to dynamic service-specific conditions that affected both their approach to HIPAA in general and their manner of participation in the various HIPAA WIPTs. These service-specific conditions produced differences in their individual interpretations of HIPAA, the new efforts they thought necessary and, thus, the extent of their "sponsorship" of HIPAA reforms within their own services. For the HIPAA Transaction and Code Set rule, the MHS and services shared common interests given the complete novelty of the requirements and its limited impact on daily operations beyond the billing operation. The HIPAA Privacy regulation built on the experience of the MHS with the Privacy Act but instituted new practices some of whose implementation could be centrally-funded and broadly shared such as posting of the Notice of Privacy Practices and training. Points of contention and practical resistance emerged where the HIPAA privacy regulations required extensive new effort at the local level as with disclosure tracking. Because it potentially required investment of new resources of time, effort and funds at the local MTF level, HIPAA Security provoked the greatest variation and controversy, particularly the requirement to conduct a local information security risk assessment.

With the engagement of MTF resources, organizational "sponsorship" required concurrence of regional and local as well as headquarters leadership. For one service, regional and local "pushback" produced a judgment that existing procedures sufficed and, thus, HIPAA security warranted no new investment of local resources. This delayed progress on implementing key HIPAA Security WIPT-approved programs in that particular service for many months. For the other services, the majority of regions and MTFs eventually concurred but at varying rates, with varying degrees of enthusiasm and with varying degrees of effectiveness. Working these new tasks into the local work routine required making adjustments in local priorities and resource allocation as well as fostering new groups. Thus, practical resistance expressed as regional and local priorities conditioned the distributed impact of strong central sponsorship from MHS and service senior leadership.

Group Level

The DoD HIPAA Security campaign required creating new groups at the MTF level, known as the Medical Information Security Readiness Teams (MISRT) (Jenkins 2002; Randolph 2004; department of the Army 2003). Envisioned as an interdisciplinary team of clinicians, medical records managers and information technologists, the MISRT were intended to function as local facilitators, staff and advocates for the MHS HIPAA security campaign. Their primary responsibilities included executing the MTF information security risk assessments, developing and implementing the plan to close gaps in the MTF's HIPAA security compliance, and securing command support for the results of their work. They brought the HIPAA security social movement to the local MTF level. Many conditions affected their ability to accomplish their tasks and mobilize HIPAA security at their MTFs.

First, by virtue of being interdisciplinary with only one of three constituencies avowedly "expert" in computerized information systems, the MISRT required training in HIPAA security and the information security risk assessment method (Jenkins 2002; Randolph 2004). Multiple rounds of training accomplished this task for over 1500 individuals from all MTFs around the globe. Second, given that the MISRTs work required adding new tasks to already full workdays, a strong mandate had to exist in order to justify diverting them from their primary tasks. When the training started in January, 2001, release of the final HIPAA security regulations seemed imminent and a strong sense of urgency existed at all levels of MHS and service leadership. Upon repeated delay of the security regulations' release, the sense of urgency and accompanying mandate waned. When the Department of Health and Human Services (DHHS) ultimately released the privacy regulations before the security regulations, the mandate shifted from security to privacy. Because HIPAA required established security controls in support of privacy, training in risk assessment continued but the actual privacy work took precedence and preempted almost all effort on risk assessment. Third, service personnel in the US military do not stay long in one post, least of all officers. With the emergence of privacy and subsequent delay in security-oriented work, many of the trained MISRT individuals transferred to new assignments. In some cases, trained individuals assumed new positions that permitted them to be reassigned to the MISRT. In many cases, however, the military mandate to diversify officers' work experience shifted trained MISRT individuals away from the HIPAA effort entirely. Fourth, thanks to the attacks on 11 September 2001, the United States went to war. Thus, in addition to experiencing turnover from the normal process of reassignment, many MTFs lost trained MISRT to deployment in support of the wars in Afghanistan and Iraq. Thus, during the period 2001-2004, conditions did not favor effectively establishing the MISRT at the MTF level.

Individual Level

The concept of "career" helps link individuals to the HIPAA security social movement. With the possible exception of local military IT staff, HIPAA tasks of whatever sort constituted an extra duty for military personnel not recognized in their job descriptions or necessarily acknowledged in considerations for promotion. Indeed, observations suggest that failures in activities like HIPAA compliance work can hurt but successes have little or no effect on chances for advancement. Consequently, service personnel have little personal or professional interest in diverting their attention from their regular assigned to new HIPAA-related duties. As a result, they seek others who can execute most of the work while they adopt a supervisory role. Consultants or government workers frequently fill this role. Thus, "sponsoring the social movement" at the local level often included providing consultants who could perform or, at least, facilitate performance of the new tasks. Because conducting the risk assessment required soliciting, interpreting and acting upon local funds of knowledge held primarily by military personnel, a conflict existed between the requirements of the task and the career requirements of military personnel participating in the MISRT. Moreover, responsibility for fostering the social movement shifted from members of the organization to outsiders with minimal authority or respect. These conditions sometimes produced what experienced military personnel know as "pencil whipping", performing the least work necessary to be said to have accomplished the task. Where military or consultant champions existed, local MTFs accomplished much beyond the minimum necessary compliance work.

To its credit, the MHS achieved its mission and compliance for all three elements of the HIPAA Administrative Simplification section on time. In the transition from achieving initial compliance to sustaining HIPAA, the MHS formed and fully staffed the TMA Privacy Office in order to continue sponsoring the HIPAA privacy and security reforms (see http://www.tricare.mil/tmaprivacy/default.cfm). This office continues to sponsor monthly meetings of HIPAA service representatives and a variety of activities in support of central, service and MTF compliance. Snook's analysis would lead us to begin checking for "practical drift" or the "slow steady uncoupling of practice from written procedure" as services and MTFs adapt their HIPAA practices to work with locally practical actions, at least until some incident occurs that highlights the differences between design and implementation some place across the MHS.

Interpreting sponsored social movement and practical resistance as paired concepts helps us recognize the fundamentally political character of bureaucratic reform. For every sponsor or grassroots champion of a reform, we find many practical resisters. From the perspective of sponsors, grassroots champions, oversight officers, and reformers, practical resisters seem like recalcitrant impediments to achieving the desired end state. From the perspective of practical resisters, however, the reforms may pose new and unnecessary barriers to accomplishing their primary obligations such as patient care in a locally efficient manner. In the case of HIPAA, FISMA and similar information security reforms, few people quarrel with the desire to protect the privacy and ensure the security of personal health information. Yet, some procedures developed as part of the reform effort interfere with the work that the overall system exists to accomplish, at least from the worker's point of view. "Compliance" with the requirements of bureaucratic reform, thus, unfolds as the emergent result of these ongoing negotiations.

TRANSCENDING THE LIMITS OF TRADITIONAL INFORMATION SECURITY

Healthcare organizations take confidence that, by implementing common good information security practices such as risk management, staff training, technical and physical controls, they adequately protect patient health information. However, deep-rooted relationships among organizational culture, information system design, and health information security generate both unexpected threats and resistance to reform in the practice of information security. An organization may assess issues that originate outside the bounds of traditional information security concerns by evaluating its operations and culture from a sociological perspective.

Karl Weick and Kathleen Sutcliffe (2001) attribute the success of High Reliability Organizations (HROs) in managing the unexpected to their "determined efforts to act mindfully." (p.3) They caution that, in all cases, failures are inevitable but should not necessarily be disabling. For an organization to recover from failure, however, it must be "mindful" of, and interrupt failure's emergence in their everyday operations. HROs "organize themselves in such a way that they are better able to notice the unexpected in the making and halting development. If they have difficulty halting the development of the unexpected, they focus on containing it. And if some of the unexpected breaks through the containment, they focus on resilience and swift restoration of system functioning." (p. 3) Weick and Sutcliffe (2001) identify five specific features that characterize mindful HROs, including:

1. **Preoccupation with failure:** HROs recognize that any lapse could be a symptom that something is wrong with the system and, if other small errors happen to coincide, severe consequences could result. To avoid this situation, they encourage reporting of errors, determining lessons learned from near misses, being wary of complacency, reducing margins of safety and drifting into automatic processing.
2. **Reluctance to simplify interpretations:** HROs take deliberate steps to simplify less and see more. They encourage those with diverse experience to cross boundaries, express skepticism toward received wisdom and to use negotiating tactics that reconcile differences in opinion yet preserve the nuances that diverse skills and knowledge detect.
3. **Sensitivity to operations:** HROs recognize that latent failures exist in the system's defenses, barriers and safeguards and that they may become manifest in inconsequential ways prior to a major accident. HROs expect normal operations to reveal such deficiencies as "free lessons" and incorporate them into their organizational safety program. Encouraging well-developed situational awareness permits continuous adjustments and prevents such errors from accumulating and enlarging.
4. **Commitment to resilience:** HROs experience but are not disabled by errors. In addition to encouraging experts to develop skills that cross domains and participate in frequent training, HROs formally assess worst case scenarios and use the equivalent of fire drills to test their ability to address these scenarios.
5. **Deference to expertise:** To prevent the deadly scenario where errors at higher levels combine with errors at lower levels of an organization to make problems catastrophic, HROs seek out the front line individuals with specific knowledge of the situation and the individuals with the most expertise, regardless of experience or rank. Decisions are made on the front line with authority coming from the experts.

Weick and Sutcliffe (2001) propose that organizations assess themselves for mindfulness by the use of an audit. We applied this approach by identifying behaviors in health information management and health information security indicative of mindfulness. To formulate our mindfulness questions, we used as guides the audit questions for the five areas of resiliency presented in Weick and Sutcliffe (p. 85-115). We suggest that health care executives use these questions as guides to evaluating their health information security programs in terms beyond the narrow orthodoxy illustrated by the previously discussed surveys The more frequently an organization answers "Yes" to these questions, the more mindfully they operate in the domain of information security. Yet, if taken in the proper spirit, answering these questions will help identify areas of relative mindlessness and, thus, of concern. At one extreme, we raise the possibility of organizations who address information security from a mere "compliance" perspective. Indifferent to the actual protection of their patient data, they only want to "pass the test". At the other extreme, we envision organizations that recognize the possibility of information security as a part of the "total task". Such organizations will mindfully attempt to reconcile the demands of information security and clinical care and, thus, minimize practical resistance such as witnessed with smartcards in the UK NHS EHR.

The audit's five section headings refer to the five characteristics of mindfulness explained above (for example, I. Assessing Your Firm's Preoccupation with Failure). The numbered statements (for example, "1. People in this organization expect, and look for a major information security breach to occur eventually.") originate from the self-audit of Weick and Sutcliffe. We have revised their questions related to mindfulness to refer specifically to information security practice. After completing the survey and developing a general picture of its information security mindfulness profile, an organization should select key issues for more detailed review, particularly but not exclusively questions that receive "No" for an answer. Areas in which an organization feels it displays strong qualities of mindfulness might offer lessons to less well-developed areas and, thus, also warrant detailed review.

MINDFULNESS IN INFORMATION SECURITY AUDIT

Please answer "Yes" or "No" for each question.

- Assessing Your Firm's Preoccupation with Failure.
    1. We focus more on information security outcomes than compliance with regulations?
    2. We treat near misses and errors as information about the health of our information security program and try to learn from them?
    3. We make it hard for security violations to go unnoticed?
    4. Managers seek out and encourage bad news about our information security program?
    5. People feel free to talk to superiors about problems with our information security program, including how it disrupts clinical practice?
    6. People are rewarded if they spot problems, mistakes, errors, or failures in our information security program?
- Assessing Your Firm's Reluctance to Simplify.
    1. People in this organization seek and expect major information security breaches to occur?
    2. Our leadership regularly queries the staff about possible deficiencies in our information security program?
    3. We actively seek opportunities to improve information security policies, procedures and practices?
    4. People in this organization feel free to bring up problems and tough issues in our information security program?
    5. Our organization thoroughly investigates actual and near miss security breaches?
    6. People are encouraged to express different views of the impact and effectiveness of the information security program?
    7. People listen carefully to all perspectives on the information security program?
    8. People are not punished for surfacing information security issues that could interrupt operations?
    9. When an information security incident occurs, people are more concerned with listening and conducting a complete analysis of the situation than with advocating for their view?
    10. We appreciate skeptics of the design and implementation of the information security program?
    11. People demonstrate trust in each other during discussions of information security issues and incidents?
    12. People show a great deal of mutual respect for each other when discuss-

ing information security issues and incidents?

- Assessing Your Firm's Sensitivity to Operations.
    1. Someone pays attention daily to information security and remains readily available for consultation if something unexpected arises?
    2. Should an information security incident occur, someone with the authority to act is always accessible and available, especially to people on the front lines?
    3. Supervisors readily engage in managing information security incidents?
    4. People openly discuss information security issues during their day-to-day activities?
    5. People are always looking for feedback about things that do not go as expected with the information security program?
    6. People are familiar with information security operations beyond their own job?
    7. We have access to resources if unexpected information security surprises emerge?
    8. Managers constantly monitor workloads and obtain additional resources if an information security issue requires extra attention and work?
- Assessing Your Firm's Commitment to Resilience.
    1. We devote great attention to assessing and analyzing information security risks?
    2. We devote resources continually to training and retraining people on the properties of the information security technical system?
    3. People have more than enough training and experience in information security?
    4. This organization actively develops staff members' skills and knowledge in information security?
    5. This organization encourages challenging stretch assignments when promoting people through the security ranks?
    6. People are known for their ability to use knowledge in novel ways when addressing information security issues, incidents and problems?
    7. This organization builds staff member competence and response repertoires in the domain of information security?
    8. People draw upon informal contacts to help solve information security problems?
    9. People learn from their information security mistakes, breaches and incidents?
    10. People are able to rely on others when attempting to solve information security problems?
- Assessing the Deference to Expertise in Your Firm.
    1. People are committed to doing information security well?
    2. People respect the information security dimension of each other's job activities?
    3. If an information security incident occurs, people know who has the expertise to respond competently?
    4. People in this organization value expertise and experience over hierarchical rank when addressing mistakes, breaches and incidents in information security?
    5. In this organization, the people most qualified to make decisions about information security make them?
    6. If an information security incident occurs, the most highly qualified

people, regardless of rank, make the decisions?

7. People typically "own" an information security problem until it is resolved?
8. It is generally easy for us to obtain expert information security assistance when something comes up that we don't know how to handle?

CONCLUSION

In this chapter, we offer a broad perspective on information security that links traditional, widely-accepted practices with the sociological literature on organizational performance. Our experience suggests two reasons for adopting a broader perspective. First, serious information security breaches may originate from organizational conditions not obviously related to traditional information security policies, procedures or practices (Collmann and Cooper 2006). For example, the failure to integrate new application development and implementation into an organization's overall information management program may inadvertently yield security breaches. Second, information security practices operate in, and are affected by the context of their parent organization (Cooper and Collmann, in press). Although it is sometimes tempting to treat information security as a domain of its own, this approach will inevitably yield failures of information security and failures for the organization. For these reasons, we offer in the chapter a survey to help health care executives link the domain of traditional information security good practice to its organizational context while planning, developing and evaluating efforts to protect the privacy and security of their patient and business health information.

We began our study with references to High Reliability Theory. In recent years, the Software Engineering Institute (SEI) has conducted an important series of studies designed to improve the resiliency of organizational information security programs through engineering design. With origins in efforts to develop self-directed information security risk assessments and understand network survivability, the SEI Resiliency Engineering Framework Team recently issued a preview version of the *CERT® Resiliency Engineering Framework* (2008). In many important ways, this work supports and converges with the approach outlined in this chapter, particularly in its attempt to integrate SEI's deep knowledge and long experience in computer science engineering in information protection with an organizational perspective. All healthcare executives should become aware of this body of work (see http://www.cert.org/resiliency_engineering). While not yet reduced to an implementable planning and design tool, the CERT Resiliency Framework should at least orient healthcare executives to specific issues in linking information protection programs to their organizational context. As a formal protocol for analysis and potential organizational change, the CERT Resiliency Framework goes beyond the objectives of this chapter. We are currently exploring the points of convergence and divergence between our approach and the CERT Resiliency Framework, particularly those rooted in differing images of "organizational context" and differing emphases on anticipation and response in the information protection developmental cycle. A middle ground must exist that enables formal protocols and meticulous examination of the flow of events to yield better methods for protecting sensitive personal and business information in complex organizations.

REFERENCES

Collmann, J., Alaoui, A., Nguyen, D., & Lindisch, D. (2005). Safe teleradiology: Information assurance as project planning methodology. *Journal of the American Medical Informatics Association*, *12*, 84–89. doi:10.1197/jamia.M1404

Collmann, J., Coleman, J., Sostrom, K., & Wright, W. (2004). Organizing safety: The conditions for successful information assurance programs. *Journal of Telemedicine and eHealth, 10*(3), 311-320.

Collmann, J., & Cooper, T. (2007). Breaching the security of the Kaiser permanente internet patient portal: The organizational foundations of information security. *Journal of the American Medical Informatics Association*, *14*, 239–243. doi:10.1197/jamia.M2195

Computer Security Institute. (2002). *Annual computer crime and security survey 2002*.

Computer Security Institute. (2003). *Annual computer crime and security survey 2003*.

Computer Security Institute. (2004). *Annual computer crime and security survey 2004*.

Computer Security Institute. (2005). *Annual computer crime and security survey 2005*.

Computer Security Institute. (2006). *Annual computer crime and security survey 2006*.

Computer Security Institute. (2007). *Annual computer crime and security survey 2007* .

Cooper, T., Collmann, J., & Demster, B. (2007). *The HIMSS privacy and security toolkit.* Retrieved from http://www.himss.org

Cooper, T., Collmann, J., & Neidermeier, H. (in press). Organizational repertoires and rites in health information security. *Cambridge Quarterly of Healthcare Ethics*.

Deloitte. (2006). *Global security survey of global financial services industry 2006*.

Department of Health and Human Services. (2000, December 28). Office of the Secretary. 45 CFR Part 160 and 164, *Standards for Privacy of Individually Identifiable Health Information: Final Rule* . *Federal Register*, *65*, 82462–82829.

Department of Health and Human Services. (2003, February 20). Office of the Secretary. 45 CFR Part 160, 162, and 164, *Security Standards: Final Rule. Federal Register*, *68*, 8333–8381.

Department of the Army. (2003, December 10). U.S. Army Medical Department Activity Fort Drum, New York, FD MEDDAC Reg. (pp. 40-45). *Medical Services, Protected Health Information and Privacy*. Retrieved from http://www.drum.amedd.army.mil/HIPAA/FD%20MEDDAC%20REG%2040-45.doc

Gostin, L. O., Turekbrezina, J., & Powers, M. (1993, November 24). Privacy and security of personal information in a new healthcare system. *Journal of the American Medical Association*, *270*(20), 2487–2493. doi:10.1001/jama.270.20.2487

House of Commons, Health Committee. (2007, July 25). *The electronic patient record, sixth report of session 2006–07*. Volume I Report, together with formal minutes.

Information Technology Association. (2006). *Survey of America federal chief information officers*.

Jenkins, S. (2004). *Health information privacy*. Health Information Management Systems Society annual meeting.

Kelly, B. (2002, February 4-7). Health insurance portability and accountability act of 1996: The commander's view. *Tricare Management Activity Conference*. Retrieved from www.tricare.mil/hipaa/downloads/OverviewBrief_TRICARE2002.ppt

Mandl, K. D., Kohane, I. S., & Brandt, A. M. (1998, September 15). Electronic patient-physician communication: Problems and promise. *Annals of Internal Medicine*, *129*(6), 495–500.

National Association of States. (2006). *Chief information officers strategic cyber security survey*.

Perrow, C. (1999). *Normal accidents: Living with high-risk technologies*. Princeton, NJ: Princeton University Press.

Randolph, L. (2002, June 18). *Memorandum to Deputy Surgeon General of the Army, Deputy Surgeon General of the Navy, and Deputy Surgeon General of the Air Force with subject "request to appoint military treatment facility/dental treatment facility health insurance portability and accountability act privacy officer."* Retrieved from http://www.trow.tma.osd.mil/TMAPrivacy/hipaa/hipaacompliance/images/pdf/Signed_HIPAA_PO_Appt_Letter.pdf

Resiliency Engineering Framework Team. Survivable Enterprise Management. (2008). *CERT® resiliency engineering framework, preview version, v0.95R, CERT program*. Pittsburgh, PA: Carnegie Mellon University. Retrieved from http://www.cert.org/resiliency_engineering/

Rochlin, G. I. (1997). *Trapped in the net: The unintended consequences of computerization*. Princeton, NJ: Princeton University Press.

Sagan, S. (1993). *The limits of safety: Organizations, accidents, and nuclear weapons*. Princeton, NJ: Princeton University Press.

Snook, S. (2000). *Friendly fire: The accidental shoot down of U.S. black hawks over Northern Iraq*. Princeton, NJ: Princeton University Press.

South Warwickshire General Hospitals Trust Board papers. (2007, January 4). *Progress report on solution to smartcard sharing*.

UK Department of Trade and Industry. (2006). *Information security breaches survey–PWC*.

U.S. Air Force Medical Service. (2003, April). *SG newswire*. Retrieved from http://airforcemedicine.afms.mil/sg_newswire/apr_03/HIPAAstandards.htm

Weick, K., & Sutcliffe, K. (2001). *Managing the unexpected: Assuring high performance in an age of complexity.* San Francisco: Jossey-Bass.

Weick, K., Sutcliffe, K., & Obstfeld, D. (1999). Organizing for high reliability: Processes of collective mindfulness. *Research in Organizational Behavior*, *21*, 81–123.

Wildavsky, A. (1988). *Searching for safety*. New Brunswick, NJ: Transaction Books.

KEY TERMS AND DEFINITIONS

Information Security: An established body of good practices developed to protect the confidentiality, integrity and availability of information.

Information Security Breach: A violation of organizational policies, procedures and established practices for protecting the confidentiality, integrity and availability of information.

Mindfulness: An organizational process that attends to small deviations from expected behavior and, thus, prevents small errors or failures from escalating into major catastrophes.

Normal Accident: A component or system failure that occurs because of the design and routine operation of the system itself rather than poor performance of individual operators.

Practical Action: Behavior that enables people to accomplish their tasks efficiently, is learned on the job and goes unquestioned because it generally works without incident.

Practical Resistance: Behavior through which people resist changing locally efficient practices developed with experience, potentially subvert compliance efforts in daily practice, and tacitly or explicitly protest against proposed changes to their standard way of doing business.

Sponsored Social Movement: A reform process that combines "top down" with "grassroots" efforts to change an existing organizational system.

This work was previously published in Handbook of Research on Information Technology Management and Clinical Data Administration in Healthcare, edited by A. Dwivedi, pp. 350-367, copyright 2009 by Medical Information Science Reference (an imprint of IGI Global).

Chapter 5.13

Demographic Differences in Telehealth Policy Outcomes

Mary Schmeida
The Cleveland Clinic, USA

Ramona McNeal
University of Northern Iowa, USA

ABSTRACT

This chapter is an analysis of demographic variables influencing policy outcomes with online health information searches in the general U.S. public. This study is based on The Internet and American Life Daily Tracking Survey, August 2006 from the Pew Research Center for the People and the Press. Multivariate regression statistical technique is used to explore changes in individual level behavior following the search for online medical information. The data show individuals in most need of healthcare services (poor, less educated, and minority groups) and those with a recent demand for services, are more likely to make changes to improve their health after accessing online medical information.

INTRODUCTION

The public sector in the U.S. is increasingly using the Internet to provide information, deliver services, and interact with citizens, businesses, and other government agencies (West, 2003, 2004). There are numerous reasons for the government adoption of electronic government (e-government) practices that "refer to the delivery of information and services via the Internet or other digital means" (West, 2004, pp 2). E-government is expected to deliver services and information around the clock, making government more efficient and transparent to the public (Tolbert and Mossberger, 2006; West, 2003). The adoption of these practices may make government more responsive through its ability to provide communication options that are quicker and more convenient for users (Thomas and Streib, 2003).

Telehealth is an important example of e-government that takes on many forms. Although there is no consensus on its definition, the United States Congress defines telehealth as the use of electronic information and telecommunication technology to support long-distance clinical healthcare; patient and professional health-related education; public healthcare and administration (U.S. House of Representatives 2157, 2001). In practice, telehealth is understood as the inclusion of telemedicine plus other on-line social services.

DOI: 10.4018/978-1-60566-002-8.ch036

Regardless of how telehealth is defined, this new medium for delivering medical services has been adopted with the goal to improve the accessibility of public and private healthcare, service quality and clinical outcomes. It is often implemented as a way to provide cost-effective healthcare. However, if we examine all the different aspects of telehealth in the U.S.—technology-enabled delivery, regulation and enabling legislation (state policies), and healthcare information available online, we find a unifying theme of broadening healthcare access. Telehealth practices may act to expand healthcare services through improving the dissemination of health information by Internet to the public, facilitating Internet based second opinions on disease management, improving consultative services to rural facilities and has the potential to reduce medical errors (Schmeida, 2005).

Despite the hopes for telehealth (as well as other forms of e-government), there is also a literature suggesting that these service delivery advancements will not live up to expectation. One barrier to the Internet for expanding healthcare access is the Internet cleavages that exist among United States citizens---people who do and do not use the Internet. These differences in Internet usage are based on a number of socioeconomic factors including age, income, education and race. The variation in Internet practices attributed to these socioeconomic factors has been linked to underlying inequalities in Internet access and technological skills, along with psychological barriers (Mossberger, Tolbert and Stansbury, 2003; Stanley, 2003). This suggests that e-government will only act to widen the gap between those that do and do not benefit from telehealth services.

Supporting this literature on Internet inequalities is research examining the differences in online health information searches among the various socioeconomic groups in the U.S. (Schmeida and McNeal, 2007). In exploring differences among socioeconomic groups in searching for Medicare and Medicaid information online, Schmeida and McNeal (2007; 2006) find some disparities are narrowing as the elderly and poor in need of these publicly subsidized health insurance programs are online searching for information at the U.S. Centers for Medicare & Medicaid Services Web site. Services and information obtainable at this Web site include eligibility criteria, enrollment procedures, Medicare plan options, local physicians and medical suppliers, pharmacy directory and healthcare chat rooms. In addition, beneficiaries can obtain personal information on their benefits and services. However, people without Internet access and experience, remain disadvantaged in accessing this critical information that can link them to needed healthcare services, suggesting that e-government service delivery advancements may not be living up to expectation.

This current research on Internet healthcare information and government services only represents an initial step in exploring the impact of online health searches and does not discuss the policy implication of these findings. To minimally understand the healthcare consequences of disparities in Internet usage in the U.S., one needs to examine if telehealth is changing how citizens take care of themselves and others. This chapter discusses these behavioral outcomes and the policy implications. In exploring this issue, this chapter will first examine the literature on barriers to the promises of e-government with a focus on the digital divide. Next, it will outline government policy toward eliminating barriers to Internet use. Finally, multivariate regression analysis will be used to empirically test the impact of one example of telehealth (seeking medical information online) and behavior directed toward improving and maintaining health.

THE REALITIES OF INTERNET USAGE IN THE UNITED STATES

Despite the promises of e-government, there is a literature suggesting there are barriers to realizing its possibilities in the United States. One reason is cleavages that exist between those who have and do not have access to this technology. These differences in access are referred to as the "digital divide." There is an extensive body of literature finding that Internet access is not distributed equally in the U.S. based on socioeconomic factors (Pew Internet & American Life Project, 2003; Mossberger, Tolbert and Stansbury, 2003).

Mossberger, Tolbert and Stansbury's (2003) research found gaps based on income, education, age and race/ ethnicity that continue to exist even after strides toward digital inclusion. The study indicated that Asian Americans had the highest predicted probability of access followed by whites with Latinos and African Americans significantly trailing behind. Furthermore, Internet access has not been adopted equally based on region and geography. West and Miller (2006) find U.S. regional disparities in Internet accessibility, privacy and security with southern states having lower levels of Internet connectivity.

Another barrier to widespread e-government is lack of technological skill. The use of e-government requires skills, such as being able to use a computer mouse and knowing how to find Internet information. Younger individuals are more likely to carry these skills because of Internet exposure in school. Respondents to the Pew Internet and American Life Project 2003 survey, *Ever-Shifting Internet Population*, were asked why they do not go online. Forty-six percent of respondents indicated they lack the technological ability to navigate the Web because of its complexity.

Mossberger, Tolbert and Stansbury (2003) find that computer technology skills can be summarized into two broad categories. The first category (technical competencies) includes the necessary skills to use hardware and software such as typing and using a mouse. The second (information or basic literacy) concerns the ability to determine what information is obtained from the Internet for specific tasks (Mossberger, Tolbert, and Stansbury, 2003: pp. 38). Their study shows the individuals lacking the technology skills necessary for Internet use includes those older, less educated, less affluent, Latino, and African American. Since these factors are the same as those associated with the "digital divide," they may work to exacerbate the gaps in usage based on access.

While the findings from the Mossberger, Tolbert and Stansbury (2003) study point to socioeconomic factors as predictors of the skill divide, other research adds psychosocial variables to the list of barriers to developing technological skills. Stanley's (2003) research found motivation as a significant element of digital skill development. Her research examined "new computer users," or individuals with limited experience and "non-computer users," those with minimal or no computer ability to determine what factors acted as a barrier in developing computer skills. The individuals in her study were primarily low income and had resisted obtaining computer skills until economic motives (finding a job, gaining a promotion, or getting a better job) led them to seek training. The findings revealed that psychological barriers (such as computer fear and poor self-concept) were more important than education in preventing computer skill development (Stanley, 2003: pp. 410-13). All of these study findings suggest there are potential barriers to the development of e-government use in the U.S., despite its promises.

U.S. GOVERNMENT POLICY ADDRESSING UNEVEN INTERNET USAGE

Although the federal government has pushed for adoption of e-government practices, its policies for eliminating Internet use disparities has been fragmented and piecemeal. Policy with the Clinton administration stressed public access strategies, emphasizing connectivity in libraries and schools with funding authorized by the Telecommunications Act of 1996. Two of these programs which provided more flexible funding were largely eliminated under the Bush administration.. The Technology Opportunities Program (TOP), offered grants for public Internet access and technology projects to solve social problems (Edutopia News, 2004). The Community Technology Centers Program provides matching grants for state-local, and nonprofit sectors providing public access in the community. Program funding fell from $32 billion to only $5 million in the 2005 budget (Edutopia News, 2004).

The government is addressing regional disparities to Internet use by mandating private-sector telephone companies to improve access and affordability of Internet to rural America. The Telecommunications Act of 1996, for example, keeps rural policy on the same trajectory as urban policy by requiring that companies provide affordable telehealth utilities in rural America as they do to urban counterparts in the same state (Schmeida, 2005). Recent Congressional hearings also target reform in the Federal Communications Commission universal service fund subsidizing rural Internet services for elementary and secondary schools public libraries and not-for-profit rural healthcare providers (U.S. House of Representatives, 2006).

Under the Clinton administration, libraries provided public access for computers and the Internet and a source for Internet training. Studies conducted by the University of Washington revealed that 30% of library patrons have no other Internet access. Job search is especially important for low-income library users, and medical information searches are prevalent in rural areas (Gates Foundation, 2004).

Under the Bush administration, policy for eliminating Internet use disparities switched from providing public access to improving Internet skills through the requirements of "The No Child Left Behind Act." Since implementing this policy, there has been progress in providing more technology in the schools (Kleiner and Lewis, 2003). Yet, schools face shortages in funding for computer maintenance and support staff and in some districts partly rely on students for technical support.

The review of the current U.S. policies regarding e-government and unequal Internet usage reveals contradictory policies. On the one hand, the federal government has strongly encouraged government units to adopt e-government practices for providing information and services. Yet, there are gaps in Internet usage based on a number of demographic factors limiting individual citizens who can benefit from the practices. This is coupled with policies addressing the disparities in Internet use that can at best be described as fragmented and piecemeal. What are the consequences of such conflicting policies with regard to telehealth? Is telehealth practice aiding those in greatest need of healthcare services, or resulting in greater inequality of service delivery?

DATA AND MEASUREMENT

In an attempt to address these questions, this chapter utilizes *The Internet and American Life Daily Tracking Survey, August 2006*; conducted for the Pew Research Center for the People and the Press, by the Princeton Survey Research Associates. The Pew survey is a random digit dial national telephone survey conducted in August 2006 and has a sample size of 2,928. In this study, we limit our exploration to the 1,594 respondents who reported searching for healthcare information online. Our dependent variable is represented by a count of the number of 6 healthcare activities an individual performed following a health information search online, see Table 1.

Since the current literature (Schmeida and McNeal, 2007; 2006; Mossberger et al, 2003) suggests that demographic and region factors are important in determining searches for online health information, variables are included for age, gender, education, income, full-time employment, part-time employment, African American, Asian American, Latino, Northeast, Midwest and the West regions. Age is in years and gender is mea-

Table 1. Dependent variable- searching for health information online (Pew Internet and American Life Project, 2006)

Did the information you found online affect a decision about how to treat an illness or condition?
Did the information you found online change your overall approach to maintaining your health or the health of someone you help take care of?
Did the information you found online change the way you cope with a chronic condition or manage pain?
Did the information you found online affect a decision about whether to see a doctor?
Did the information you found online lead you to ask a doctor new questions, or to get a second opinion from another doctor?
Did the information you found online change the way you think about diet, exercise, or stress management?

sured using a binary variable coded 1 for male and 0 for females. Education is measured using a 7-point scale, ranging from less than a grade-eight education to a Ph.D. education. The income measure is based on an 8-point scale where 1 indicates that family income ranges from \$0 to \$10,000 and 8 signifies a family income of \$100,000 or more.[1] A binary variable is used for full-time employment coded 1 for full-time and 0 other wise, a similar variable is used for part-time employment. To control for race and ethnicity, dummy variables are included for African Americans, Asian Americans, and Latinos with non-Hispanic whites as the reference group. Three variables are used to measure region---Northeast, Midwest and West with South as the reference group. Measures for need/ demand were also added including recent medical care experience, recent medical diagnosis and recent medical emergency. Each is binary coded 1 for yes and 0 for otherwise.[2]

FINDINGS

Since the dependent variable represents a count of different behavioral health outcomes/ action to online health information searches, a Poisson regression model in Table 2 is reported. A number of demographic factors were found to statistically predict policy outcomes. Contrary to expectation, many demographic groups who are least likely to have Internet access at home are most likely to have taken health-related action to the health information they searched on the Internet. Our model shows the less-educated, poor, African Americans, Latinos and those living in the south were more likely to have taken action after reading online healthcare information. Additionally, people with a recent new medical diagnosis and recent medical emergency experience were also more likely to have taken action. Table 2 shows the coefficient for education is statistically significant and negative. As education decreases, the probability of behavioral outcomes increases even after controlling for age, gender, income, employment, race, ethnicity, geography, and demand. The less educated are not only less likely to have Internet use at home (Mossberger et al., 2003) but those who do have access and searched for health information online are more likely to take some health-related action after their searches.

The coefficient for income is also significant and negative. The poor are more likely to take health-related steps after an online health information search than the wealthy. Our model also indicates that minority groups (African American and Latino) were statistically more likely than Caucasians to take action after online searches. Region is also a significant predictor in our model. The coefficient for *Midwest Region* was significant and negative. This suggests that residents of the South searching for health information online have a greater chance of taking action following their search than those living in the Midwest.

Two demand variables were important predictors in our model. We find the online health searchers who have had some type of recent interface with the health system are more likely to take some type of health-related action after their online information searches. The variable for *Recent Medical Diagnosis* was significant

Table 2. Poisson regression models- health behavior outcomes to online health searches

VARIABLES	β (se)	p>|z|
Age	.001(.002)	.727
Male	-.039(.049)	.428
Education	**-.053(.017)**	**.002**
Income	**-.028(.013)**	**.032**
Full-time Employment	-.025(.058)	.664
Part-time Employment	-.129(.085)	.127
African American	**.288(.075)**	**.000**
Asian American	.162(.176)	.359
Latino	**.212(.105)**	**.044**
Northeast Region	-.038(.070)	.588
Midwest Region	**-.104(.061)**	**.086**
West Region	.019(.065)	.773
Recent Medical Care Experience	.094(.070)	.181
Recent Medical Diagnosis	**.141(.053)**	**.008**
Recent Medical Emergency	**.110(.050)**	**.027**
Constant	1.274 (.133)	.000
Pseudo R^2	.0301	
LR chi^2 (15)	80.52	
N	657	

Poisson regression estimates with standard errors in parentheses. Unstandardized coefficients reported. Reported probabilities are based on two-tailed tests. Statistically significant coefficients at .10 or less in bold (Pew Internet and American Life Project, 2006).

and positive. Individuals who either personally or had someone close recently diagnosed with a chronic medical condition (such as asthma, diabetes, heart disease, or high blood pressure) and then searched for health information online had a greater chance for taking some type of action after the search. The factor *Recent Medical Emergency* was also significant and positive. Individuals (or someone close) who had faced a serious medical emergency or crisis and then searched for information online had a greater chance for taking a health-related action.

DISCUSSION

Our chapter attempts to explore the differences in policy outcomes with online health information searches in the general U.S. public. It goes beyond the current research exploring differences based on demographic factors in the use of telehealth without exploring the consequences of these inequalities. The outcomes under study are the health behaviors that occur as an effect to online health information searches at home---seeking a second opinion from another doctor, changing self-care practices, changing one's way of pain management, among other.

We find that certain demographic variables are statistically associated with behavioral outcomes of online health information searches. The demographic groups found in this study (less educated, poor, African American, Latino) to act on online healthcare information are surprisingly the same groups found least likely to have Internet access and Internet literacy skills for the U.S. In other words, those least likely to use the Internet are most likely to take steps toward improving their health if they do access healthcare information online. We also find that severity of need/ demand to online searches (individual facing medical crisis and new medical diagnosis) is important in influencing the health-related behaviors that occur after online health information searches are made.

How do we settle the contradiction in our findings? Why are those individuals who are least likely to have Internet access and the necessary skills to use it, most likely to benefit from healthcare searches online? To answer this question, we turn to previous work by Mossberger, Tolbert and Stansbury (2003). They found that even though African Americans and Latinos were less likely than similarly-situated whites to have home computers or home Internet access, to use the Internet as frequently, to report sufficient skills, or to use the Internet at all, they were more likely than whites to express positive attitudes about technology. Additionally, they found that

African Americans were statistically more likely than whites to use the Internet for activities, such as job search and online classes. Mossberger and Tolbert (2005) resolved the contradiction in their earlier findings through using hierarchical linear modeling to illustrate that factors, such as concentrated poverty and racial segregation are responsible for what seem like racial differences in Internet usage. Their research indicated that factors, such as community educational attainment and median income, explained more of the variation in frequency of Internet use than individual characteristics.

The findings of this chapter and the research by Mossberger and Tolbert (2005) are somewhat reassuring. Despite fears that those individuals most likely to benefit from e-government would be left out, they appear to be using the Internet to access services, such as healthcare, education and job searches. Furthermore, this chapter shows those most in need of healthcare services are more likely to take measures to improve their health after reading health/ medical information online. However, there is also indication that the policies enacted in the U.S. to alleviate gaps in Internet use are insufficient and under stress. Libraries have become the temporary solution for inequalities in Internet access and skill. Nevertheless, they are showing the strain of this responsibility as funding of public libraries is insufficient to keep up with Internet access demand (Bertot, McClure, Jaeger, and Ryan, 2006; Gates Foundation, 2005). Given the potential for telehealth and other forms of e-government to help deliver services and information to citizens, there is a significant need for a holistic policy for closing the gap between those who do and do not access the Internet.

REFERENCES

Bertot, J., McClure, C., Jaeger, P., & Ryan, J. (2006). *Public libraries and the Internet 2006: study results and findings*. Retrieved from http://www.ala.org/ala/washoff/contactwo/oitp/papersa/papers.cfm

Edutopia News. (2004). *Ed-tech funding reduced for 2005*. Retrieved 1, December 2004 from, http://www.edutopia.org/products/changeformat.php

Gates Foundation. (2004). U.S. library program: summary of research reports. Retrieved from http://www.gatesfoundation.org/Libraries/USLibraryProgram/Evaluation/default.htm

Gates Foundation. (2005). U.S. public libraries providing unprecedented access to computers, the Internet, and technology training. Retrieved from http://www.gatesfoundation.org/Libraries/USLibraryProgram/Announcements/Announce-050623.htm

Jacobus, C., & Lichtenstein, E. Cybernet Medical. (June 2006). Telehealth outcomes. Available Online: www.cybernetmedical.com

Kleiner, A., & Lewis, L. (2003). Internet access in U.S. public schools and classrooms: 1994-2002 (NCES 2004-011). *U.S. Department of Education. Washington, D.C.: National Center for Education Statistics.*

Mossberger, K., Tolbert, C. (2005). Race, place and information technology. *Report prepared for the U.S. Department of Housing and Urban Development*. Grant H-21439RG.

Mossberger, K., Tolbert, C., & Stansbury, C. (2003). *Virtual inequality beyond the digital divide*. Washington, DC: Georgetown University Press.

Pew Internet and American Life Project. (April 16, 2003). *The ever-shifting Internet population: A new look at Internet access and the digital divide*. Retrieved from http://www.pewinternet.org/reports/.

Pew Internet and American Life Project. (August 2006). *Daily tracking survey*. Retrieved from http://www.pewinternet.org/

Schmeida, M. (December 2005). *Telehealth Innovation in the American States*. Dissertation. Ann Arbor, MI: ProQuest.

Schmeida, M., & McNeal, R. (2007). The telehealth divide: disparities to searching public health information online. *Journal of Health Care for the Poor and Underserved*, *18*(3), 549–563. doi:10.1353/hpu.2007.0068

Stanley, L. (2003). Beyond access: psychosocial barrier to computer literacy. *The Information Society*, *19*, 407–416. doi:10.1080/715720560

Thomas, J., & Streib, G. (2003). The new face of government: citizen-initiated contacts in the era of e-government. *Journal of Public Administration: Research and Theory*, *13*(1), 83–102. doi:10.1093/jpart/mug010

Tolbert, C., & Mossberger, K. (2006). The effects of e-government on trust and confidence in government. *Public Administration Review*, *66*(3), 354–369. doi:10.1111/j.1540-6210.2006.00594.x

U.S. House of Representatives, Committee on Small Business Hearing. (May 3, 2006). *Future of rural telecommunications: is universal service reform needed?,* CIS-NO: 2006-H721-24. (pp. 1-78).

West, D. (September 2003), State and federal e-government in the United States (2003). Center for Public Policy, Brown University, Retrieved from www.insidepolitics.org/egovt03us.pdf

West, D. (2004). E-government and the transformation of service delivery and citizen attitudes. *Public Administration Review*, *64*(1), 15–27. doi:10.1111/j.1540-6210.2004.00343.x

West, D., & Miller, E. (2006). The digital divide in public e-health: barriers to accessibility and privacy in state health department Web sites. *Journal of Health Care for the Poor and Underserved*, *17*, 652–666. doi:10.1353/hpu.2006.0115

KEY TERMS

Demographics: Population statistics about socioeconomic factors such as gender, age, education, income, marital status, ethnicity, etc.

Electronic Government (E-Government): The delivery of information and services online through the Internet or other digital means (West, D.M., 2000; p. 2)

Internet: A worldwide computer network that is capable of linking all network users.

Poisson Regression: A linear model, Poisson regression analysis is used when the response variable represents counts.

Telehealth: The term is often interchanged with telemedicine. There is no consensus on its definition. However, the United States Congress defines it as the use of electronic information and telecommunications technologies to support public health and health administration,long-distance clinical healthcare, patient and professional health-related education (H.R. 2157, 2001). An example of e-government.

Telehealth Policy: An electronic government policy that uses the Internet to improve accessibility of public and private and non-profit healthcare services in rural and urban areas, while improving the quality of services at lower service costs.

Technological Skill: Skills, such as being able to use a computer mouse and knowing how to find Internet information. Younger individuals are more likely to have developed these skills because of Internet exposure in school. A barrier to widespread e-government is lack of technological skill.

U.S. Internet Cleavages: Internet cleavages that exist among United States citizens---people who do and do not use the Internet, and can be based on a number of socioeconomic and psychological factors.

ENDNOTES

[1] This variable is further defined as the total 2005 family income from all sources, before taxes (Pew Internet and American Life Project, 2006).

[2] The variable *Recent Medical Care Experience* asks: "In the last 12 months have you visited a doctor or medical clinic for any reason, including check-ups or visits to the emergency room or hospital outpatient department?" The variable *Recent Medical Diagnosis* asks: "In the last 12 months have you or has someone close to you been diagnosed with a chronic medical condition, such as asthma, diabetes, heart disease, or high blood pressure?" *Recent Medical Emergency* asks: "In the last 12 months have you or has someone close to you faced a serious medical emergency or crisis?" (Pew Internet and American Life Project, 2006).

This work was previously published in Handbook of Research on Distributed Medical Informatics and E-Health, edited by A. Lazakidou; K. Siassiakos, pp. 500-508, copyright 2009 by Medical Information Science Reference (an imprint of IGI Global).

Chapter 5.14

Developing Global Competitiveness in Healthcare:

A Thai Healthcare Organization's Perspective

William P. Wall
Shinawatra University, Thailand

ABSTRACT

Healthcare is a competitive business in its own right. Global competition in healthcare adds yet another complex dimension to the success of a healthcare organization. Providing state of the art technology along with the manpower and management skills to bridge boundaries and cultures, confronts today's healthcare organizations with challenges that, while on the surface may appear simple, may also prove to be a bigger challenge to their success and survival than the medical care they are actually providing. This case study explores one major healthcare organization in Thailand posing the question of what it sees as critical to the success of healthcare competition in the global community. An inductive approach was utilized for a method of determining competitiveness. The resulting qualitative analysis of that data addresses issues of seeking and maintaining global competitiveness, providing superior quality care with competitive and reasonable pricing of sub-specialty and high acuity services and work effectively through strategic alliances. In the case of the healthcare organization in this study, global competitiveness is maintained through what they term "Thainess". That "Thainess" or ability to provide comfort and hospitality at the same time as providing excellent medical care and facilities give them both economy of scale to provide reasonable pricing and a uniqueness in the medical care provided. Uniqueness and quality in service attracts strategic alliances of similar quality and allows for expansion into global communities that were not possible in the past.

INTRODUCTION

As global economics change, the competitive pressure on companies and organizations becomes more intense. This is never more evident that in the current economic environment that is seen today. To that end, the main question to be answered today is what does the healthcare organization in this case study see from their perspective as critical to the success of healthcare competition in the global community? The private healthcare organization in this case study is one of a total of 344 hospitals with 35,086 beds in Thailand. Of these hospitals, 102 are private hospitals with a total of 15,000 beds located in Bangkok. 43% of the entire country's facilities are concentrated mainly in Bangkok (Kasikorn Research, 2007). Thailand as a destination for medical treatment has rocketed in recent years. As an example, over 60,000 United Arab Emirates citizens a year come to Thailand to avail treatment (Tourism Authority of Thailand, 2007). Over the past three years, the number of foreign patients has grown at a rate of 12.4% and is expected to reach 1.54 million this year. Medical tourism is quickly becoming one of Asia's fastest growing industries. It is projected by 2012 to be worth a minimum of $4 billion USD. Why? 1.3 million Tourists get the promise of low cost quality healthcare in countries like Thailand where the average medical tourist spends on average $362 USD per day, compared to the average traveler spending $144 USD. In addition those costs are five to ten times less expensive than in Europe and the US as in the following examples:

- **Cardiac surgery:** India $4,000 vs. United States $30,000 (Stokes, 2007)
- **Hip replacement:** Thailand, Singapore $13,000-$13,500 vs. United States $44,500 - (Global Doctor Options Guide, 2008)
- **Knee replacement:** India $7,000 vs. United States $45,000 (Wockhardt Hospitals, 2008)

The main reasons for this influx of medical travelers are lack of health insurance and the high cost of healthcare (Bernheim, 2008).

Private hospitals have also expanded their presence in regions where there are many foreign tourists and residents and increased business is also predicted from wealthy citizens of neighboring countries such as Vietnam, Laos, Cambodia and Burma.

Can management, technology and medicine be combined to provide a solution to healthcare that is both beneficial as well as affordable? What are the challenges facing hospitals today and in the coming years? How will they overcome those challenges? These questions must be continually addressed if today's healthcare system is to be effectively and efficiently competitive on a global scale (Cortez, 2008).

If an organization is to be profitable it needs to focus on three major areas of operation: quality service, competitive/reasonable pricing and the effective and efficient delivery of that service. Today's hospital must also be a strong financial institution.

METHODOLOGY

The research was conducted by way of a survey. To gather the required data to address the research questions, the main survey technique used was a questionnaire. While other instruments may be used to collect this data, it was found that the questionnaire is relatively inexpensive to administer and reasonably easy to analyze the data collected.

The construction of the questionnaire was accomplished by reviewing prior examples (Bowling, 2005). The procedure of the questionnaire construction is explained here addressing the subjects, the development of the questionnaire, components of the questionnaire, administration, collection and validity and reliability.

The objective of this research was to determine what major factor contributed to global competitiveness of this healthcare organization.

At this major healthcare organization, fifty subjects were investigated in this study: Senior Management (4); Administrators (8); Medical Personnel (21); and, Staff (17). These 50 subjects were chosen because it was believed that they represented the most significant subjects working in their respective divisions at the present time. The highest level of education among the subjects was a Doctor degree (33%) followed by a Master degree (57%) and all with Bachelor degrees with 23 subjects being male and 27 being female.

The questionnaire used in this research consisted of 17 questions written in English and was given to all 50 subjects. Closed-end and open-ended questions were used and the questionnaire was designed to relate to the purpose of the research and obtain relevant information from subjects (Appendix A). The administration of this questionnaire and the resulting clarification interviews were conducted by the researcher. Of the subjects given questionnaires, 40 were interviewed. These interviews were used as a means to expand and allow subjects to discuss openly and freely some of their responses to the questionnaire. From the data collected and from the information obtained, some irrelevant items were excluded and some ambiguities were clarified.

Questionnaire construction and subsequent interviews were conducted with no predetermined outcome in an effort to avoid any type of bias. Bias may arise in quantitative analysis, where quantitative researchers sometimes use it, for example in discussions of significance levels (Levine, 1993). It may also be used by qualitative researchers. Becker argued that sociological analysis is always from someone's point of view, and is therefore partisan (Becker, 1967). In this qualitative research, every effort was made to avoid biases and therefore, as stated in the previous paragraph, subjects were allowed to discuss their responses in the interviews openly and freely. The researcher also had no predetermined agenda or result in mind in the construction of the questionnaire or the resulting information derived from the questionnaire or the subsequent interviews.

Every effort was made to assure the validity of the research instrument. Development and construction of the questionnaire was based on literature and research reviews and preliminary discussions with subjects used in this research. Comments and suggestions were then incorporated into the final instrument to reflect a reasonable claim of face validity as justification of the questionnaire produced. The reliability value of the questionnaire was calculated using Cronbach's Alpha Method revealing the reliability coefficient of the questionnaire was .9693

The questionnaire (Appendix A) used in this study included 'open' questions that resembled interview scripts. Written responses were more likely to be one of conscious effort and not repetitive, while in an interview interesting responses could be explored interactively in great depth. Categories derived from the questionnaire responses were combined with categories derived from interviews in grounded theory analysis.

Grounded Theory (Strauss & Corbin, 1998) and Porter's Diamond (Porter, 1990) was used in the qualitative analysis (Ezzy, 2002) of this study to discover patterns, aspects and importance of global competitiveness as well as the interrelationship of those factors from the data collected. Qualitative analysis was used also since it was not the objective of this study to compile the data collected numerically (Miles, 1994). The field of inquiry was limited to areas, subjects, people and questions that would directly relate to data necessary to be analyzed (Wolcott, 1994). Qualitative conclusions also lent themselves to communicating the vision, mission and support of the organization's current plans and those of the future.

Porter's Diamond (Porter, 1990) was used to identify key areas of competitiveness utilized by the healthcare organization in this study addressing four broad attributes - factor conditions, demand conditions, related and supporting industries and firm strategy, structure and rivalry - of an organization that shape the environment in which firms compete and either promote or impede the creation of competitive advantage. Porter's Model for Competitive Advantage was utilized addressing cost leadership, differentiation and focus (Porter, 1998).

With cost leadership through economies of scale, the company has a better ability to manage growth and hold off competition. For instance, by establishing a hospital facility where little or no hospital services or medical care exist, distributed fixed costs can remain fairly stable and services can be priced to be more profitable (Bushe, 1995).

Differentiation is achieved by concentrating on specific specialties or sub-specialties creating a service that is perceived as unique by the patient. This is perceived as superior value by the patients and therefore, since the patient sees the service as unrivaled unequaled, the price value can be adjusted to be more flexible. This also tends to develop more brand loyalty and helps insulate the organization against the competition.

The focus is important because the organization seeks to be more competitive by being more effective than efficient. Hence the focus to specialty and sub-specialty practice to set the organization apart as being the best in a certain segment of the business within a group of businesses.

This competitive advantage is key for organizations such as the one studied here to perform well and survive in today's highly globalized and intensely competitive healthcare market.

An inductive approach (Thomas, 2006) for analysis of data was initially used to consolidate and refine that data followed by a more concise triangulation of information as a qualitative process to specifically determine conclusions of this study.

Background of the Healthcare Organization

Established in 1972, started by a group of doctors and pharmacists with five specialists and 30 full time nurses, this healthcare organization became the largest hospital in Thailand with more than 400 fulltime consultant physicians and 600 nurses. One hospital has now turned into 12 hospitals, 16 specialty centers and 15 clinics at home and eight other facilities in Cambodia, Vietnam, Burma and Bangladesh.

Specialized centers come completely equipped with the latest treatment and diagnostic methods and tools that cover a range of services from pediatrics to geriatrics, neurology, cardiology and ophthalmology and treatments for sports related injuries.

Patient's requirements for different cultural and personal needs are attended to through specially designed outpatient clinics. Each clinic has unique facilities such as International, Japanese and Arabic services and is broken into four groups: Internal medicine; Surgery; Obstetric and Gynecology; and, a special clinic to deal with psychiatric disorders such as insomnia, depression and behavioral problems of children.

Investment is made in the latest technology, medical expertise and support facilities and is in continuous development contributing to the hospital's reputation and current status as one of the top medical organizations in Southeast Asia. A state-of the-art videoconferencing system links all of its hospitals, clinics and medical professionals in Thailand enabling the sharing of medical images while minimizing time for treatment administration and discussion of cases by specialists and physicians in different centers throughout the country. This allows the group to operate its branches as a single entity and is currently being developed for Southeast Asian inclusion.

This organization is dedicated to maintaining the highest international standards of medical practice by delivering quality patient care to each and every patient. Their vision statement tells it all – "our patients' complete satisfaction."

Seeking and Maintaining Global Competitiveness

One of the big questions for healthcare is why even be globally competitive in the first place?

One reason is that the healthcare market in Thailand will eventually saturate. To maintain growth, this Thai healthcare organization needs to look outside the country. Another reason is that healthcare today is being transformed in part from medical travelers from those wealthy patients from developing countries traveling to seek high quality medical care at affordable prices. In the case of this Thai healthcare organization, their market is expanding to Abu Dhabi. Due to the increasing cost of travel, eventually foreigners, especially in the Middle East, will not be able to afford to travel. The main reason for this is in examples found of long term care. Traditionally in the Middle East relatives typically accompany the patient. Not just the cost of health care, but accommodation, plane ticket, extra expenses and pocket money are increasing to the point of making a trip abroad prohibitive. The Middle East is also trying to discourage people from seeking health care outside the country. For instance, there is only one hospital in Saudi Arabia that has long term care. Rich people can still afford to travel, but the poor may not be able to afford the care outside the country.

The "why" of global expansion for competitiveness for this healthcare organization is answered by addressing location and planning. Being a pioneer in healthcare in Thailand, this organization has served both local and foreign patients and their communities with prompt professionalism in world-class facilities at reasonable prices for more than 26 years making it difficult for its closest competitors to follow.

It has positioned itself as a convenient, integrated solution to often complex healthcare. This is due largely to a well established differentiation in its infrastructure where Positioning (convenient and integrated healthcare solutions), Differentiation (wide network, wide range of services) and Brand working in conjunction with Brand Integrity, Image and Identity all work together to create a winning situation for both patient and healthcare organization (Porter, 2006).

This healthcare organization is currently building a hospital in Abu Dhabi. Abu Dhabi is a wealthy country and still underdeveloped in the areas of medical care and their economy. Conversely, Dubai is saturated with medical facilities and a multitude of hospitals, the population growth is slowing down. Abu Dhabi is now working on a plan to catch up with Dubai. There has been a population explosion in Abu Dhabi and they currently have produced a 22 year plan regarding growth and population planning.

Abu Dhabi is a modern society shaped by an ancient culture. The strategic policies in this Urban Structure Framework Plan, "Plan Abu Dhabi 2030", provide a way of reversing sometimes inappropriate development trends and of satisfying the needs of a growing population (Abu Dhabi Plan 2003, 2007). These policies are grounded by the three basic elements of sustainability: the natural environment, economic development and cultural heritage. Abu Dhabi is only the beginning of this active search for expandable locations. Doha, Qatar and Saudi Arabia are the next areas that may be looked at. Saudi Arabia has a population of more than 30 million people and the healthcare structure there is still underdeveloped.

Investment is not the only answer. Establishing and maintaining that global competitiveness can be focused into three main areas:

1. Expanding the reach as a healthcare provider into key strategic locations such as urban and industrial areas where patients reside as well as specific tourist destinations.
2. Providing quality with sub-specialty and high acuity services with global and national patient care quality standards together with state-of-the-art medical technologies.
3. Efficiency of shared services among network hospitals, sharing resources, consolidating back offices and decreasing monitoring and administrative work.

In addition, by utilizing this network approach the duplication of services can be avoided while concentrating on providing the best possible service to the customer at a reasonable cost.

Superior Quality Care, Reasonable Cost

Of all of these issues the biggest factor in determining global competitiveness is assurance to the patient of quality care. The organizational growth and improvement of the quality of services is clearly linked to an organization's commitment to improvement (Spulber, 2007). How this improvement process is driven, the use of performance measurement, external verification and the difficulties in accessing relevant data is a constant challenge. In healthcare today the pursuit of excellence is no longer an option (Asch, et al., 2006). It is essential.

Encouraged by the government's drive to make Thailand a regional hub for healthcare, this organization raised its bed capacity and looked beyond the local market, currently serving over 10,000 outpatients and 1,000 in-patients per day. The International division is now staffed with an international team who is culturally aware of the needs of patients and the need to provide those patients with a comfortable and reassuring environment and ambiance to make their stay as pleasant as possible. Hotel-style rooms and specially catered meals suiting every dietary requirement are provided to patients as well as access to the hospital's language translation service covering 26 different languages to help patients in making inquires and to explain medical conditions as well as instructions for treatment and maintenance. In-patient care is prompt and professional with care taken for consideration of special cultural, personal and religious needs and the tension of medical treatments is eased by specially selected services like Thai massage or personal grooming.

What standards are provided to assure the patient of safety and reliability in treatment? In the case of this health care organization, quality care is determined based on American standard practices of medicine as well as accreditation by the Joint Commission International (JCI).

JCI's mission is to continuously improve the safety and quality of care in the international community through the provision of education and consultation services and international accreditation. As the largest accrediting agency of health care organizations in the United States, it surveys nearly 20,000 health care programs through a voluntary accreditation process. (Joint Commission International, 2007).

Specific services for sub-specialty and high acuity services are not only targeted demographically, but are coordinated with state of the art technology to provide a standard of quality that patients can rely on time after time. Customer relationship management (CRM) (Buttle, 2003) helps to develop and improve Key Performance Indicators (KPI) (Shahin, 2007). Key Performance Indicators help a healthcare organization to define and measure progress toward organizational goals. Once the healthcare organization has analyzed their mission, identified all their stakeholders and defined their goals, they need a way to measure progress toward those goals. Key Performance Indicators are those measurements.

Faster availability of data is beginning to becoming more and more a concern. Delays of a month or two may provide unreliable information as demographics change. So technology is needed to blend with organizational goals.

Cost efficiency is accomplished through a network of shared services among network hospitals sharing services and resources, consolidating back offices and decreasing monitoring and administrative work and Key Performance Indicators (KPI) are watched closely and once the network has been established a number of issues are addressed. The main areas of analyses are:

1. Volume numbers related to patients (new patients, existing status and patient attrition).
2. Patient turnover by market segment (demographic studies).
3. Analysis of individuals demographically who may be potential patients.
4. Profitability by demographic segments and segmentation of customers by profitability.

This combination of cost control to provide reasonably priced health services in areas that are lacking not only in the quality but availability of healthcare allows this healthcare organization to be competitive in the market outside Thailand. It is important to note that a company must be explicit about its choice of strategy with regard to value creation (differentiation) and low cost (Porter, 1996).

Strategic Alliances

Alliances and contractual relations between collaborating partners in the healthcare market are shifting rapidly, therefore the need to be adaptive to the changing environment and be competitive both domestically and internationally are critical. Strategic alliances have allowed this healthcare organization to have revenue with a diversified base with a different environment, currency, nationality and behavior. The challenge is to manage those factors and get a positive result.

Today's healthcare industry is characterized by new and often problematic, opportunities and challenges in greatly expanding markets that can change overnight by research findings, a financial report, new legislation, new regulations, or the introduction of new technology. The healthcare industry is a "turbulent environment where companies worldwide and across many industries are turning to alliances as a cooperative, inter-organizational mechanism for adaptation" (Zuckerman, 2002). Strategic alliances enable participating organizations to extend their operations and expand toward desirable strategic goals. They can help to be more than a convenient arrangement to help healthcare providers to get through a tough period or resolve a major problem. Strategic alliances are now used in the healthcare field as a viable operational and strategic consideration. In today's environment of continual change and unpredictable developments, organizations may many times face circumstances where strategic alliance is necessary to stay timely and competitive. Strategic alliances are designed to achieve strategic purposes not attainable by one single organization. They provide flexibility and the ability to be responsive while retaining the basic structure of participating organizations (Lieberman, 1987).

The rationale to form these alliances is to recognize their value in engendering flexibility and allow them to access to a broadening array of resources and markets. These are essential considerations of any corporation that hopes to continue to remain relevant and vibrant (Stein, 1992). In the case of this Thai healthcare organization, a strategic alliance in Abu Dhabi tends to be particularly important in an unfamiliar market. While this provider has dealt with the Middle Eastern client base for a number of years, trying to enter the local market through a strategic alliance was a sound practice to build local alliances since local knowledge and connections are extremely valuable. It also enabled them to network ties outside their traditional boundaries and to possibly expand global resources of materials, capital, and/or expertise.

More enhanced operational capabilities and higher strategic goals are not achieved automatically. Management issues can be continual and difficult to resolve. These issues must be met by experienced, capable businesspersons, if an alliance is to be workable, productive and beneficial. Some alliances come apart; and some do not fulfill their purposes. Management complexities are enormous. To justify all the short term, extra costs, the rewards to both the hospital as well as the community must be enormous (Size, 1995).

Strategic alliances currently have been formed by this healthcare organization in Cambodia and presently in Abu Dhabi and the 30 bed facility currently in progress at Abu Dhabi is in negotiation to expand to a 60 bed facility. Abu Dhabi, however, presents a diverse challenge.

Issues such as cross-cultural communication present reoccurring problems that must be resolved on a daily basis. The Health Authority in Abu Dhabi (HAAD) has mandated that all health care facilities' staff need to be culturally sensitive and deliver culturally competent health care for the population residing in the Emirate of Abu Dhabi (Health Authority - Abu Dhabi, 2007). They have also identified five specific elements that are expected if the staffing and service delivery system is to become more culturally competent:

1. Value diversity
2. Have the capacity for cultural self-assessment
3. Be conscious of the dynamics inherent when cultures interact
4. Institutionalize cultural knowledge
5. Develop programs and services that reflect an understanding of diversity between and within cultures

A strong source of competitive advantage can come from understanding and proactively managing these cultural differences. If the management is poor, it can create a source of poor team performance and divided patient/provider relationships. Cultural norms in one country can differ greatly from those of another country making a seemingly minor incident into something of extraordinary proportion.

Being an effective and trusted global healthcare services provider requires not only a network of competent healthcare professionals, but a genuine understanding by all key administrators, doctors, nurses and support staff of the cultural issues that affect the core of the healthcare process in another country. This healthcare organization has addressed active steps to generate value from the diversity of their internal talent to help them be best placed to compete in the increasingly international healthcare environment.

CONCLUSION

Competitive strategy has been experiencing a dramatic transformation from a situation where one competitor gains at the expense of another, to one that is a mutually beneficial collaborative effort, where that joint effort creates more economic value for all parties. This new competition involves looking forward and positioning oneself in future and possibly still undefined markets and developing these markets with collaborative efforts. In today's competitive global economy with its intensively interconnected business environment, a major challenge faced by healthcare organizations is how to maximize shareholder value and sustain growth, while at the same time creating economic value for all. Two necessary strategic ingredients are needed to achieve these long range organizational objectives:

1. To set up and be the central focal point of a cluster of partners with whom a new and continuous stream of attractive and innovative services with value are developed and offered to customers, and
2. Identifying unique combinations of these services by actively engaging customers in the development of those customized services to meet their continuously unique and changing needs.

The conclusion drawn from this research is that if a company wants to attain a competitive advantage and remain profitable, the strategy, operations and organization must be consistent with each other coupled with unique service.

Markets must be sought out that lack sufficient medical care to service their population. The most often sited reason for the global competitiveness of this healthcare provider using triangulation of data received was the ability to provide comfort and hospitality or “Thainess” (90% response) at the same time as providing excellent specialty and sub-specialty medical care and facilities (82% response) giving the organization both economy of scale to provide reasonable pricing and uniqueness in the medical care provided. In turn, that uniqueness and quality in service has attracted strategic alliances that provide further inroads to a wider base of patients in the global community.

It is in this venue that this Thai healthcare organization competes not to maximize their market share, but to maximize the value of service offered to the customer, those providing them with a stable position in the competitive global healthcare industry.

Further study will be done on how cross-cultural management affects the strategy, operations and organization of the company in additional research. That data will ultimately be combined with this study to conclude additional research.

ACKNOWLEDGMENT

The author acknowledges the Editor-in-Chief of the Journal, Professor John Wang, and the anonymous reviewers for their indispensible input that improved the paper significantly.

REFERENCES

Abu Dhabi Health Authority. (2007). *Policy on Cultural Sensitivity and Awareness in Health Care Facilities.* Reference Number: PPR/HCP/P0004/07 Issue Date: May 2007 Revision Date: May 2009 Version: II. Abu Dhabi, UAE: Author.

Abu Dhabi Urban Planning Council (UPC). (2007). *Abu Dhabi Plan 2003.* Abu Dhabi, UAE: Author.

Asch, S. M., Kerr, E. A., Keesey, J., Adams, J. L., Setodji, C. M., Malik, S., & McGlynn, E. A. (2006). Who is at greatest risk for receiving poor - quality health care? *The New England Journal of Medicine*, *354*(11), 1147–1156. doi:10.1056/NEJMsa044464

Becker, H. S. (1967). Whose side are we on? *Social Problems*, *14*, 239–247. doi:10.1525/sp.1967.14.3.03a00010

Bernheim, (2008). Influence of patients’ socioeconomic status on clinical management decisions: A qualitative study. *Annals of Family Medicine*, *6*, 53–59. doi:10.1370/afm.749

Bowling, A., & Ebrahim, S. (2005). *Handbook of health research methods*. Buckingham: Open University Press.

Bushe, G. R. (1995). Organization development. Faculty of Business Administration, Simon Fraser University . *Organization Development Journal*, *13*(3), 14–22.

Buttle, F. (2003). *Customer relationship management: Concepts and tools*. Elsevier Butterworth-Heinemann, Oxford.

Cortez, N. (2008). Patients without Borders: The Emerging Global Market for Patients and the Evolution of Modern Health Care. *Indiana Law Journal, 83*. SMU Dedman School of Law Legal Studies Research Paper No. 00-24.

Ezzy, D. (2002). *Qualitative analysis: Practice and innovation*. Crows Nest, New South Wales, AU: Allen & Unwin.

Global Doctor Options. (2008). *Global Doctor Options Guide.* Las Vegas, NV: Author.

Joint Commission International. (2007). *Joint Commission International Accreditation: Getting Started*. Oak Brook, IL: Author.

Kasikorn Research. (2007, October). Thailand Hospital Statistics. *Medical Tourism News.*

Levine, J. H. (1993). *Exceptions are the Rule: An Inquiry into Methods in the Social Sciences.* Boulder, CO: Westview Press.

Lieberman, M. B. (1987, Sep. - Oct.). The learning curve, diffusion, and competitive strategy. *Strategic Management Journal*, *8*(5), 441–452.

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook*. Thousand Oaks, CA: Sage Publications.

Porter, M. E. (1990). *The competitive advantage of nations.* New York: Free Press.

Porter, M. E. (1996, November-December). What is Strategy? *Harvard Business Review*, 61–78.

Porter, M. E. (1998). *Competitive advantage: Creating and sustaining superior performance*. New York: Free Press.

Porter, M. E., & Teisberg, E. O. (2006). *Redefining health care: Creating value-based competition on results.* Boston, MA: Harvard Business School Press.

Shahin, A., & Mahbod, M. A. (2007). Prioritization of key performance indicators: An integration of analytical hierarchy process and goal setting. *International Journal of Productivity and Performance Management*, *56*(3), 226–240. doi:10.1108/17410400710731437

Size, T. (1995). *Strategic alliances: Some lessons from experience*: A Commentary, from Partners for the Dance. In A.D. Kaluzny, H.S. Zuckerman & Thomas C. Ricketts, III (Eds.), *Forming Strategic Alliances in Health Care* (pp. 40-52). Foundation of the American College of Healthcare Executives. Ann Arbor, MI: Health Administration Press.

Spulber, D. F. (2007). *Global competitive strategy*. Cambridge, MA: Cambridge University Press.

Stein, B. (1992). *Strategic alliances: Some lessons from experience*. New York: Simon & Schuster.

Stokes, B. (2007). Bedside India. *National Journal*, *39*(18), 36–40.

Strauss, A., & Corbin, J. (1998). *Basics of qualitative research: grounded theory and procedures and techniques.* Newbury Park, Calif.: Sage Publications.

Thomas, D. R. (2006). A general inductive approach for analyzing qualitative evaluation data. *The American Journal of Evaluation*, *27*, 237–246. doi:10.1177/1098214005283748

Tourism Authority of Thailand. (2007). *Medical Tourism in Thailand.* Bangkok, Thailand: Author.

Wockhardt Hospitals. (2008). Retrieved November 14, 2008 from http://www.companion-globalhealthcare.com/agents/providernetwork/wockhardthospitalsmumbai.aspx

Wolcott, H. F. (1994). Transforming qualitative data: Description, analysis, and interpretation. *Journal of Phenomenological Research*, *14*, 197–242.

Zuckerman, H. S. (2002). *Strategic alliances: A worldwide phenomenon comes to health care*. Washington, DC: Beard Books.

This work was previously published in Developing Global Competitiveness in Healthcare: A Thai Healthcare Organization's Perspective, edited by J. Wang, pp. 61-72, copyright 2009 by IGI Publishing (an imprint of IGI Global).

Chapter 5.15

Physician Characteristics and EMR Attitudes

David Meinert
Missouri State University, USA

Dane K. Peterson
Missouri State University, USA

ABSTRACT

Despite the numerous purported benefits of Electronic Medical Records (EMR), the medical profession has been extremely reluctant to embrace the technology. One of the barriers believed to be responsible for the slow adoption of EMR technology is resistance by many physicians who are not convinced of the advantages of using EMR systems. This study examined potential characteristics of physicians that might help identify those individuals that are most likely to pose a threat to the successful implementation of an EMR system in a multi-specialty clinic. The results demonstrated that older physicians and physicians with only minimal computer skills are more likely to have negative attitudes regarding EMR technology. Medical specialists were most likely to have positive attitudes with respects to the use of EMR systems, while primary care physicians were most likely to have doubts regarding the purported benefits of EMR technology.

PHYSICIAN CHARACTERISTICS AND EMR ATTITUDES

An Electronic Medical Record (EMR) is a computerized system that contains a patient's long-term legal health record generated by encounters at one particular medical practice. Thus an EMR electronically stores such items as x-rays, prescriptions, physician's notes, structured data, diagnostic images, wave forms, scanned images of paper documents, and other types of medical documentation. EMR technology offers a number of potential benefits, including improved quality of patient care, more efficient healthcare workflows, and reduced costs (Thompson, Osheroff, Classen, & Sittig, 2007). Improvement in the quality of patient care can be credited to several attributes of an EMR system including superior documentation, flexible data organization, integrated systems, and assisted clinical decision making (Shekelle, Morton, & Keeler, 2006).

Because of the many potential benefits associated with EMR technology, a number of experts believe the market for EMR systems will grow rapidly over the next decade. A recent study projected a13.5 percent growth rate for EMR technology in the U.S. over the next four years (Pizzi, 2007). This study estimated that the 2005 EMR market of $1 billion will grow to more than $4 billion by the year 2015. The prospects for market growth in the EMR industry are further enhanced by evidence suggesting that the U.S. represents only a small proportion of the market potential for EMR technology. Enormous growth is also anticipated on the global level, making EMR software an exceptional opportunity not only for the current market players, but also for new entrants into the market.

Despite the numerous benefits associated with EMR systems, there is extensive documentation indicating that the healthcare industry in the United States has been extremely reluctant to embrace the technology (Fonkych & Taylor, 2005). As a whole, the healthcare industry is almost 20 years behind the rest of the nation's industries in the adoption of information technology (Ilie, Courtney, & Slyke, 2007). The financial service industry for example spends nearly $200 billion a year on information technology, while the healthcare industry spends only about one-tenth of that amount ("From clipboards to keyboards," 2007). Estimates of the number of hospitals in the U.S. that have adopted the technology range from about 30 to 56 percent depending largely on how EMR systems are defined (Fonkych & Taylor, 2005). The slow growth rate has prompted possible intervention by the U.S. government to facilitate the implementation of EMR systems. In 2004, the U.S. federal government announced a framework to accelerate the adoption of health information technology, with the goal of having electronically stored medical records for most Americans within the next decade (Health IT Strategic Framework, 2004).

The slow adoption pace for EMR systems has been attributed to a number of barriers, such as privacy concerns and interoperability. In hospital settings, one of the key obstacles to successful EMR implementation is resistance among physicians. Physicians may be reluctant to accept EMR technology for a number of reasons, including the perception that the use of an EMR system requires extensive training and interferes with the quality of physician-patient interaction. Many physicians are skeptical about claims that EMR systems reduce errors, increase productivity and the overall assertion that the benefits of EMR technology outweigh the costs (Handy, Whiddett, & Hunter, 2001). While the validity of these issues have been addressed in a number of previous studies, it is important to note that physician acceptance of EMR technology is dependent on the physicians' perceptions and not necessarily the actual value of EMR technology.

Since physicians must use EMR systems in their day to day work, physician acceptance is crucial to widespread adoption of EMR technology (Mazzoleni et al., 1996). Many unsuccessful attempts to implement EMR technology have been attributed to the physicians' dissatisfaction with the EMR system (Van Der Meijden, Tange, Troost, & Hasman, 2003; Wager, Lee, & White, 2002). This is exemplified by several highly publicized EMR implementation fiascos, including the Cedars Sinai Medical Center in Los Angeles, in which physicians revolted and forced the administration to scrap a $34 million computer system (Connolly, 2005).

On the other hand, instances in which physicians approached the adoption of EMR technology with a positive attitude were often associated with successful implementations (Darr, Harrison, Shakked, & Shalom, 2003). Thus, a better understanding of the factors that are associated with physicians' attitudes toward the adoption of EMR systems is a key to achieving the substantial benefits associated with EMR technology (Reardon & Davidson, 2007). Therefore, this study examined the perceptions of physicians associated with a multi-purpose clinic to identify potential barriers to the acceptance of EMR technology. Such information may be useful in developing EMR training programs to enhance the prospects for successful EMR implementation.

PHYSICIANS' PERCEPTIONS REGARDING EMR TECHNOLOGY

One concern for many physicians is the amount of training time required to become proficient users of EMR technology. Although most EMR vendors claim extensive training is not required, adequate training appears to be crucial for the successful implementation of EMR systems (Miller & Sim, 2004). The exact amount of training required to become a proficient user of EMR technology is difficult to ascertain, since the necessary training time appears to be dependent on a number of factors (Bergeron, 2006; Ovretveit, Scott, Rundall, Shortell, & Brommels, 2007; Vanmeerbeek, 2004). For instance, it appears the specific type of EMR system being implemented, the training method employed, and the general computer proficiency of the physicians influence the required amount of training time (Aaronson, Murphy-Cullen, Chop & Frey, 2001; Kirshner, Solomon, & Chin, 2004). Thus, it appears that in some instances, the empirical evidence supports the concerns of many physicians that extensive training time may be necessary. Consequently, the present study examined physicians' views regarding the willingness of their colleagues to expend the time necessary to become proficient EMR users.

Quality of care, particularly the significance of physician-patient interaction, has been a primary concern among many physicians (Russell & Spooner, 2004). At issue is whether incorporating computers in the examination room detracts from the quality of communication between the physician and the patient (Aaronson et al., 2001). The results from empirical investigations appear to be mixed. For instance, one study reported that gazing at the computer monitor was inversely related to physician engagement in psychosocial questioning, emotional responsiveness to the patient, and overall psychosocial exchange during patient visits (Margalit, Roter, Dunevant, Larson, & Reis, 2006). In addition, keyboarding activity (physician order entry) has been reported to adversely influence the medical dialogue between physicians and patients. On the other hand, other investigations have not observed any negative consequences associated with the use of computers in the examination room (McGrath, Arar, & Pugh, 2007). In fact, some evidence suggests equipping examination rooms with computers may a positive effect on physician-patient interactions (Hsu, Huang, Fung, Robertson, & Jimison, 2005).

The conflicting results regarding use of EMR systems and physician-patient interaction may be the result of differences in the level of EMR experience among the physicians. That is, use of computers in the exam room may be less likely to interfere with physician-patient interaction as physician become more experienced with EMR systems (Rouf, Whittle, Lu, & Schwartz, 2007). This conclusion is based on objective methods of investigating physician-patient interaction, such as eye contact with the patient. However, the successful implementation of EMR systems may be more influenced by physicians' attitudes than such factors as amount of eye contact. Thus, the present investigation examined physicians' perceptions regarding the influence of EMR systems on quality of patient care.

One of the many claims made by vendors is that the use of EMR systems can result in a reduction of medical errors. Certainly, medical errors in hospital settings are both prevalent and costly (Crane & Crane, 2006), and there is some empirical evidence that the use of EMR technology can reduce medical errors. For instance, one study reported that use of EMR technology reduced documentation errors by over five percent (Gearing et al.2006). However, a review of the literature suggested that using EMR technology does not always result in a reduction of errors (Sidorov, 2006). One comprehensive investigation examined 17 measures regarding the quality of care in ambulatory settings. The results credited EMR technology with improvement for two outcome measures, but EMR technology resulted in a worse outcome for one measure, and no differences on the remaining 14 measures (Linder, Bates, Middleton, & Stafford, 2007). Thus, there would appear to be some valid reasons why physicians may not perceive EMR technology as a useful means for reducing medical errors. The present investigation provides a current examination of how physicians' view the effectiveness of EMR technology to reduce medical errors.

Increased productivity, or the number of patients seen per day, is another benefit often touted by EMR vendors (Joos, Chen, Jirjis, & Johnson, 2006). Although increased productivity is widely claimed as one of the benefits of EMR technology, there is only a modest amount of evidence to support the proposition and much of the evidence is anecdotal (Gonzales & Puri, 2008; Thakkar & Davis, 2006). Thus it is quite reasonable to expect physicians to be skeptical about the claimed benefits associated with increased productivity (Handy, Whiddett, & Hunter, 2001). Given the conflicting evidence, it would seem beneficial in this study to examine the current perceptions of physicians regarding the usefulness of EMR technology for increasing physician productivity.

A number of studies have attempted to assess the overall cost/benefits of EMR technology (Gearing et al., 2006). Developing an effective and valid assessment procedure has proven to be a difficult task (Thompson et al. 2007). However, the majority of the evidence suggests that the benefits of EMR technology outweigh the considerable costs of the technology (Hillestad et al., 2005; Simon & Simon, 2006). Even in instances in which physicians were initially skeptical about cost/benefits of EMR technology, the objective evidence indicated a substantial return on investment (Mullen, & Donnelly, 2006). To ascertain how the empirical evidence has influenced physicians' perceptions of EMR technology, this study examined physicians' views on the cost/benefits of EMR systems.

Finally, this study asked physicians if they believe their colleagues were aware of the benefits of EMR technology, whether the clinic should adopt EMR technology, and if EMR technology is adopted, will it be necessary for administration to mandate the use of the system in order to achieve successful implementation.

Attitudes and Physician Characteristics

Most theories on the diffusion of information technology suggest that the attitudes and perceptions of users is a key to successful implementation (Bagozzi, Davis & Warshaw, 1992). Thus, a number of studies have examined potential relationships between characteristics of physicians and attitudes regarding EMR technology with the hope of identifying the physicians most likely to resist EMR implementation. The goal is to determine which physicians represent the greatest obstacle to successful EMR implementation and thus, the physicians who would benefit the most from EMR training programs. Some of the primary factors investigated include the physician's age, computer sophistication, and medical specialty.

With respect to age, most studies have found that younger physicians are more likely to use EMR technology (Burt, Hing, & Woodwell, 2005; Terry, 2005). However, while younger physicians may be more likely to use EMR technology, some studies have reported that younger physicians are also more likely to have negative attitudes regarding the EMR system they are currently using (Darr et al., 2003; Terry, 2005).

Several researchers have suggested that a lack of computer sophistication among physicians may impede the implementation of EMR technology (Anderson, Asher, & Wilson, 2007; Rabinovitch, 2007: McGowan, Passiment, & Hoffman, 2007). Although there appears to be a substantial need for improvement in the computer skills among some physicians, studies examining the relationship between computing skills and EMR acceptance has produced contradictory results. Some studies have found a positive association between level of computer sophistication among physicians and use of EMR technology, while other studies did not observe a significant relationship between these variables (Joos et al. 2006).

Studies examining EMR adoption by medical specialty have also failed to produce consistent results. While some studies have found primary care physicians are most likely to use EMR technology (Terry, 2005), other studies have reported medical specialist are more likely to adopt to EMR systems (Audet et al., 2004; Burt et al., 2005; Corey & Grossman, 2007).

Study Objectives

To date, most studies examining EMR adoptions have reported general findings in terms of system "availability" or "usage." Unfortunately, such studies provide minimal understanding of what drives physician acceptance or resistance of EMR systems. While global measures such as "availability" and "usage" provide information regarding the rate of adoption of EMR systems they fall short of providing detailed insight into variables relevant to their successful widespread implementation.

The objective of the present investigation was to examine the attitudes of physicians at one large multi-specialty hospital regarding EMR technology. In addition, the study examined how perceptions regarding EMR technology were related to age, computer sophistication, and medical specialty of the physicians. Identifying which physicians are likely to have positive attitudes regarding EMR technology could assist hospital administrators and technology managers identify potential "innovators". Innovators, or early adopters, can play an important role as "opinion leaders" in the diffusion of information technology (Andrews, Pearce, Sydney, Ireson, & Love, 2004). Similarly, identifying physicians that are most likely to be resistant to EMR technology may provide administrators with information on who may benefit the most from technology training. Studies have shown that proper training improves attitudes toward EMR technology, even among physicians who were initially resisted the adoption of EMR systems (Kirshner, Salomon, & Chin, 2004).

METHODOLOGY

Sample

To examine physicians' attitudes regarding EMR systems, a mail survey of 358 physicians affiliated with a large, multi-specialty clinic in the Midwest was conducted. The clinic is a physician-led, professionally managed group practice in an integrated health-care system. Although some of the physicians had prior experience using EMR technology in other settings, the survey was conducted before the clinic had implemented an EMR system.

Targeting physicians at one multi-specialty clinic made it possible to obtain a high response rate to the questionnaire, avoiding a common problem encountered by many similar studies. In addition, the clinic was only in the preparation stage for adopting EMR technology. Thus most of the physicians had only read about EMR technology, but had little experience with specific EMR systems. Hence, their opinions were not likely to be overly influenced by use of one specific EMR system.

Questionnaires were mailed to physician homes, with follow-up mailings to non-respondent's homes (3 weeks later) and offices (5 weeks later). Preaddressed, postage-paid return envelopes were provided. A total of 266, or 74 percent, of the questionnaire were returned. Five of the questionnaires (1.4%) were excluded because at least half of the items were not completed. Thus, useable data was obtained from 261 (73%) respondents. The high response rate and percentage of usable questionnaires was a result of reminders by administrators and physician-executives to participate in the research. These reminders were conveyed via email, weekly newsletters and staff meetings.

Questionnaire

The questionnaire asked respondents to rate their degree of agreement regarding eight items on a forced Likert scale (no neutral point) ranging from 1 - strongly agree to 6 - strongly disagree. The eight items are listed in Table 1. These items were derived through an examination of the literature, discussions with administrators at the multi-specialty clinic and physicians in other clinics. The questionnaire also contained items to assess the physician's age, computer sophistication, and medical specialty. As in previous studies (Audit et al., 2004; Burt et al., 2005), physician age was classified as under 35, 35 to 44, 45 to 54, and over 54. Based on the same reasoning, medical specialty was classified as Primary Care, Surgical, and Medical Specialist. It was determined that computer sophistication was best assessed by a single item that asked respondents to rate their "Knowledge/experience working with Windows based applications (e.g., Word, PowerpPoint, Excel)" on a scale from 1 – "Proficient" to 4 – "Non-existent". Due to the small number of respondents indicating non-existent computer skills (n = 22), the last two categories were combined (i.e., minimal and non-existent computer skills).

RESULTS

The percent of physicians agreeing with each statement (respondents checking 1, 2, or 3 on the Likert scale) is displayed in Table 1. The physicians generally agreed that EMR technology would be beneficial. That is, nearly 80 percent of the

Table 1. Percent of physicians agreeing with each item

Concerns	Percent Agreeing
1. Physicians will devote the time necessary to be trained using an EMR	68.3
2. An EMR will improve the quality of patient care	76.6
3. An EMR will reduce the number of errors	82.6
4. An EMR will increase a physician's productivity	60.2
5. The benefits of an EMR system will outweigh the costs	72.0
6. The clinic's physicians are familiar with EMR functions and benefits	43.8
7. The clinic should implement an EMR system	79.6
8. EMR usage will have to be mandated	71.5

Table 2. Attitudes and physicians' age

	Under 35	35 to 44	45 to 54	Over 54	F
Sample Size	23	97	91	44	
1. Physicians will devote necessary time to training	3.31	2.81	3.17	3.41	2.70*
2. EMRs improves quality of patient care	1.95	2.49	2.79	3.20	4.27**
3. EMRs reduce errors	1.82	2.27	2.54	2.86	3.76*
4. EMRs increase physicians' productivity	2.19	2.99	3.53	3.59	6.35**
5. EMR benefits outweigh costs	2.24	2.46	2.84	3.39	4.82**
6. Clinic should implement EMR systems	2.04	2.29	2.49	3.21	4.18**
7. EMR usage will have to be Mandated	2.86	2.57	2.80	3.07	1.10
8. Familiar with EMR functionsand benefits	3.62	3.72	3.71	3.98	0.61

** P < .05, ** p < .01*

physicians agreed that the clinic should implement an EMR system and 72 percent agreed the benefits will outweigh the costs. However, the physicians were somewhat pessimistic regarding the acceptance of EMR technology by their colleagues. Only 43.8 percent of the physicians believe that their colleagues are familiar with the benefits of EMR technology and 79.6 percent believe the clinic will need to mandate the use of EMR systems in order to achieve widespread use of the technology.

Only 55 of the 261 respondents were females. Statistical tests indicated no gender differences on any of the eight dependent measures. Thus, all subsequent analyses were based on all 261 respondents without including gender as a separate factor. A separate ANOVA was performed on each of the eight dependent measures. Of the three independent variables, a chi-square test indicated that only physician age and computer proficiency were significantly related. That is, younger physicians were more likely to rate themselves as proficient computer users and less likely to have minimal or non-existent computer skills (chi-square = 20.36, p = .002). Chi-square tests on the relationship between physician age and medical specialty and between computer proficiency and medical specialty were not significant.

The ANOVA results for physician's age are summarized in Table 2. The analysis indicated the difference between the age groups was significant for all items except mandated use of EMR systems and familiarity with EMR benefits. For each item in which significant age differences were observed, younger physicians had a more positive attitude regarding EMR technology.

The results for physician's computer knowledge are summarized in Table 3. As expected,

Table 3. Attitudes and physicians' computer proficiency

	Proficient	Adequate	Minimal/ Non-existent	F
Sample Size	68	112	72	
1. Physicians will devote necessary time to training	2.74	2.93	3.63	11.62**
2. EMRs improves the quality of patient care	2.18	2.34	3.67	26.99**
3. EMRs reduce errors	1.94	2.21	3.20	20.90**
4. EMRs increase physicians' productivity	2.64	2.95	4.17	24.51**
5. EMR benefits outweigh costs	2.18	2.45	3.69	24.69**
6. Familiar with EMR functions and benefits	3.23	3.68	4.29	14.84**
7. Clinic should implement an EMR system	1.84	2.15	3.59	32.33**
8. EMR usage will have to be mandated	2.38	2.66	3.31	7.27**

** P < .05, ** p < .01*

Table 4. Attitudes and physicians' specialty

	Primary Care	Surgical Specialist	Medical Specialist	F
Sample Size	106	35	107	
1. Physicians will devote necessary time to training	3.15	3.11	2.99	0.50
2. EMRs improves the quality of patient care	3.03	2.60	2.32	6.52**
3. EMRs reduce errors	2.72	2.29	2.16	5.10**
4. EMRs increase physicians' productivity	3.48	3.18	2.96	3.21*
5. EMR benefits outweigh costs	2.87	2.85	2.54	1.38
6. Familiar with EMR functions and benefits	4.00	4.00	3.39	8.28**
7. Clinic should implement an EMR system	2.72	2.47	2.25	2.40
8. EMR systems will have to be mandated	2.71	2.83	2.80	0.13

** P < .05, ** p < .01*

physicians who were more proficient with computers were more likely to agree with the items. The difference between the groups was significant on all eight items.

Table 4 summarizes the results for physician specialty. The differences between physician specialties were significant for four of the items, namely quality of patient care, reduced errors, physician productivity, and familiarity with EMR benefits. Although the results were significant on only four of the eight items, the pattern of results were the same for all questions. That is, medical specialists were most likely to agree with the statements indicating a more positive attitude with respect to EMR technology. Primary care physicians were least likely to agree with the items.

CONCLUSION

One of the strengths of the present study was the high response rate (74%) which overcomes a limitation in some previous studies in which the results might be biased because the physicians completing the surveys may be those with the most interest in EMR technology. With the high response rate in this study, the results should be highly representative of the views of physicians working in multi-specialty clinics.

In general, the results suggest that physicians agree that EMR technology can be beneficial. The majority believed EMR technology can improve the quality of patient care, reduce errors, increase physician productivity, and believe the benefits of EMR technology outweigh the costs of implementing an EMR system. Consequently, nearly 80 percent of the physicians agreed that the clinic should implement an EMR system. However, only 43.8 of the physicians agreed that their colleagues were familiar with EMR functions/benefits and only 68.3 physicians believed their colleagues would be willing to devote the time necessary to be trained in using EMR technology. Thus, it is not be surprising that 71.5 percent of the physicians believe that in order to achieve successful implementation of an EMR system, the clinic will need to mandate the use of the technology.

The results overwhelmingly demonstrate that younger physicians have a more positive attitudes regarding EMR technology. Younger physicians were more likely to agree that EMR technology improves patient care, reduces errors, increases productivity, and that the benefits outweigh the costs. They are also more likely to agree the clinic should implement EMR technology. Similar results were found for computer proficiency. That is, physicians who rated themselves as proficient computer users had more positive attitudes regarding EMR technology than those with minimal or non-existent computer skills. As observed in many previous studies outside the medical profession, age and computer proficiency were highly related (Marquie, Jourdan-Boddaert, & Huet, 2002). Thus it is difficult to independently assess the importance of physician age and computer proficiency on physician attitudes.

The results of the present study also show that medical specialists are more likely to have a positive attitudes regarding EMR technology than surgeons, and surgeons are more likely to have a positive attitude with respect to EMR technology than primary care specialists. Thus the results are consistent with most previous investigation examining medical specialty (Audet et al., 2004; Burt et al., 2005; Corey & Grossman, 2007), but contradicts the of one recent investigation (Terry, 2005). The conflicting results of the latter study may be attributed to the classification categories used for medical specialty. Studies such as the current investigation that have classified physicians as primary care, surgeons, or medical specialist have generally produced consistent results.

LIMITATIONS AND CONCLUSION

There are limitations to all research and it is important to note those that may affect the implications of the present study. An obvious limitation is that all physicians were affiliated with the same multi-specialty clinic. While this approach provided several advantages such as a high response rate and more control over physician experience with specific EMR systems, it limits the generalizations that can be made from the study. Clearly, replications with different subject population would add significantly to the literature. A second issue pertains to the classification of medical specialties. While the division into three medical specialties was based on procedures used in several previous studies, there are other classification schemes that have could be used (e.g., see Corey and Grossman, 2007). It may be useful in future studies to examine potential differences in perceived importance of EMR functions using alternative methods of classifying medical specialty. A third concern pertains to controlling for the degree of previous EMR experience. Thorough information on physicians' previous experience with EMR technology and the types of information physicians used to form their perceptions regarding EMR technology would be helpful to understanding differences in perceived usefulness of EMR technology. Future investigation may examine how perceptions change depending on specific sources of information available to physicians and their personal experiences with specific EMR systems.

In conclusion, the results indicate that resistance to EMR implementation may be most likely to occur among older, less computer proficient physicians, particularly among primary care physicians. The fact that younger physicians are more computer proficient may suggest medical schools are taking the advice of researchers who have been advocating a curriculum that devotes more time to teaching computer skills (McGowan et al., 2007). Thus, it may be expected that resistance to implementing EMR technology may diminish over time as younger physicians with greater computer skills enter the profession.

REFERENCES

Aaronson, J. W., Murphy-Cullen, C. L., Chop, W.M., & Frey, R.D. (2001). Electronic medical records: the family practice resident perspective. Family Medicine, 33(2), 128-132.

Anderson, D. M., Asher, L. M., & Wilson, E. A. (2007). Physician computer skills: A prerequisite to the future in healthcare services. Journal of Kentucky Medical Association, 105(2), 67-71.

Andrews, J. E., Pearce, K. A., Sydney, C., Ireson, C., & Love, M. (2004). Current state of information technology use in a US primary care practice-based research network. Informatics in Primary Care. 12(1), 11-8.

Audet, A., Doty, M, Peugh, J., Shamasdin, J., Zapert, K., & Schoenbaum, S. (2004). Information technologies: When will they make it into physicians' black bags? Medscape General Medicine, 6(4), 843-853.

Bagozzi, R. P., Davis, F. D., & Warshaw P. R. (1992). Development and test of a theory of technological learning and usage. Human Relations, 45(7), 659-686.

Bergeron, B. P. (2006). I have an EMR system – now what? Journal of Medical Practice Management, 22(3), 131-132.

Burt, C. W., Hing, E., & Woodwell, D. (2005). Electronic medical record use by office-based physicians: National Center for Health Statistics. Retrieved February 4, 2008 from http://www.cdc.gov/nchs/products/pubs/pubd/hestats/electronic/electronic.htm

Connolly, C. (2005, March, 21). Cedars-Sinai Doctors Cling to Pen and Paper. The Washington Post, p. A01. Retrieved February 4, 2008 from http://www.washingtonpost.com/wp-dyn/articles/A52384-2005Mar20.html

Corey, C. & Grossman, J. M. (2007). Clinical information technology adoption varies across physician specialties. Center for Studying Health System Change. Data Bulletin, Number 34. Retrieved February 4, 2008 from http://www.hschange.com/CONTENT/945/

Crane, J. & Crane, F. G. (2006). Preventing medication errors in hospitals through a systems approach and technological innovation: A prescription for 2010. Hospital Topics, 84(4), 3-8.

Darr, A., Harrison, M. I., Shakked, L., & Shalom, N. (2003). Physicians' and nurses' reaction to electronic medical records. Journal of Health Organization and Management, 17(5), 349-359.

From clipboards to keyboard (2007, May 19). The Economist, pp. 68-69.

Fonkych, K. & Taylor, R. (2005). The state and pattern of health information technology adoption. The Rand Corporation Monograph. Retrieved February 4, 2008 from http://www.rand.org/pubs/monographs/MG409/

Gearing, P,, Olney, C. M., Davis, K., Lozano, D., Smith, L. B., & Friedman, B. (2006). Enhancing patient safety through electronic medical record documentation of vital signs. Journal of Healthcare Information Management, 20(4), 40-5.

Gonzalez, C. M. & Puri, L. (2008) Productivity and cost implications of implementing electronic medical records into an ambulatory surgical subspecialty clinic. Urology, 71(2), 173-7.

Handy, J., Whiddett, R., & Hunter, I. (2001). A technology acceptance model for inter-organizational electronic medical records systems. AJIS, 9(1), 39-50.

Health IT Strategic Framework (2004), Office for the National Coordinator for Health Information Technology. United States Department of Health and Human Services. Retrieved February 4, 2008 from http://www.hhs.gov/healthit/preface.html

Hillestad, R., Bigelow, J., Bower, A., Girosi, F., Meili, R., Scoville, R., & Taylor, R. (2005) Can electronic medical record systems transform health care? Potential health benefits, savings, and costs. Health Affairs, 24(5), 1103-17.

Hsu, J., Huang, J., Fung, V., Robertson, N. & Jimison, H. (2005). Health information technology and physician-patient interactions: Impact of computers on communication during outpatient visits. Journal of American Medical Informatics Association, 12, 474-480.

Ilie, V., Courtney, J. F., & Slyke, C. V (2007). Paper versus electronic: Challenges associated with physicians' usage of electronic medical records. Proceedings of the 40th Hawaii International Conference on Systems Science.

Joos, D., Chen, Q., Jirjis, J., & Johnson, K. B. (2006). An electronic medical record in primary care: Impact on satisfaction, work efficiency, and clinical processes. AMIA Symposium Proceedings, 394-398.

Kirshner, M., Salomon, H., & Chin, H. (2004). An evaluation of one-on-one advanced proficiency training in clinicians' use of computer information systems. International Journal of Medical Informatics, 73(4), 341-348.

Linder, J. A., Bates, D. W. Middleton, B., & Stafford, R. S. (2007). Electronic health records use and the quality of ambulatory care in the United States. Archives of Internal Medicine, 167(13), 1400-1405.

Margalit, R. S., Roter, D., Dunevant, M. A., Larson, S. & Reis, S. (2006). Electronic medical record use and physician-patient communication: An observational study of Israeli primary are encounters. Patient Education and Counseling, 61(1), 134-41.

Marquie, J. C., Jourdan-Boddaert, L., & Huet, N. (2002). Do older adults underestimate their actual computer knowledge? Behaviour & Information Technology, 21(4), 273-280.

Mazzoleni, M. C., Baiardi, P., Giorgi, I., Franchi, G., & Cortesi, M. (1996). Assessing users' satisfaction through perception of usefulness and ease of use in the daily interaction with a hospital information system. Proceeding of the AMIA Annual Fall Symposium.

McGrath, J. M., Arar, N. H., & Pugh, J. A. (2007). The influence of electronic medical record usage on nonverbal communication in the medical interview. Health Informatics Journal, 13(2), 105-18.

McGowan, J. J., Passiment, M., & Hoffman, H. M. (2007). Educating medical students as competent users of health information technologies: The MSOP data. MedInfo, 12 1414-1418.

Miller, R.H. & Sim I. (2004). Physicians' use of electronic medical records: Barriers and solutions. Health Affairs. 23(2), 116-26.

Mullen, R. & Donnelly, J. T. (2006). Keeping it real--building an ROI model for an ambulatory EMR initiative that the physician practices espouse. Journal of Healthcare Information Management, 20(1), 42-52.

Ovretveit, J., Scott, T., Rundall, T. G., Shortell, S. M., & Brommels, M. (2007). Improving quality through effective implementation of information technology in healthcare. International Journal for Quality in Health Care, 19(5), 259-266.

Pizzi, R. (2007). U.S. EHR market to approach $5 billion by 2015, Healthcare IT News, Retrieved February 4, 2008 from. www.healthcareitnews.com/story.cms?id=6332 - 31k

Reardon, J. L. & Davidson, E. (2007). How do doctors perceive the organizing vision for electronic medical records? Preliminary findings from a study of EMR adoption in independent physician practices, Proceedings of the 40th Hawaii International Conference on Systems Science.

Rabinovitch, I. (2007, July). Speedy EMR implementations. Technology for Doctors.

Rouf, E.. Whittle, J., Lu, N., & Schwartz, M. D. (2007). Computers in the exam room: Differences in physician-patient interaction may be due to physician experience. Journal of General Internal Medicine, 22(1), 43-48.

Russell, S. C. & Spooner, S. A. (2004). Barriers to EMR adoption in internal medicine and pediatric outpatient practices. Tennessee Medicine, 97(10), 457-60.

Shekelle, P. G, Morton, S. C., & Keeler, E. B., (2006). Costs and benefits of health information technology, Evidence Report/Technology Assessment, 132, 1-71.

Sidorov, J. (2006). It ain't necessarily so: The electronic health record and the unlikely prospect of reducing health care costs. Health Affairs, 25(6), 1745.

Simon, S. J. & Simon, S. J. (2006). An examination of the financial feasibility of Electronic Medical Records (EMRs): A case study of tangible and intangible benefits. International Journal of Electronic Healthcare, 2(2), 185-200.

Terry, K. (2005, January 21). Exclusive survey: Doctors and EHRs, Medical Economics, Retrieved 2/4/08 from http://www.memag.com/memag/article/articleDetail.jsp?id=143144

Thakkar, M. & Davis, D. C. (2006). Risks, barriers, and benefits of EHR systems: a comparative study based on size of hospital. Perspectives in Health Information Management, August 14, 3-5.

Thompson, D. I., Osheroff, J., Classen, D., & Sittig, D. F. (2007). A review of methods to estimate the benefits of electronic medical records in hospitals and the need for a national benefits database, Journal of Healthcare Information Management, 21(1), 62-68.

Van Der Meijden, M. J., Tange, H. J., Troost, J., & Hasman, A. (2003). Determinants of success of inpatient clinical information systems: A literature review. Journal of the American Medical Informatics Association, 10(3), 235-243.

Vanmeerbeek, M. (2004). Exploitation of electronic medical records data in primary health care. Resistance and solutions. Study in eight Wallon health care centres. Studies in Health Technology and Informatics, 110, 42-48.

Wager, K., Lee, F. W., & White, A. W. (2002). Life After a Disastrous Electronic Medical Record Implementation: One Clinic's Experience, Idea Group Publishing, Hershey, PA.

This work was previously published in International Journal of Healthcare Delivery Reform Initiatives, Vol. 1, Issue 2, edited by M. Guah, pp. 39-51, copyright 2009 by IGI Publishing (an imprint of IGI Global).

Chapter 5.16

Physician Characteristics Associated with Early Adoption of Electronic Medical Records in Smaller Group Practices

Liam O'Neill
University of North Texas, USA

Jeffery Talbert
University of Kentucky, USA

William Klepack
Dryden Family Medicine, USA

ABSTRACT

To examine physician characteristics and practice patterns associated with the adoption of electronic medical records (EMRs) in smaller group practices. Primary care physicians in Kentucky were surveyed regarding their use of EMRs. Respondents were asked if their practice had fully implemented, partially implemented, or not implemented EMRs. Of the 482 physicians surveyed, the rate of EMR adoption was 28%, with 14% full implementation and 14% partial implementation. Younger physicians were significantly more likely to use EMRs ($p = 0.00$). For those in their thirties, 45% had fully or partially implemented EMRs compared with 15% of physicians aged 60 and above. In logistic regression analyses that controlled for practice characteristics, age, male gender, and rural location predicted EMR adoption. Younger physicians in smaller group practices are more likely to adopt EMRs than older physicians. EMRs were also associated with an increased use of chronic disease management. [Article copies are available for purchase from InfoSci-on-Demand.com]

INTRODUCTION

Electronic medical records (EMRs) have the potential to transform health care in the United States. Achieving the goal of a standardized, interoperable EMR would offer significant economic and social benefits. An EMR-based health care system would shift the balance away from acute care and specialists and toward primary care and prevention. The experience of the Veterans Affairs (VA) system over the last decade offers some important lessons in this area. In the mid-1990s, the VA invested in a system-wide EMR, eliminated excess hospital beds, and shifted its focus toward health promotion, prevention, and outpatient care. The result has been the transformation into a "full-service" integrated delivery system (Greenfield and Kaplan 2004). One recent study found that VA patients received higher quality care than Medicare patients for 11 out of 11 measures, including preventive services and treatment of chronic diseases, such as diabetes and hypertension (Jha et al., 2003).

A target date of 2014 has been established by President Bush to achieve the widespread adoption of an inter-operable EMR. Yet progress to date has been slow. According to a recent study from the Centers for Disease Control (CDC), only 12.4 percent of physicians nationwide reported using a comprehensive, fully-functional EMR (Hing, Burt and Woodwell 2007). Adoption rates tend to be higher in large academic medical centers and lower in smaller, primary care practices (Rosenthal and Layman, 2008; Hing et al., 2007). Among the reasons given for not adopting EMRs were the following: lack of capital; difficulty finding a system to meet needs; uncertain that EMR investment would produce an economic return; concern that the system would become obsolete; and apprehension over loss of productivity (Conn, 2007).

Historically, some physicians have viewed clinical information technology with skepticism and as a threat to their professional autonomy (Shortliffe, 2005). And whereas some physicians have embraced IT in the clinical setting, others are concerned that IT might interfere with the physician-patient relationship and promote a "cookie cutter" approach to medicine. In a recent editorial, Hartzband and Groopman (2008) warned of the "clinical plagiarism" that occurs when physicians cut and paste each other's notes into the patient's record. They also argued that EMRs would constrain creative thinking and promote a rigid, unreflective approach that they termed "automatization."

Numerous studies have examined the economic aspects of EMR adoption. These include the estimated total savings from a nationwide EMR (Hillestad et al 2005), and the "business case" for adopting EMRs at the practice level (Wang et al. 2003; Miller et al., 2005). Yet the business case alone has proven to be insufficient to bring about widespread adoption (Kleinke, 2005). Smaller practices may lack the resources to implement EMRs, and most of the benefits tend to accrue to other stakeholders, such as insurers, patients, and society.

In smaller practices, physicians are the primary decision-makers on IT investments. Without physician acceptance, a clinical information system will have little chance of success. Yet the role of physicians in EMR adoption decisions and the characteristics of "early adopters" has not been adequately studied and is poorly understood. Our purpose is to address this gap in the literature.

BACKGROUND AND CONCEPTUAL FRAMEWORK

Compared to other OECD countries, the US lags 5-10 years behind in public investment for health information networks. For example, the United Kingdom (UK) has invested $11.5 billion in an enterprise-wide EMR, as compared with $125 million U.S. Federal spending on Health Information Technology (HIT) over a comparable period (Anderson et al. 2006). Hence these countries have moved beyond the planning stage and toward implementation. Patients in the UK can now choose hospitals and make appointments through a national, on-line scheduling system.

Canada expects to have EMRs for half its population by 2009.

Policy measures have attempted to address this problem by encouraging EMR adoption through changes in reimbursement. "Pay-for-performance" systems, now being used by both private and public payers, offer bonus payments for reporting and meeting quality targets (Rosenthal et al. 2007). These incentives encourage IT adoption, since the data management and reporting required would be difficult to implement without robust information systems (Shortliffe, 2005). For example, it would be extremely costly and time-consuming for a practice with paper records to report on the immunization status of its patient panel. However, the typical bonus payment is small at only 2 - 3 percent of total reimbursement. Thus it is debatable how much these financial incentives would actually change provider behavior (Berwick 2005). Other policy initiatives include the "Wired for Health Care Quality Act" that would require most providers to adopt EMRs within three years. This bill is currently under consideration in the U.S. Senate, although it is unlikely to be enacted.

Everett Rogers (1995) developed a well-known framework to describe the social process of technology diffusion. Assuming that "innovativeness" follows a normal distribution, then potential adopters can be grouped into five categories, based on how quickly they adopt an innovation (Figure 1). These five categories are the following: Innovators (2.5%), Early Adopters (13.5%), Early Majority (34%), Late Majority (34%), and Laggards (16%). Innovators are the first to adopt and are characterized by their venturesomeness and tolerance of risk. They have the resources to absorb the economic loss of a failed innovation. However, they are often socially disconnected and are rarely opinion leaders. In contrast, Early Adopters are frequently opinion leaders and serve as role models for other members of the social system. The Early Majority are more deliberate and cautious than Early Adopters and more local in their perspectives. They are more likely to adopt an innovation because it meets an immediate need than because it is an interesting idea. The Late Majority adopts only when the innovation has become the norm. They wait until the uncertainty has been removed and the price of adopting has dropped. The choice to adopt may also be the result of network pressure from peers. Laggards are the last to adopt an innovation; they tend to be isolated and localized in their social networks. This group has also been called "traditionalists" in that they swear by the tried and true (Berwick 2003).

Using the framework developed by Rogers (1995), we will, in the first stage, examine the physician characteristics associated with early adoption of EMRs. We will restrict our focus to group practices with five or fewer physicians, since individual physician characteristics are of lesser importance in larger practices, where decisions on IT adoption tend to be more bureaucratic and "top-down." Organizational variables that may influence EMR adoption are also included in the model, such as size of the practice, urban/rural location, and the percentage of Medicaid patients treated (Menachemi et al. 2007). In the second stage, we examine the impact of EMR adoption on disease management and preventive services.

In practice, the conversion to EMRs takes place in stages and over many months or even years (O'Neill and Klepack, 2007). The first stage involves the use of EMRs for internal operations, such as billing, scheduling, patient progress notes, internal communications, and organizing electronic information (Figure 2). The second and third stages involve using EMRs to communicate with clinical partners and for advanced functions, such as preventive services and disease management. Thus we define "Partial EMR Adoption" as Stage 1 implementation and "Full EMR Adoption" as those who have reached Stages 2 and 3. In practice, there is often significant overlap among these stages.

SURVEY DATA AND METHODS

We used a cross-sectional design to survey primary care physicians regarding their practice's use of information technology and practice patterns, in terms of prevention and disease management. The survey was administered in conjunction with the Kentucky Department for Medicaid Services. The initial panel consisted of a statewide random sample of 2,000 providers with at least one Medicaid patient visit in the previous year. The survey methodology followed the Dillman design process (Dillman 2000), with four overall mailings (a pre-survey letter, a survey packet, follow-up postcard, and a final survey packet). After eliminating 62 providers due to bad addresses, 1,928 providers remained in the final sample. The survey process began with mailings in April, 2006, with the final survey coding completed in June, 2006. There were 533 surveys returned for a response rate of 27.6%.

Only 50 out of 533 respondents (9.3%) were in medium-sized or large group practices (those with six or more physicians), and these were excluded from further analysis. Providers were asked if their practice had fully implemented, partially implemented, or not implemented EMRs. Physicians were asked what percentage of their patients received preventive services and disease management in a typical week.

A county was considered "urban" if it was located in a metropolitan area, with the largest city having a population of 50,000 or greater. Six of Kentucky's 120 counties met this criterion; the rest were considered "rural."

Statistical Analysis

Significant differences between EMR adopters (full or partial) and non-adopters were identified using χ^2 tests for dichotomous variables. For ordinal variables, the Mann-Whitney (non-parametric) test was used.

Two separate logistic regression models were used to predict the likelihood of 1) full EMR adoption and 2) full or partial EMR adoption. Candidate variables for the logistic regression models included physician characteristics (age, gender, board certified) and practice characteristics (solo, rural, percentage of Medicaid patients, percentage of managed care patients, and number of physicians in the practice). Variables were selected for the final logistic regression model using the SPSS stepwise procedure (SPSS for Windows, 13.0) and significance was considered at the $p < 0.05$ level.

RESULTS

Of the 482 physicians surveyed, the rate of EMR adoption reported was 28%, with 14% full implementation and 14% partial implementation. This result is consistent with a 2006 nationwide survey of 3,350 office-based physicians conducted by the CDC. In that survey, 29.2% of physicians reported using "any EMR" and 12.4% reported using a "comprehensive EMR", as defined by functionality (Hing et al., 2007).

Physicians who had fully or partially implemented EMRs differed from non-adopters in several important respects (Table 1.) EMR adopters were 5.9 years younger than non-adopters (47.5 vs. 53.4; $p<0.01$). They were also less likely to be in solo practice (65.1% vs. 75.8%; $p<0.01$), more likely to practice in a rural area (79.9% vs. 69.3%; $p<0.05$), and had fewer managed care enrollees (12.5% vs. 17.8%; $p<0.01$).

In terms of practice patterns, physicians who had fully or partially implemented EMRs provided more chronic disease management than non-adopters (49.6% vs. 40.6%; $p<0.01$). Physicians who had fully implemented EMRs provided more preventive services than those who had not adopted or partially adopted EMRs (34.1% vs. 25.5%; $p=0.07$). Further investigation revealed that preventive services differed by

Table 1. Physician and practice characteristics associated with use of electronic medical records

Physician Characteristics	Full or Partial EMRs	Non-Adopters	Difference
Sample size	134	348	--
Age (MD)	47.5	53.4	-5.90 **
Male	84.8%	80.1%	4.7%
Board Certified	88.0%	83.9%	4.1%
Disease Management	49.6%	40.6%	9.1% **
Preventive Services	30.1%	25.5%	4.6%
Practice Characteristics			
Solo Practice	65.1%	75.8%	-10.7% *
Size (Number of MDs)	1.67	1.54	0.13 *
Rural	79.9%	69.3%	10.6% *
Medicaid Patients (%)	25.7%	24.4%	1.3%
Managed Care (%)	12.5%	17.8%	-5.3% **

** P-value<0.01
* P-value<0.05.

specialty ($p<0.001$). For physicians with a specialty of internal medicine or family medicine (n = 109), those with full EMR adoption provided significantly more preventive services than practices with partial or no EMR adoption (46.7% vs. 29.4%; $p = 0.027$).

Two separate multivariate logistic regression models were used to predict full EMR adoption and full or partial EMR adoption, based on physician and practice characteristics (Table 2). Physician age ($p<0.001$), male gender ($p<0.05$), and rural location ($p<0.05$) were significant predictors of EMR adoption. Other physician and organizational characteristics, such as board certified, solo practice, percentage of Medicaid and managed care patients, and the practice size (number of physicians) were not significant.

The relationship between EMR adoption and physician age is clearly shown in Figure 3 and Table 2. For physicians in their thirties, 45% had fully or partially implemented EMRs as compared to less than 15% of those physicians aged 60 or above. The rate of full EMR adoption was 30% for physicians in their thirties and less than 5% for physicians age 60 and older.

This study has several limitations. By design, survey data depend on the ability of participants to give accurate responses. Further, surveys with

Table 2. Logistic regression equations for predicting emr adoption based on physician and practice characteristics

Full EMRs

Physician Characteristics	Regression Coefficient	Standard Error	Relative Odds	P-value
Constant	0.607	0.799		0.447
Age (10 years)	-0.796	0.150	0.451	0.000
Male	0.912	0.423	2.489	0.031
Rural	0.860	0.376	2.363	0.022

Full or Partial EMRs

Physician Characteristics	Regression Coefficient	Standard Error	Relative Odds	P-value
Constant	0.800			0.178
Age (10 years)	-0.553	0.107	0.575	0.000
Male	0.669	0.307	1.952	0.029
Rural	0.607	0.263	1.834	0.021

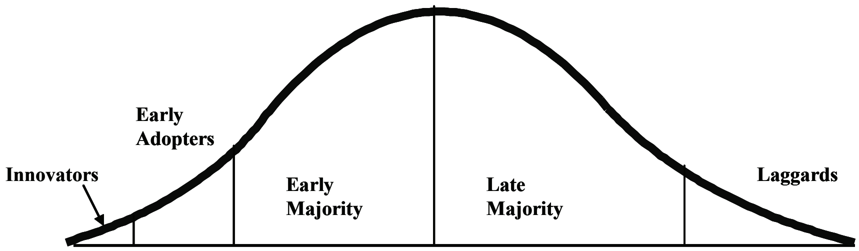
less than a perfect response rate are subject to response bias. Because the data come from one state, care should also be taken in generalizing the findings to other geographic areas. Overall, EMR adoption was found to be highest in the West and Midwest regions, as compared to the Northeast and South regions (Hing et al., 2007).

DISCUSSIONS AND CONCLUSION

Numerous studies have examined the economic aspects of EMR adoption. Yet few studies have examined the crucial role of physicians in the "social process" of EMR diffusion. This study found that early adopters of EMRs were younger on average than non-adopters and that the likelihood of adopting decreased with increasing age. Previous studies across different industries have found an inconsistent relationship between age and innovativeness (Rogers, 1995). In a survey of office-based physicians, Burt and Sisk (2005) found that physician age was not a significant predictor of EMR adoption. In an e-mail survey of 2,145 primary care physicians, Anderson and Balas (2006) did not find a significant relationship between physician age and clinical IT usage.

Our survey response rate was 27.6%, which is consistent with other published studies with a similar design. For example, three studies on the physician adoption of IT had response rates that ranged from 21 to 28 percent (Gans, Kralewski et al., 2005; Brooks and Menachemi, 2006; Rosenthal and Layman, 2008). For the smaller practices studied, physician rather than organizational characteristics were found to be primary determinants of EMR adoption. Previous studies had found that organizational characteristics, such as the percentage of Medicaid patients, to be significant predictors of EMR adoption (Menachemi et

Figure 1. Categories of EMR adopters



Adapted from Rogers, 1995

al., 2007). Our study found EMR adoption to be higher in rural areas. A previous study of North Carolina physicians found lower EMR adoption in poorer, rural counties (Rosenthal and Layman, 2008).

According to Rogers (1995), early adopters also serve as opinion leaders who are influential in persuading their peers to adopt the innovation. The advocacy of opinion leaders is often needed to achieve a "critical mass," that is, the tipping point where the process becomes self-sustaining and is typically reached at adoption levels of 10 - 20 percent. Here the diffusion process follows the S-shaped curve, also known as the "epidemic model." According to the CDC, the nation-wide adoption of "comprehensive EMRs" increased from 9.3% in 2005 to 12.4% in 2006. Thus, we appear to be entering Stage 2 of the process in Figure 1. This is a critical phase in that it can determine whether the innovation spreads throughout the population or stagnates. During this phase, Early Adopters can play a pivotal role in facilitating the diffusion of this technology. For example, they can demonstrate to those in the Early Majority how EMRs meet an immediate, practical need.

This approach of enlisting early adopters has been used successfully in other countries. In Australia, "enthusiastic adopters" were identified, and these became local clinical champions and volunteer advocates for Health*Connect,* the country's national health network (Anderson et al., 2006). The NHS in the United Kingdom has also used "pull marketing" techniques to encourage and then leverage these EMR early adopters. Due to its significant ($11 billion) public investment, the UK currently has a national health network for on-line appointment scheduling and electronic prescribing. It plans to achieve full EMR adoption by 2014.

As with other information technologies, such as fax and e-mail, EMRs have significant network effects, in that their utility increases in proportion to the number of other users in the network. In Kentucky, the level of inter-connectivity of health networks remains low. For example, only 27 percent of the physicians in this study who used EMRs reported filing prescriptions electronically. Concerned with this lack of connectivity and the problem of rising Medicaid costs, the Kentucky state government has recently launched an "E-Health Action Plan" that consists of a consortium of purchasers, payors, providers, and practitioners (ehealth.ky.gov). It mission is to increase provider connectivity and lower costs by investing in health information networks. This state initiative can assist the "partial adopters" who are currently in Stage 1 (see Figure 2) to become "full adopters" by establishing electronic linkages with pharmacies, insurers, and hospitals.

We hypothesized that physicians who use EMRs provide more chronic disease management for such conditions as asthma, congestive heart

Figure 2. Stages of EMR implementation

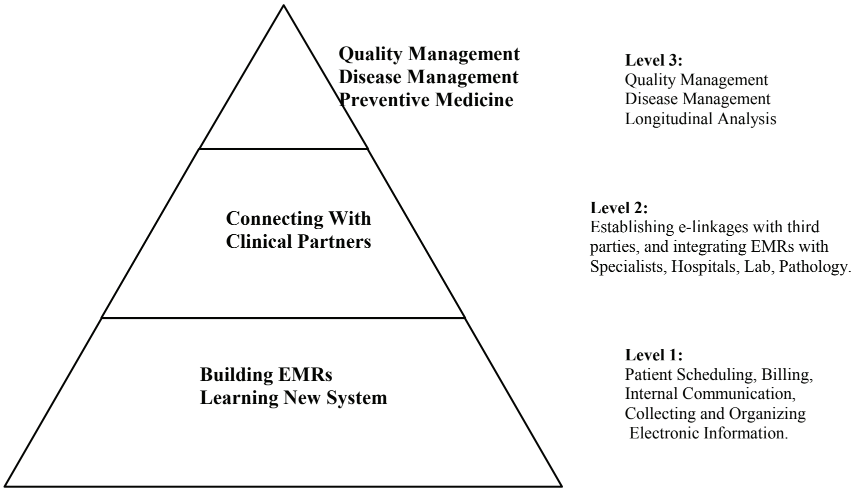
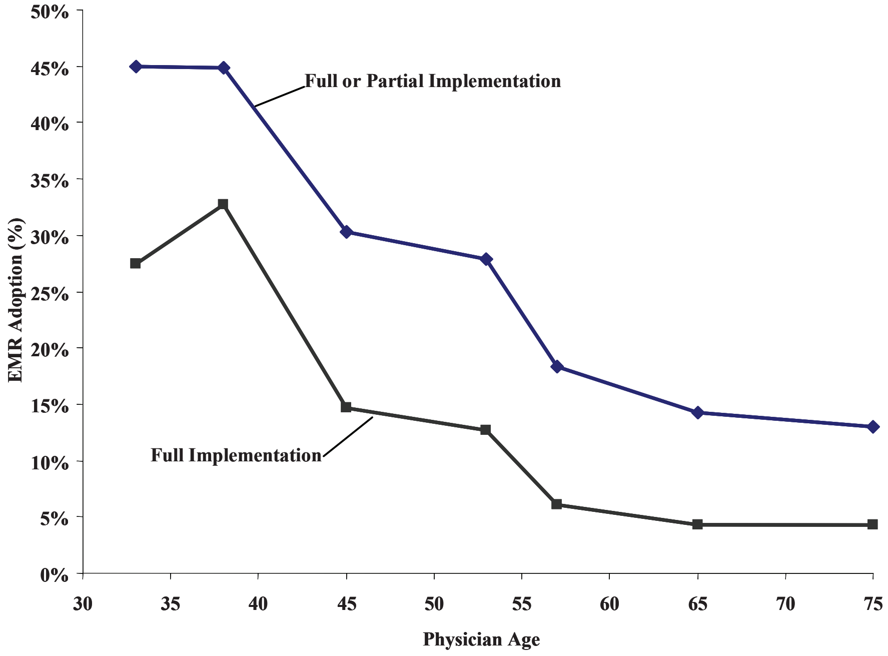


Figure 3. Relationship between EMR adoption and physician age



Adapted from O'Neill and Klepack (2007)

failure, diabetes, HIV, and hypertension, and our results support this hypothesis. Physicians who used EMRs and with a specialty of internal medicine or family medicine also provided more preventive services. In order to check for possible confounding, a two-stage regression analysis was performed, and a propensity score to adopt EMRs was calculated using logistic regression in the first stage, as shown in Table 2. The predicted values from this model were used as a predictor variable in the second stage. "Propensity to adopt EMRs" was not a significant predictor of physician practice patterns, whereas "EMR usage" was significant (p=0.026). This finding further supports the hypothesis by ruling out potential confounders. But whereas these early results are encouraging, they should be interpreted with caution. The learning curve associated with EMRs is long, and the impact of EMRs on these higher level functions (prevention and disease management) may take a year or more to measure (O'Neill and Klepack 2007). Moreover, they require viable "health information networks," that include hospitals, pharmacists, and other providers. Thus the "partial adopters", that is, those in Stage 1 (See Figure 2) cannot expect to realize the full benefits of EMRs.

The impact of EMRs on health care quality as measured by prevention and disease management has significant policy implications. Over the long term, an investment in preventive medicine today can be expected to yield lower costs tomorrow, in the form of fewer hospitalizations and a lower disease burden. Thus, previous studies on "EMR economics" may have underestimated these long-run benefits. Much more research is needed in this area, especially regarding the impact of EMRs on pharmaceutical usage for chronic conditions, such as diabetes and high cholesterol, and their impact on spending for hospital (inpatient) care.

Whereas the costs of EMR adoption in primary care are mostly borne by small group practices, the benefits often accrue to other stakeholders, such as consumers or society. Physicians are not currently reimbursed based on cancer deaths prevented or hospitalizations avoided. Other countries, such as Canada, England, and Australia, have recognized EMRs as a public good that requires substantial public investment (Anderson et al. 2006). "Pay-for-performance" attempts to re-align incentives toward prevention and quality, thereby encouraging EMR adoption.

The identification of early adopters and opinion leaders presents an alternative policy response that could accelerate the uptake of EMRs. Future research could extend this study by examining the needs, attitudes, and beliefs of physicians about the role of clinical information technology in their practice, especially those in the "Early Majority" and "Late Majority" categories.

REFERENCES

Anderson, G. F., Frogner, B. K., Johns, R. A., & Reinhardt, U. E. (2006). Health care spending and use of information technology in OECD countries. *Health Affairs (Project Hope), 25*(3), 819-831.

Anderson, J.G., & Balas, E.A. (2006). "Computerization of Primary Care in the United States." *International Journal of Healthcare Information Systems and Informatics* 1 (3): 1 – 23.

Berwick, D. (2005). 'A deficiency of will and ambition': A conversation with donald berwick. interview by robert galvin. *Health Affairs (Project Hope), Suppl Web Exclusives*, W5-1-W5-9.

Berwick, D. M. (2003). Disseminating innovations in health care. *JAMA : The Journal of the American Medical Association, 289*(15), 1969-1975.

Brooks, R. G., & Menachemi, N. (2006). Physicians' use of email with patients: Factors influencing electronic communication and adherence to best practices. *Journal of Medical Internet Research, 8*(1), e2.

Burt, C. W., & Sisk, J. E. (2005). Which physicians and practices are using electronic medical records? *Health Affairs (Project Hope), 24*(5), 1334-1343.

Gans, D., Kralewski, J., Hammons, T., & Dowd, B. (2005). Medical groups' adoption of electronic health records and information systems. *Health Affairs (Project Hope), 24*(5), 1323-1333.

Greenfield, S., & Kaplan, S. H. (2004). Creating a culture of quality: The remarkable transformation of the department of veterans affairs health care system. *Annals of Internal Medicine, 141*(4), 316-318.

Hartzband, P., & Groopman, J. (2008). Off the record--avoiding the pitfalls of going electronic. *The New England Journal of Medicine, 358*(16), 1656-1658.

Hillestad, R., Bigelow, J., Bower, A., Girosi, F., Meili, R., Scoville, R., et al. (2005). Can electronic medical record systems transform health care? potential health benefits, savings, and costs. *Health Affairs (Project Hope), 24*(5), 1103-1117.

Hing, E. S., Burt, C. W., & Woodwell, D. A. (2007). Electronic medical record use by office-based physicians and their practices: United states, 2006. *Advance Data, (393)*(393), 1-7.

Jha, A. K., Perlin, J. B., Kizer, K. W., & Dudley, R. A. (2003). Effect of the transformation of the veterans affairs health care system on the quality of care. *The New England Journal of Medicine, 348*(22), 2218-2227.

Kleinke, J. D. (2005). Dot-gov: Market failure and the creation of a national health information technology system. *Health Affairs (Project Hope), 24*(5), 1246-1262.

Menachemi, N., Matthews, M. C., Ford, E. W., & Brooks, R. G. (2007). The influence of payer mix on electronic health record adoption by physicians. *Health Care Management Review, 32*(2), 111-118.

Miller, R. H., West, C., Brown, T. M., Sim, I., & Ganchoff, C. (2005). The value of electronic health records in solo or small group practices. *Health Affairs (Project Hope), 24*(5), 1127-1137.

O'Neill, L., & Klepack, W. (2007). Electronic medical records for a rural family practice: A case study in systems development. *Journal of Medical Systems, 31*(1), 25-33.

Rogers, E. M. (1995). *Diffusion of innovations* (4th ed.). New York: Free Press.

Rosenthal, M. B., Landon, B. E., Howitt, K., Song, H. R., & Epstein, A. M. (2007). Climbing up the pay-for-performance learning curve: Where are the early adopters now? *Health Affairs (Project Hope), 26*(6), 1674-1682.

Rosenthal, D. A., & Layman, E. J. (2008). Utilization of information technology in eastern north carolina physician practices: Determining the existence of a digital divide. *Perspectives in Health Information Management / AHIMA, American Health Information Management Association, 5*, 3.

Shortliffe, E. H. (2005). Strategic action in health information technology: Why the obvious has taken so long. *Health Affairs (Project Hope), 24*(5), 1222-1233.

Wang, S. J., Middleton, B., Prosser, L. A., Bardon, C. G., Spurr, C. D., Carchidi, P. J., et al. (2003). A cost-benefit analysis of electronic medical records in primary care. *The American Journal of Medicine, 114*(5), 397-403.

This work was previously published in International Journal of Healthcare Information Systems and Informatics, Vol. 4, Issue 2, edited by J. Tan, pp. 69-80, copyright 2009 by IGI Publishing (an imprint of IGI Global).

Chapter 5.17

An Exploratory Study of Patient Acceptance of Walk-In Telemedicine Services for Minor Conditions

Christina I. Serrano
University of Georgia, USA

Elena Karahanna
University of Georgia, USA

ABSTRACT

Though healthcare costs continue to soar, the healthcare industry lags other service industries in applying information technology to improve customer (i.e., patient) service, improve access to healthcare services, and reduce costs. One particular area of concern is overuse and overcrowding of emergency departments for nonurgent care. Telemedicine is one potentially important application of information technology in this realm. The objective of this study is to examine the antecedents of patient acceptance of walk-in telemedicine services for minor ailments. Drawing upon theoretical models in the healthcare and technology acceptance literatures and based on salient beliefs elicited during interviews with 29 potential adopters, the authors develop a conceptual model of antecedents of patient acceptance of walk-in telemedicine services for minor conditions. While relative advantage, informational influences, and relationship with one's physician emerged as important predictors of acceptance, media richness and e-consultation diagnosticity emerged as central concerns for potential adopters. They discuss the study's implications for research and practice and offer suggestions for future empirical studies.

INTRODUCTION

In the United States (U.S.), the healthcare industry lags other service industries in applying information technology to business practices. Healthcare spending in the U.S. continues to outpace gross domestic product (GDP), comprising nearly $1.9 trillion, or 16 percent, of GDP in 2004 and is projected to rise to 20 percent of GDP by 2015 (Borger et al., 2006). With the healthcare economy rapidly growing but suffering from pervasive organizational inefficiencies, there is vast opportunity for implementing technological innovations to meet the demands of both industry and consumers, reduce overall costs, and provide widespread access to healthcare at affordable rates.

One particular area of concern is patients' increased use of emergency departments for non-urgent conditions. While this trend contributes to the rising costs of healthcare, patients often choose this option because their primary care physician is not readily accessible or because they do not have a usual source of care (Afilalo et al., 2004; Howard et al., 2005). Proposed solutions to this problem include walk-in urgent care clinics and emergency department fast tracks, often staffed by nurse practitioners and physician assistants (Howard et al., 2005). Another potential solution is a walk-in clinic for minor conditions that uses telemedicine (telecommunication systems to facilitate healthcare consultations between individuals remotely) to connect patients to healthcare providers. Advantages of a telemedicine walk-in clinic include fewer required staffing resources compared to a traditional walk-in clinic and the potential to provide patients, particularly those in rural areas, greater access to routine healthcare services.

Thus, the current study investigates this new application of telemedicine[1] that provides healthcare services for minor ailments to walk-in patients via a teleconferencing e-health center. The first facility of this kind in the U.S., the Health e-Station (HES), opened in 2006 in Georgia. Designed primarily to promote patient empowerment and improve access to healthcare during off-hours, HES is open weekdays from 4:00 p.m. to 8:30 a.m. and for 24 hours on weekends—i.e., during times when primary care providers are generally unavailable. Proponents of HES argue that its main advantages over emergency rooms are its lower cost for services and quicker access to healthcare providers (Health e-Station, 2006).

A typical HES visit involves patient interaction with a trained technician, who connects the patient to an available physician via videoconferencing and operates the instruments to perform the patient examination. The videoconferencing technology transmits images and sounds taken from the patient examination to the physician and permits real-time interaction, via video and audio, between the physician and patient. Moreover, the patient is able to view the transmitted images on a display monitor in the examination room.

Though research on adoption of other telemedicine technologies exists, our understanding of the antecedents leading to patient adoption of telemedicine services that are readily offered to a broad population to diagnose minor conditions is limited. With this type of health services model, the choice to seek health services originates from the patient, as opposed to other types of telemedicine (e.g., telepsychiatry or teledermatology), which typically involve a provider referral to the telemedicine service. Further, it differs from telemedicine use for telemonitoring of chronic conditions since this service is used for diagnosing minor conditions and not for recurrent monitoring of an existing condition. As such, the determinants of patient acceptance of walk-in telemedicine services for minor conditions are likely to differ from other applications of telemedicine and warrant new investigation. Thus, the research question for this study is: *"What are the antecedents of patient adoption of walk-in telemedicine services for minor conditions?"* In this study, patient perspectives concerning walk-in telemedicine services (WITS) for minor conditions are assessed by eliciting potential adopter beliefs concerning use of HES. Using qualitative methods, the study identifies the salient factors that influence patient acceptance, builds a theoretical model, and derives propositions that can be investigated empirically in future studies.

BACKGROUND

A growing body of literature focuses on patient satisfaction with telemedicine, and a few researchers have published extensive literature reviews in this area. These reviews suggest that most patient satisfaction studies have been published since 1995, conducted in the U.S., and focused on a particular medical specialty, with telepsychiatry and teledermatology being some of the most prominent (Mair & Whitten, 2000; Williams et al., 2001). Given many studies' focus on a particular specialty, generalizations across studies may not be appropriate. Different conditions involve different costs, different types of sensory requirements (e.g., psychiatry versus dermatology), and different degrees of severity and risk—all factors that influence patient adoption and satisfaction beliefs. Moreover, patient adoption choices will likely be influenced differently by periodic minor conditions versus ongoing or more serious conditions, by diagnostic versus monitoring care, and by synchronous versus asynchronous interaction.

Furthermore, many studies were descriptive, comparing patient experiences between telemedicine and face-to-face consultations. Some authors caution that patients' perceptions may be skewed when they receive both telemedicine and face-to-face care for the same health condition, calling for further investigation of telemedicine being used as a replacement for, rather than an adjunct to, face-to-face care (Mair & Whitten, 2000; Williams, et al., 2001). These authors also report on the dearth of qualitative studies concerning patient acceptance of telemedicine.

Though some theory-driven studies have been conducted regarding *physician* perspectives on telemedicine (e.g., Gagnon et al., 2003; Lehoux, Sicotte, Denis, Berg, & Lacroix, 2002), few studies apply theory to explore *patient* perspectives on telemedicine (Whitten & Love, 2005). Further, while some studies have applied theory to investigate telemedicine adoption or use from a multiple-adopter perspective (e.g., LeRouge, Hevner, & Collins, 2007; Menachemi, Burke, & Ayers, 2004) and provide some insights into theoretical frameworks underlying patient acceptance of telemedicine, the studies focused on a general range of telemedicine services and did not always specify the type of telemedicine applications, making generalizations to the current setting unclear. Wilson and Lankton (2004) developed a model of patient acceptance of provider-delivered e-health based on technology acceptance theories. However, the antecedents leading to patient use of a Web-based health application at home and those leading to patient use of a *telemedicine clinic* that delivers health services (which is the focus of the current study) likely differ because the latter focuses specifically on synchronous clinical care within the structural boundaries of a healthcare facility.

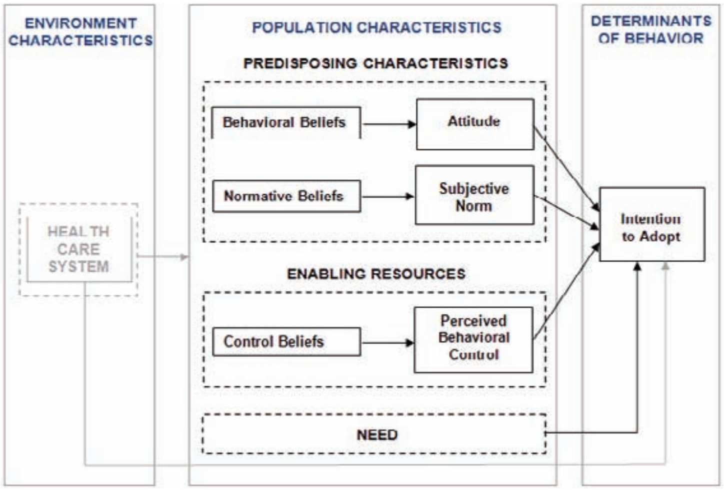
THEORETICAL FRAMEWORK

Theoretically, the study lies at the intersection of technology acceptance and healthcare services use. As such, two broad theories, the Behavioral Model of Health Services Use (BMHSU) and the Theory of Planned Behavior (TPB), were combined in an overarching framework that guides the research.

BEHAVIORAL MODEL OF HEALTH SERVICES USE

In the health services literature, the BMHSU has been a widely accepted and used model to explain access to and use of healthcare services (Andersen, 1995; Andersen & Newman, 1973). According to this model, the use of health services is dependent on people's predisposing characteristics, enabling resources, need for medical care, and external environmental factors. Predisposing characteristics include individuals' attitudes, beliefs, knowledge, values, demographic characteristics, and social structure. Enabling resources are the barriers or facilitating conditions that influence decisions

Figure 1. Combined BMHSU and TPB framework adapted from Ajzen (1991) and Andersen (1995)



to use healthcare services. Perceived need takes into account people's perceptions of their own general health, how they experience illness and anxiety symptoms related to their health, and whether their health state sufficiently warrants need of professional assistance. Aside from population characteristics, BMHSU posits that environmental factors—primarily the healthcare system—affect health services use. Inclusion of the healthcare system concept acknowledges that national healthcare policy and resources play a significant role in determining the population's use of healthcare services. However, because this study focuses on individual perceptions, an assessment of the national healthcare system is beyond the scope of evaluation.

Consistently, research has shown that perceived need is the prime determinant of healthcare use. The two remaining determinants of use, predisposing characteristics and enabling resources, are conceptually similar to determinants of behavioral intention in the TPB. An integration of these two models forms the underlying framework used in this study (Figure 1).

THEORY OF PLANNED BEHAVIOR

TPB (Ajzen, 1991) has been used to predict behavior in multiple contexts, including the technology acceptance domain (e.g., Pavlou & Fygenson, 2006; Taylor & Todd, 1995). According to TPB, behavior is a function of individuals' intention to engage in a behavior and their perceived behavioral control in achieving the target behavior. Behavioral intention is determined by individuals' attitudes, subjective norm, and perceived behavioral control.

Attitude is an overall evaluation of the pros and cons of engaging in a behavior. It is determined by salient behavioral beliefs regarding the consequences of engaging in a behavior and the evaluation of these consequences. Attitude and the corresponding behavioral beliefs are conceptually similar to the notions of attitudes, beliefs, and values included in the construct of predisposing characteristics of the BMHSU.

Subjective norm (SN) represents the social element of TPB and suggests that people decide to enact behaviors, in part, due to their perceptions of referent others' opinions about how they should behave. SN is determined by an individual's salient normative beliefs, or perceived expectations of

Table 1. Sample demographics

Demographics	Frequency (%)		Demographics	Frequency (%)	
Gender	16	(55%)	**Income**	1	(3.4%)
Female	13	(45%)	Less than $9,999	1	(3.4%)
Male			$10,000-14,999	5	(17.2%)
Age	2	(6.9%)	$15,000-24,999	3	(10.3%)
18-24	10	(34.5%)	$25,000-34,999	8	(27.6%)
25-34	8	(27.6%)	$35,000-49,999	7	(24.1%)
35-44	5	(17.2%)	$50,000-74,999	2	(6.9%)
45-54	3	(10.3%)	$75,000-99,999	1	(3.4%)
55-64	1	(3.4%)	$100,000-149,999	1	(3.4%)
65+			$200,000 and above		
Race	15	(51.7%)	**Highest Education**	1	(3.4%)
White	5	(17.2%)	Less than high school	16	(55.2%)
Black/African American	3	(10.3%)	High school	8	(27.6%)
Asian	3	(10.3%)	Bachelor's degree	2	(6.9%)
Hispanic	3	(10.3%)	Master's degree	2	(6.9%)
Multiracial			Doctorate degree		

referent others, and motivation to comply with these expectations. SN is conceptually similar to the notion of social structure included in the construct of predisposing characteristics of the BMHSU.

Perceived Behavioral Control (PBC) refers to one's perceptions of the level of ease or difficulty in engaging in a behavior. Thus, even if an individual has strong intentions to engage in a behavior, if he/she does not perceive the existence of resources and opportunities to achieve this goal, then there is less likelihood that he/she will realize the target behavior. The determinants of PBC are an individual's salient control beliefs and perceived power of these beliefs to facilitate or inhibit the behavior. PBC is conceptually similar to the enabling resources construct of the BMHSU.

According to TPB, all other constructs influence behavior through their effects on beliefs, attitudes, SN, and PBC. Therefore, demographic characteristics and other individual differences that are part of BMHSU's predisposing characteristics will influence behavior through their effect on beliefs, attitudes, SN, and PBC. Though the model specifies the relationships across the constructs, it is silent in terms of the specific behavioral, normative, and control beliefs that are salient in the context of patient acceptance of telemedicine services. In order to determine these, a process of belief elicitation was undertaken (Ajzen & Fishbein, 1980).

METHODS

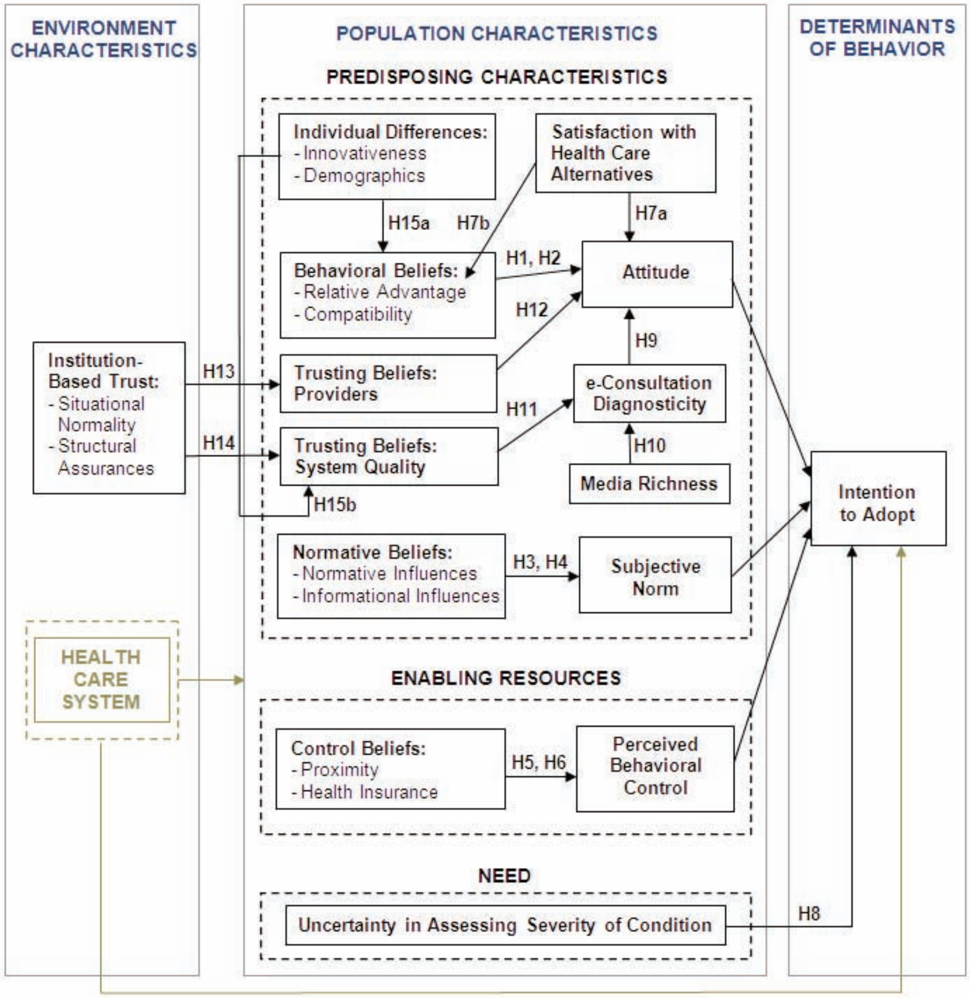
A total of 29 individuals were interviewed in 2007. All respondents were adults capable of making decisions concerning their own healthcare. Respondents varied in age, gender, race, education, and socio-economic status (see Table 1 for demographic data). For each interview, the respondent first watched an online video that describes HES, an example of a WITS clinic for minor ailments, by demonstrating a patient examination and discussing potential pros and cons of using the telemedicine services at this facility. The video can be viewed online (A Doctor's Visit, 2006), and a complete transcript of the video can be requested of the researchers. Showing the video was necessary since none of the respondents were familiar with WITS for minor conditions. After watching the video, respondents were asked structured interview questions based on the belief elicitation guidelines suggested by Ajzen and Fishbein (1980). While the interview questions were pre-specified, we allowed

Table 2. Frequency of elicited salient beliefs

Salient Beliefs	Description	Frequency (%)	
Behavioral Beliefs	Relative Advantage – Wait Time	25	(86%)
	Relative Advantage – After-Hours Availability	17	(59%)
	Media Richness	16	(55%)
	e-Consultation Diagnosticity	15	(52%)
	Relative Advantage – Convenience	14	(48%)
	Relative Advantage – Cost	11	(38%)
	Compatibility – Values	9	(31%)
	Compatibility – Personal Lifestyle	6	(21%)
	Complexity	2	(7%)
	Relative Advantage – Advantage over Alternatives	2	(7%)
	Relative Advantage – Less Exposure to Germs	1	(3%)
	Relative Advantage – Patient Empowerment	1	(3%)
Normative Beliefs – Normative Influence	Family Members	12	(41%)
	Healthcare Providers (Physicians and Nurses)	8	(28%)
	Health Insurance Companies	5	(17%)
	Friends	3	(10%)
	Employer/Employer-related	2	(7%)
	Other	2	(7%)
Normative Beliefs – Informational Influence	Interpersonal Network	9	(31%)
	News Media/Expert Opinions	7	(24%)
Control Beliefs	Proximity	21	(72%)
	Health Insurance	14	(48%)
	Public Transportation (on Bus Route)	3	(10%)
Trusting Beliefs – System Quality	Functionality, Reliability, Data Integration	7	(24%)
Trusting Beliefs – Providers	Technicians	6	(21%)
	Physicians	2	(7%)
Institution-Based Trust	Structural Assurances	11	(38%)
	Situational Normality	10	(34%)
Individual Differences	Demographics	15	(52%)
	Innovativeness	9	(31%)
Satisfaction with Healthcare Alternatives	Satisfaction with Healthcare Alternatives	14	(48%)
Nature of Condition	Uncertainty in Assessing Severity	8	(28%)
	Personal/Private	3	(10%)
	Telemedicine Technology Fit-to-Condition	2	(7%)
	Pain	2	(7%)
Reinvention*	Use Other Than Intended Use	6	(21%)
Relationship with WITS Provider	Familiarity with WITS Provider	3	(10%)
Facility Characteristics	Cleanliness	3	(10%)
Friendliness of Office Staff	Receptionists and Administrative Staff	2	(7%)

*Because we are interested in acceptance of WITS *as is*, we excluded the concept of reinvention from the model.

Figure 2. Emergent model - factors influencing patient adoption of walk-in telemedicine services for minor conditions



respondents to freely discuss their opinions of WITS for minor conditions and added questions as new concepts developed. Hence, there was an iterative process between the data gathering and conceptual development.

Twenty-three interviews were conducted in person, three via phone and three via email. We stopped collecting data when theoretical saturation (Glaser & Strauss, 1967) was achieved and no new concepts were emerging. Interviews were transcribed, and concepts were coded and sorted into conceptually similar categories. Both researchers separately coded all transcribed interviews and subsequently met to resolve disagreements. After four rounds of coding, there was 100% inter-rater agreement.

RESULTS

Table 2 contains the constructs (beliefs) that emerged through the interviews and their corresponding frequencies and Figure 2 shows the resulting theoretical model. To identify *salient* beliefs, we used Ajzen's and Fishbein's recommendation of including those beliefs mentioned by at least 20 percent of respondents. Then these beliefs were mapped on the TPB behavioral, normative, and control beliefs based on whether they referred to beliefs about consequences of adopting or not adopting the service (behavioral beliefs), important referent opinions as to whether the respondent should or should not adopt (normative beliefs), and perceptions of obstacles or facilitators to adopting (control beliefs). In addition to the salient belief categories of TPB, other concepts emerged and were added to the resulting theoretical model. Below we discuss the constructs and relationships that emerged from our analysis and present these in hypotheses format. The resulting model and hypotheses can be further tested in future research.

BEHAVIORAL BELIEFS

Two concepts from Rogers' (1995) Innovation Diffusion Theory (IDT) emerged as salient beliefs about the consequences of adopting WITS for minor conditions: *relative advantage* and *compatibility.* Relative advantage is the degree to which using an innovation is perceived as being better than its precursor while compatibility is the degree to which using an innovation is perceived as consistent with the existing values, practices, and experiences of potential adopters (Rogers, 1995). Empirical studies in technology acceptance (Karahanna, Straub, & Chervany, 1999; Moore & Benbasat, 1991) and a meta-analysis by Tornatzky and Klein (1982) suggest that these two constructs have been consistent significant predictors of innovation adoption behaviors.

Relative Advantage

According to IDT, relative advantage is a multi-dimensional construct that captures the benefits of an innovation in comparison to the practice it supersedes (Rogers, 1995). Rogers (1995) provides some possible dimensions to this construct, such as lower costs, savings in time and effort, and social prestige. Clearly, the specific benefits to be derived from an innovation vis-à-vis its precursor will be context-specific. In fact, Rogers (1995) states, "The nature of the innovation determines what specific type of relative advantage (such as economic, social, and the like) is important to adopters" (p. 212). Thus, there is no universal *a-priori* list of relative advantage dimensions and the dimensions need to be determined for each specific context.

The most significant relative advantage dimensions that emerged in our study were wait time, hours of availability, convenience and cost. In fact, all respondents mentioned that reduced wait time, or quick service, is one of the main advantages of using HES. Many individuals also perceived benefits in service availability during after-hours periods when physician offices are closed. Some indicated that after-hours availability was also attractive because it enabled them or their children to receive healthcare services without having to miss work or school:

You can go here at a more convenient time. There would be times when I didn't want to take off work or adjust my schedule just to get to the doctor by 4 p.m.

You'll get help late at night. For kids, if they have a rash or something, you can get a prescription real fast, so they don't miss school.

Further, many individuals indicated that this is a more *convenient* service than the emergency room or their physician's offices.

I would use a Health e-Station because it would be a fast and convenient alternative to visiting the emergency room.

Finally, the perceived lower cost of service relative to an emergency room visit was another commonly cited advantage.

I would use this over an emergency room because it's cheaper.

The health services literature also has revealed that these factors have been identified empirically as some of the most significant factors driving patient satisfaction with health services (Andersen, 1995). As such, we propose the following:

H1a-H1d: *Beliefs concerning the relative advantage of wait time, availability, convenience, and cost will positively affect attitude toward adoption of WITS for minor conditions.*

Compatibility

Based on Rogers' definition of compatibility, Karahanna, Agarwal, and Angst (2006) define compatibility as a multi-dimensional construct comprised of four dimensions: compatibility with values, compatibility with existing practices, compatibility with preferred work style, and compatibility with prior experience. The first two dimensions emerged as salient beliefs in our study.

In regards to healthcare, some respondents expressed strong values as to how healthcare should be delivered. Therefore, *compatibility with their values* about healthcare delivery became an important factor in determining their attitude toward the service. For instance, a few respondents indicated that they subscribe to holistic healing teachings. As such, they perceived WITS-provided care to be incompatible with their holistic healing values. Other respondents said that they associate use of WITS with the perpetuation of hasty, profit-driven healthcare.

There's a clear separation, where people can not be seen in a holistic way. I think it's driving medicine further and further from real interaction with the patient.

It's a more of an assembly line approach to healthcare…get the patient in and out, no rapport with the doctor. [The] patient may feel cheated, impersonal, violated.

On the other hand, some respondents made it clear that they had a preference for quick care and viewed this type of care as *compatible with their lifestyles*. Typically, these respondents noted that they have very busy schedules and, in some cases, travel routinely and find it difficult to establish connections with primary care practitioners.

For me, it's cool because I don't have a regular doctor; I move around a lot. For simple situations like an ear infection or strep throat, and you just need a prescription, it's really useful.

Hence, regarding compatibility, we propose that the higher the compatibility of WITS with existing values and lifestyle, the more positive the attitude towards using this facility:

H2a-H2b: *Beliefs about the compatibility of telemedicine use with healthcare values and beliefs about compatibility with lifestyle will positively affect attitude toward adoption of WITS for minor conditions.*

NORMATIVE BELIEFS

Two types of social influence emerged: normative influences that refer to influences that motivate individuals to comply with the expectations of others, and informational influences (Bearden, Calcich, Netemeyer, & Teel, 1986; Burnkrant & Cousineau, 1975; Karahanna et al., 1999) that refer to accepting information from others as evidence of reality.

Normative Influence

Two main referent groups emerged as sources of normative influences for the adoption of WITS: family members and healthcare professionals.

Seventy-three percent of respondents mentioned that their family members' opinions regarding the respondents' adoption of WITS would be important considerations. Respondents also indicated that their healthcare provider's opinion (approval or disapproval) would influence their adoption decision.

H3a: *Beliefs about family members' opinions will positively impact the subjective norm of adoption of WITS for minor conditions.*

H3b: *Beliefs about healthcare professionals' opinions will positively impact the subjective norm of adoption of WITS for minor conditions.*

Informational Influence

Adopting an innovation is high in uncertainty about the characteristics of the innovation and the consequences of adopting (Rogers, 1995). Thus, potential adopters examine two kinds of uncertainty reducing information: (a) information to determine what the innovation is, what it does, and why it works (principles knowledge) and (b) innovation-evaluation information about the innovation's advantages and disadvantages. Once such information-seeking activities have reduced the uncertainty about the innovation's expected consequences to a tolerable level, a decision concerning adoption or rejection will be made.

Therefore, communication channels are highly influential in providing information about WITS and its potential advantages and disadvantages. Mass media channels have a greater impact in gathering information about the innovation (WITS), while interpersonal channels more strongly influence the decision making process of whether or not to adopt (Agarwal & Prasad, 1998; Brancheau & Wetherbe, 1990; Rai, 1995; Rogers, 1995). Overall, respondents have indicated that communication from both channels would be influential in their decision to adopt WITS for minor ailments. Word-of-mouth influences through interpersonal networks, especially from individuals who will have used WITS, were cited as important sources of evaluative information and influential in the adoption decision. Additionally, media sources, such as news channels and the expert opinions of health professionals, were influential informational sources.

People who I know who have used this clinic before would influence me. That's the only way I would use this clinic, if people I know gave me favorable feedback about the clinic.

If it becomes a consensus in the medical field that this is adequate and if media report positive aspects of it…that would influence me to use it.

H4a: *Word-of-mouth communications will positively impact the subjective norm of adoption of WITS for minor conditions.*

H4b: *Media communications from news and expert sources will positively impact the subjective norm of adoption of WITS for minor conditions.*

CONTROL BELIEFS

Two salient control beliefs were identified: proximity and health insurance acceptance. Respondents mentioned that the closer in proximity a WITS clinic is to their location, the easier it would be to visit this facility. Furthermore, the facility's acceptance of the respondents' health insurance would be instrumental in determining whether they adopt the service. Though the latter represents an aspect of the Healthcare System environment in BMHSU, it is a control belief in our model since it will inhibit patient adoption despite otherwise positive beliefs on advantages.

H5: *The proximity of a WITS facility is positively related to perceived behavioral control over adoption of WITS for minor conditions.*

H6: *The acceptance of a patient's health insurance policy will positively affect perceived behavioral control over adoption of WITS for minor conditions.*

SATISFACTION WITH HEALTHCARE ALTERNATIVES

Adoption of WITS for minor conditions occurs in the context of other alternatives. As such, perceptions of relative advantage will be influenced by one's satisfaction with these alternatives. Specifically, respondents who were satisfied with and had a good relationship with their primary physician saw fewer advantages and were less likely to adopt WITS:

With your own physician, you build up a rapport. I would rather wait and make an appointment with my doctor.

H7a: *Satisfaction with healthcare alternatives will have a negative influence on attitude toward adoption of WITS for minor conditions.*
H7b: *Satisfaction with healthcare alternatives will have a negative influence on the relative advantage of WITS for minor conditions.*

UNCERTAINTY IN ASSESSING SEVERITY OF CONDITION

Several respondents indicated that the nature of their health condition would influence their decision to use WITS. While we framed the research questions within the context of minor health conditions, some respondents still expressed concern that they would not be able to assess whether their condition is minor or severe. These respondents indicated that they would use WITS for minor conditions only when they are confident in their assessment of the severity of their health condition.

I would use it only if I could self-diagnose myself or if my condition is simple.

H8: *Uncertainty in assessing the severity of one's own health condition will be negatively associated with adoption of WITS for minor conditions.*

Technology and Trust Factors

Though technology applications can be very promising and useful, technology is not infallible; inevitably, there will be system failures, power outages, glitches in software, and so forth. Further, in telemedicine, the technology limits the extent of communication cues between the patient and physician; hence, there is less richness in telecommunication versus face-to-face communication (Daft & Lengel, 1986). Many respondents noted that, by its very nature, telemedicine-based care can not be as comprehensive as in-person healthcare because the physician can not utilize all senses in assessing the condition of the patient. In other words, when utilizing telemedicine, the physician is limited to visual and auditory senses and can not take advantage of tactile and olfactory senses in deciding on a proper diagnosis. We discuss this group of factors next.

Perceived E-Consultation Diagnosticity

We introduce a new construct, perceived e-consultation diagnosticity, which is defined as the perceived ability of the telemedicine technology and users to convey to physicians sufficient patient diagnostic information that helps physicians in accurately understanding and evaluating the health conditions of remote patients. This concept is adapted from the marketing literature, in which the concept of perceived product diagnosticity has been studied. Perceived product diagnosticity involves consumer judgments of product trials—the extent to which consumers perceive that the product trial process is helpful in allowing them to evaluate products and their specific attributes (Kempf & Smith, 1998). In the context of e-consultation diagnosticity, physicians evaluate the specific symptoms and health conditions of patients without being present to "touch and feel" the patients; rather, they rely on images and sounds transmitted through technology. Respondents in this study shared concerns as to whether physicians can provide a thorough evaluation of patients via telemedicine's inherent indirect means and, thus, correctly diagnose their condition.

> *You still need the human touch when you're dealing with doctors…Even though you can see the person, sometimes you actually have to touch the person to see if something is swollen.*

> *A doctor may not be able to make a 100% accurate diagnosis every time because he is limited to only video images and audio to diagnose a problem.*

> *It's not a full, proper exam, even though you can still see and hear… Using the technology would not bring across the symptoms, secondary symptoms, and underlying symptoms associated with your health problem.*

In the words of one of the respondents, "*The diagnosis is the most important part of the visit.*" As such, perceived e-consultation diagnosticity and related media richness concerns were the fourth and third most frequently mentioned factors influencing adoption of the telemedicine service. Patients visit WITS to receive diagnoses for minor health conditions. If patients perceive that they can receive accurate diagnoses, then they will have more favorable evaluations of adopting WITS. In contrast, patients who doubt that they will receive accurate diagnoses will have more negative overall attitudes toward adopting WITS.

H9: *Perceived e-consultation diagnosticity will have a positive impact on attitude toward adoption of WITS for minor conditions.*

Media Richness

Media richness is a medium's ability to convey rich information (Daft & Lengel, 1986; Daft, Lengel, & Trevino, 1987) and is based on the ability of the medium to provide instantaneous feedback; to convey multiple cues, such as social presence, voice inflection, body gestures, words, and graphic symbols; to provide language variety (e.g., numbers and natural language); and to enable conveyance of personal feelings and emotions. Though media have an "objective" level of richness, this may be perceived differently across individuals and, thus, our focus is on perceived media richness (e.g., Carlson & Zmud, 1999).

The telemedicine technology enables instantaneous feedback as well as language variety to the same extent as a face-to-face encounter. Therefore, it is not surprising that respondents only identified multiple cues and ability to convey emotions as salient factors. Specifically, social presence, the availability of all sensory cues, and personal interaction with the physician were commonly cited as limitations of the telemedicine technology and sources of concern.

> *The doctor may not see subtle things that he/she may see in person…the way the patients talk or other things.*

> *The doctor can't see how the patient actually feels. One-on-one contact is different.*

The extent of telemedicine media richness perceived by patients will influence their perceptions of e-consultation diagnosticity because the technology limits the cues available for diagnosis:

> *A doctor may not be able to make a 100% accurate diagnosis every time because he is limited to only video images and audio to diagnose a problem, as opposed to visual, auditory, olfactory, and tactile methods.*

H10: *Perceptions of media richness will positively influence perceived e-consultation diagnosticity.*

TRUST IN TECHNOLOGY BELIEFS: SYSTEM QUALITY

Since diagnosis is mediated through technology, the quality of the telemedicine system is paramount in facilitating an effective exchange between the patient and physician and diagnosis of the condition. As such, system quality concerns were an important consideration by respondents. Though the literature suggests various dimensions of system quality (DeLone & McLean, 1992), our respondents focused on reliability, dependability, accuracy, and functionality of the technology.

Just because you're depending on technology, that stuff can break sometimes or not show a good picture or get good reception.

There's all this room for error when you deal with technology. I don't think the technology would work right.

When expressing system quality concerns, respondents said they do not "trust the technology."

I don't trust those machines…You're taking a risk by relying on the machines and the technicians. What if the images are different – the image isn't high quality, or it doesn't transmit exactly the same?

Trust in technology has been defined as the extent to which a user is confident in and willing to depend on the technology (Lankton & McKnight, 2008; Madsen & Gregor, 2000) and is based on trusting beliefs of competence, benevolence, integrity (Wang & Benbasat, 2005), predictability, dependability, faith, competence, responsibility, and reliability (Muir & Moray, 1996). These trusting beliefs are similar to the dimensions of system quality identified by our respondents (e.g., accuracy, reliability, dependability, and functionality). In some comments, beliefs on system quality were inextricably linked with comments on trusting the technology. Therefore, in the context of telemedicine, trusting beliefs in technology refer to beliefs about the quality of the system. Further, as respondents indicate, their beliefs about system reliability, accuracy, and functionality influence their perceptions of e-consultation diagnosticity:

The technology limits the extent of diagnoses and tests they can do from a distance.

This center, being more tech-inclined, may have more of the latest technologies, diagnosis tools, information…that might mean better care.

H11: *Beliefs concerning system quality will positively impact perceived e-consultation diagnosticity.*

TRUSTING BELIEFS: PROVIDERS

Concern for one's own physical well-being is likely to influence potential adopters' perceived risk of using WITS and ultimately make trust a salient consideration in the adoption of WITS. Trust has been defined as one's trusting beliefs of ability, benevolence, and integrity concerning the trustee, or the object of trust (Mayer, Davis, & Schoorman, 1995). Ability refers to the competence that the trustee possesses to perform the task. Benevolence reflects the goodwill of the trustee—i.e., the extent to which the trustee will not take advantage of the trustor or otherwise act opportunistically. Integrity refers to the belief that the trustee will adhere to the principles perceived to be acceptable by the trustor.

Respondents indicated three categories of healthcare providers associated with a WITS facility: physicians, office staff, and technicians. However, only beliefs concerning *technicians' ability* surfaced as salient beliefs. Because the technician is the one interacting with the patient face-to-face and coordinating the communication between the patient and physician, patients are more concerned with trust issues with regard to technicians. Without the technicians' expertise, the interaction between the patient and physician can not properly take place. It is interesting to note that respondents expressed no concerns about the ability, benevolence, or integrity of the physicians or benevolence and integrity of the technician.

You're basically at the mercy of your technician, so they would need to be properly trained and motivated.

What if the technician measured you wrong or missed something? Do they know what they're doing?

H12: *Trusting beliefs in the technician's ability will positively influence attitude toward adoption of WITS for minor conditions.*

INSTITUTION-BASED TRUST

Institution-based trust (IBT) is defined as the perception that impersonal structures are in place to protect individuals (Shapiro, 1987) and is an antecedent of trusting beliefs (McKnight, Cummings, & Chervany, 1998). There are two types of IBT: situational normality and structural assurances (McKnight et al., 1998). Situational normality refers to the sense that the situation is customary and as expected and as such it instills a confidence that the transaction will be a success (Baier 1986; Lewis & Weigert, 1985). This assures people that everything in the setting is as it ought to be and that a shared understanding of what is happening exists (McKnight et al., 1998; Zucker, 1986). Structural assurances refer to the safety nets (e.g., regulations, guarantees, legal recourse, and contracts) an institution puts in place in order to protect individuals (McKnight et al., 1998; Shapiro, 1987; Zucker, 1986). Perceptions of institutional safeguards at a WITS facility will emanate trust in both the healthcare providers and the technology.

Situational Normality

Respondents favorably inclined to adopt WITS specifically noted that a WITS visit did not appear to be too different from a regular physician's visit or an emergency room visit. In contrast, respondents skeptical of the efficacy of WITS observed low situational normality.

I would just use it because it doesn't seem too different than a regular doctor's visit. The only difference is that the doctor is not there with you. But if you talk to the doctor on camera, or on TV, the doctor would still be able to diagnose what's going on with you.

If the person operating the telemedicine equipment is just a technical person rather than trained in medicine, I would be more hesitant to think it's the same as seeing a doctor.

Thus, to the extent that patients perceive that WITS are similar to other models of healthcare delivery, they will show increased trust in both the providers and telemedicine system.

H13a: *Situational normality will positively influence trusting beliefs toward the providers.*

H13b: *Situational normality will positively influence trusting beliefs concerning system quality.*

Structural Assurances

Some respondents referred to various structural assurances issues. For example, because HES does not have nurses or physicians on staff, nor the wide range of medical technology resources that a hospital has to treat serious conditions, some respondents suggested that patients' misdiagnoses of the severity of their own symptoms may result in dire consequences. Hence, respondents indicated that they would put more trust in WITS for minor conditions if appropriate resources or safeguards were available to protect patients who have unexpected serious health conditions. Other examples of structural assurances that were mentioned include concerns regarding information security and physical security. Some respondents expressed skepticism that the network-based technology would be a secure channel for protecting their patient confidentiality.

It's wide open for fraud with insurance companies. How easy is it to hack into the Internet? What's the proof that somebody went to the clinic and saw a doctor?

People may be wary of privacy issues... because information is traveling through networked technology, the information is not private.

With structural assurances in place, patients will exhibit higher levels of trust in the providers and telemedicine system. Regarding providers, for example, if quality assurance guarantees exist, patients are more likely to believe that the providers possess competence, benevolence, and integrity. Likewise, if safeguards and procedures are in place to prevent system hacks and downtime, patients will put more faith in the quality of the telemedicine system.

H14a: *Structural assurances will positively affect trusting beliefs toward the providers.*

H14b: *Structural assurances will positively affect trusting beliefs concerning system quality.*

INDIVIDUAL DIFFERENCES

Two groups of relevant individual differences emerged through the interviews: demographic characteristics and the personality trait of innovativeness. Respondents indicated that younger individuals may be more likely to adopt, likely because they are more open to technological innovations (Morris & Venkatesh, 2000). In addition, people in rural areas and of lower income may find the enhanced access to healthcare and the lower costs more attractive than people who have better access (geographic and financial) to alternative services. Finally, respondents who viewed themselves as innovative were excited about the possibility of at least trying WITS. Personal innovativeness with respect to information technology (the willingness of an individual to try out any new information technology) has been shown to be an important factor in technology acceptance decisions by influencing salient beliefs (Agarwal & Prasad, 1998).

I wouldn't go to a Health e-Station. It's too new. The first try is so risky that I wouldn't do it, unless it's proven.

The technology is pretty interesting, the fact that you can see the scope of your throat or eardrum… that's pretty innovative. Right now, I'm not sick very often. I probably would just go out of curiosity.

H15a: *Personal innovativeness with respect to technology will positively influence behavioral beliefs toward adopting WITS for minor conditions.*

H15b: *Personal innovativeness with respect to technology will positively influence trusting beliefs towards system quality.*

Though we do not posit hypotheses with respect to demographic variables, we include it in the model to highlight the fact that demographic variables such as age, geography, and socio-economic status are likely influential factors in the nomological network leading to patient acceptance of telemedicine services.

LIMITATIONS

Like all research, the current study has limitations. Though our sample is diverse in age, gender, race, education, and socio-economic status, it may not be entirely representative and, as such, generalizability of findings should be interpreted with care. For example, our sample did not include many individuals with lower socio-economic status, without health insurance, and over the age of 65; additional perceptions and challenges may emerge for these groups.

While most of the data were collected in face-to-face interviews, email and phone were used for six respondents. Though inspection of responses showed no differences in the types of beliefs elicited, method differences in responses cannot be conclusively ruled out. However, since the objective was to elicit salient beliefs, the use of multiple methods is not a threat to the validity of the results. Additionally, our focal telemedicine service is HES. To the extent that other telemedicine services differ significantly from HES, results of the study may not generalize to patient acceptance of other telemedicine services.

Furthermore, our methodology involves showing potential adopters a video of HES, which relays expert opinions (pros and cons) of this telemedicine service. Though this was necessary given the newness of the application and given that none of the respondents were familiar with walk-in telemedicine services, these expert opinions may have introduced bias in the respondents' reported beliefs concerning WITS for minor conditions. It is possible that the respondents may have been influenced in the beliefs elicited not only by the description of the facility and illustration of how it works to diagnose a minor medical condition, but also by the experts who were presenting their opinions (one pro and one against) regarding WITS (HES, specifically). Thus, certain beliefs, such as wait time, cost, and uncertainty in assessing the severity of the condition, may have become more salient in this study and, thus, may be over-represented in frequency. Though this is not unlike how beliefs are formed prior to adoption—i.e., mass media and interpersonal networks play an important role in shaping beliefs (Rogers, 1995)—the model developed in this study should be tested empirically with potential adopters who become aware of WITS via other means. The model should also be tested with users of WITS for minor conditions who have *first-hand* experience with the service since antecedents of adoption and repeated use may not be the same necessarily (Karahanna et al., 1999).

DISCUSSION AND DIRECTIONS FOR FUTURE RESEARCH

The study has provided insights into the antecedents of patient acceptance of WITS for minor conditions. While the majority of the respondents (n=15, 52%) reported that they would use WITS, there were a few (n=4, 14%) who indicated that they would never use WITS. Furthermore, there were several respondents (n=10, 35%) who specified that they would only use WITS under certain conditions (e.g., if the WITS facility would accept their health insurance plan, if they could self-diagnose their condition, if they could not see their own physician within a reasonable amount of time, etc.), indicating that many respondents are not ready to embrace e-consultations as a replacement for face-to-face consultations if the face-to-face option is readily available.

Specifically, perceived e-consultation diagnosticity, perceptions of relative advantage and compatibility, trust in technology and in the providers, and institutional guarantees all emerged as important salient behavioral beliefs. Proximity and health insurance acceptance emerged as salient control beliefs while both informational and normative influences emerged as important sources of social influence. Other antecedents that were identified include individual differences in age, socio-economic status, and geographic location as well as the personality trait of innovativeness and one's satisfaction with his/her local healthcare provider.

Extant studies on technology acceptance suggest that perceived usefulness (or relative advantage in terms of efficiency and effectiveness), ease of use, compatibility with work style, and social influence are key determinants of user acceptance of technology (see Venkatesh, Morris, Davis, & Davis, 2003 for a synthesis). Results of the study highlight that while some commonalities exist, patient acceptance of telemedicine technology entails some unique antecedents. Specifically, perceived e-consultation diagnosticity emerged as a central concern for potential adopters. Given the possible personal risk entailed in healthcare decisions, and the technology-mediated nature of the interaction with the physician, potential adopters raised concerns about the efficacy of the technology in enabling diagnoses of their health condition. These concerns emanated from perceptions that the technology was not rich enough to permit "touch and feel" cues that are important in diagnosing as well as questions about trusting the technology to be reliable and accurate. As more technology-mediated healthcare services become available and given the dire potential risks of misdiagnoses, the concept of perceived e-consultation diagnosticity will likely continue to be a central concern for patient acceptance. As such, future research should focus on developing measures of this construct as well as additional antecedents and consequents.

In addition, the potential higher personal risk involved in healthcare decisions manifested in the emergence of additional trust-based antecedents of patient acceptance. Both types of institution-based trust, structural assurances and situational normality, as well as trust in the provider beliefs were identified as significant factors. Thus, to instill trust, at least initially, telemedicine services should resemble other professional health services and use similar procedures. Salient structural assurances included guarantees about the security and privacy of information and safeguards to assure proper treatment of more serious medical conditions. The existence of guarantees, legal recourse, and safeguards appears to be a focal trust-building mechanism and an important way in which to reduce perceptions of risk. Future research should identify other specific structural assurances that can instill trust in telemedicine services.

Further, while innovation diffusion theory posits relative advantage as an important determinant of adoption (Rogers, 1995; Tornatzky & Klein, 1982), it does not specify the relevant dimensions of relative advantage that are salient in each context. Our study suggests that potential adopters perceive benefits in wait times, hours of availability, convenience, and cost. The advantages are reflective of current patient frustrations with extant alternatives in the U.S. Additional or different dimensions may emerge in other countries where physicians' office hours, for example, are more convenient for the patients or where physicians make home visits. As such, though the model suggests that relative advantage is an important determinant of adoption, it is likely that its specific dimensions will be country-specific. Identifying these dimensions and determining their generalizability across countries is a fruitful direction for future research.

The study makes three important theoretical and practical contributions. First, using both belief elicitation and guided by theory, we develop a model of patient acceptance of WITS for minor conditions. Future research should empirically test the emergent research model to validate and further develop and refine the nomological network. The current research focused on identifying pre-adoption beliefs. Future research should examine how patient beliefs change over time and determine beliefs that lead to continued WITS usage. Second, we develop perceived e-consultation diagnosticity as an important construct in the nomological network leading to patient acceptance and we identify its antecedents. Perceived e-consultation diagnosticity emerges due to the technology-mediated nature of telemedicine diagnoses. As telemedicine services grow, we expect the construct to be of interest to academics and practitioners in health informatics. Finally, from a practical perspective, the factors identified in the model provide leverage to practitioners in designing and implementing telemedicine systems and in deploying marketing efforts to enhance acceptance of telemedicine services.

ACKNOWLEDGMENT

The research was supported by a Terry-Sanford grant from the Terry College of Business, University of Georgia.

REFERENCES

A doctor's visit is just a click away [video on the Internet]. (2008). [cited 2006 November 15]. Available from: http://video.msn.com/v/us/msnbc.htm?g=5e52a295-85e6-4c60-8037-9ef7975b3ef4&f=00&fg.

Afilalo, J., Marinovich, A., Afilalo, M., Colacone, A., Léger, R., & Unger, B. (2004). Nonurgent emergency department patient characteristics and barriers to primary care. *Academic Emergency Medicine*, *11*(12), 1302–1310. doi:10.1111/j.1553-2712.2004.tb01918.x

Agarwal, R., & Prasad, J. (1998). A conceptual and operational definition of personal innovativeness in the domain of information technology. *Information Systems Research*, *9*(2), 204–215. doi:10.1287/isre.9.2.204

Ajzen, I., & Fishbein (1980). *Understanding attitudes and predicting social behavior.* Englewood Cliffs: Prentice Hall.

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes*, *50*(2), 179–211. doi:10.1016/0749-5978(91)90020-T

Andersen, R. M. (1995). Revisiting the behavioral model and access to medical care: Does it matter? *Journal of Health and Social Behavior*, *36*(1), 1–10. doi:10.2307/2137284

Andersen, R. M., & Newman, J. F. (1973). Societal and individual determinants of medical care utilization in the United States. *The Milbank Memorial Fund Quarterly. Health and Society*, *51*(1), 95–124. doi:10.2307/3349613

Baier, A. (1986). Trust and antitrust. *Ethics*, *96*(2), 231–260. doi:10.1086/292745

Bearden, W. O., Netemeyer, R. G., & Teel, J. E. (1989). Measurement of consumer susceptibility to interpersonal influence. *The Journal of Consumer Research*, *15*(4), 473. doi:10.1086/209186

Borger, C., Smith, S., Truffer, C., Keehan, S., Sisko, A., & Poisal, J. (2006). Health spending projections through 2015: Changes on the horizon. *Health Affairs*, *25*, W61–W73. doi:10.1377/hlthaff.25.w61

Brancheau, J. C., & Wetherbe, J. C. (1990). The adoption of spreadsheet software: testing innovation diffusion theory in the context of end-user computing. *Information Systems Research*, *1*(2), 115–143. doi:10.1287/isre.1.2.115

Brennan, D. M., Holtz, B. E., Chumbler, N. R., Kobb, R., & Rabinowitz, T. (2008). Visioning technology for the future of telehealth. *Telemedicine and E-Health*, *14*(9), 982–985. doi:10.1089/tmj.2008.0116

Burnkrant, R. E., & Cousineau, A. (1975). Informational and normative social influence on buyer behavior. *The Journal of Consumer Research*, *2*(3), 206–215. doi:10.1086/208633

Carlson, J. R., & Zmud, R. W. (1999). Channel expansion theory and the experiential nature of media richness perceptions. *Academy of Management Journal*, *42*(2), 153–170. doi:10.2307/257090

Daft, R. L., & Lengel, R. H. (1986). Organizational information requirements, media richness and structural design. *Management Science*, *32*(5), 554–571. doi:10.1287/mnsc.32.5.554

Daft, R. L., Lengel, R. H., & Trevino, L. K. (1987). Message equivocality, media selection, and manager performance: Implications for information systems. *MIS Quarterly*, *11*(3), 354–366. doi:10.2307/248682

DeLone, W. H., & McLean, E. R. (1992). Information systems success: The quest for the dependent variable. *Information Systems Research*, *3*(1), 60–95. doi:10.1287/isre.3.1.60

Gagnon, M.-P., Godin, G., Gagne, C., Fortin, J.-P., Lamothe, L., & Reinharz, D. (2003). An adaptation of the theory of interpersonal behaviour to the study of telemedicine adoption by physicians. *International Journal of Medical Informatics*, *71*(2-3), 103–115. doi:10.1016/S1386-5056(03)00094-7

Glaser, B. G., & Strauss, A. (1967). *The discovery of grounded theory.* Chicago: Aldine.

Health e-Station [homepage on the Internet]. (2006). [cited 2006 November 15]. Available from: http://www.healthestation.com/.

Howard, M. S., Davis, B. A., Anderson, C., Cherry, D., Koller, P., & Shelton, D. (2008). Patients' perspective on choosing the emergency department for nonurgent medical care: A qualitative study exploring one reason for overcrowding. *Journal of Emergency Nursing: JEN*, *31*(5), 429–435. doi:10.1016/j.jen.2005.06.023

Karahanna, E., Agarwal, R., & Angst, C. M. (2006). Reconceptualizing compatibility beliefs in technology acceptance research. *MIS Quarterly*, *30*(4), 781–804.

Karahanna, E., Straub, D. W., & Chervany, N. L. (1999). Information technology adoption across time: A cross-sectional comparison of pre-adoption and post-adoption beliefs. *MIS Quarterly*, *23*(2), 183–213. doi:10.2307/249751

Kempf, D. S., & Smith, R. E. (1998). Consumer processing of product trial and the influence of prior advertising: A structural modeling approach. *JMR, Journal of Marketing Research*, *35*(3), 325–338. doi:10.2307/3152031

Lankton, N., & McKnight, H. (2008). Incorporating trust in technology into expectation disconfirmation theory (Working paper). East Lansing, MI: Michigan State University.

Lehoux, P., Sicotte, C., Denis, J. L., Berg, M., & Lacroix, A. (2002). The theory of use behind telemedicine: How compatible with physicians' clinical routines? *Social Science & Medicine*, *54*(6), 889–904. doi:10.1016/S0277-9536(01)00063-6

LeRouge, C., Hevner, A. R., & Collins, R. W. (2007). It's more than just use: An exploration of telemedicine use quality. *Decision Support Systems*, *43*(4), 1287–1304. doi:10.1016/j.dss.2006.02.007

Lewis, J. D., & Weigert, A. (1985). Trust as a social reality. *Social Forces*, *63*(4), 967–985. doi:10.2307/2578601

Madsen, M., & Gregor, S. (2000). Measuring human-computer trust. In *Proceedings of the 11th Australian Conference on Information Systems*. Brisbane, Queensland.

Mair, F., & Whitten, P. (2000). Systematic review of studies of patient satisfaction with telemedicine. *British Medical Journal*, *320*(7248), 1517–1520. doi:10.1136/bmj.320.7248.1517

Mayer, R. C., Davis, J. H., & Schoorman, F. D. (1995). An integrative model of organizational trust. *Academy of Management Review*, *20*(3), 709–734. doi:10.2307/258792

McKnight, D. H., Cummings, L. L., & Chervany, N. L. (1998). Initial trust formation in new organizational relationships. *Academy of Management Review*, *23*(3), 473–490. doi:10.2307/259290

Menachemi, N., Burke, D., & Ayers, D. (2004). Factors affecting the adoption of telemedicine—A multiple adopter perspective. *Journal of Medical Systems*, *28*(6), 617–632. doi:10.1023/B:JOMS.0000044964.49821.df

Moore, G. C., & Benbasat, I. (1991). Development of an instrument to measure the perceptions of adopting an information technology innovation. *Information Systems Research*, *2*(3), 192–222. doi:10.1287/isre.2.3.192

Morris, M. G., & Venkatesh, V. (2000). Age differences in technology adoption decisions: Implications for a changing work force. *Personnel Psychology*, *53*(2), 375–403. doi:10.1111/j.1744-6570.2000.tb00206.x

Muir, B. M., & Moray, N. (1996). Trust in automation. Part II. Experimental studies of trust and human intervention in a process control simulation. *Ergonomics*, *39*(3), 429–460. doi:10.1080/00140139608964474

Pavlou, P. A., & Fygenson, M. (2006). Understanding and predicting electronic commerce adoption: An extension of the theory of planned behavior. *MIS Quarterly*, *30*(1), 115–143.

Rai, A. (1995). External information source and channel effectiveness and the diffusion of CASE innovations: An empirical study. *European Journal of Information Systems*, *4*(2), 93–102. doi:10.1057/ejis.1995.11

Rogers, E. (1995). *Diffusion of innovations*. New York: Free Press.

Shapiro, S. P. (1987). The social control of impersonal trust. *American Journal of Sociology*, *93*(3), 623–658. doi:10.1086/228791

Taylor, S., & Todd, P. A. (1995). Understanding information technology usage: A test of competing models. *Information Systems Research*, *6*(2), 144–176. doi:10.1287/isre.6.2.144

Tornatsky, L., & Klein, K. (1982). Innovation characteristics and innovation-adoption implementation: A meta-analysis of findings. *IEEE Transactions on Engineering Management*, *EM-29*(1), 28–45.

Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User acceptance of information technology: Toward a unified view. *MIS Quarterly*, *27*(3), 425–478.

Wang, W., & Benbasat, I. (2005). Trust in and adoption of online recommendation agents. *Journal of the Association for Information Systems*, *6*(3), 72–101.

Whitten, P., & Love, B. (2005). Patient and provider satisfaction with the use of telemedicine: Overview and rationale for cautious enthusiasm. *Journal of Postgraduate Medicine*, *51*(4), 294–300.

Williams, T. L., May, C. R., & Esmail, A. (2001). Limitations of patient satisfaction studies in telehealthcare: A systematic review of the literature. *Telemedicine Journal and e-Health*, *7*(4), 293–316. doi:10.1089/15305620152814700

Wilson, E. V., & Lankton, N. K. (2004). Modeling patients' acceptance of provider-delivered e-health. *Journal of the American Medical Informatics Association*, *11*(4), 241–248. doi:10.1197/jamia.M1475

Zucker, L. G. (1986). Production of trust: Institutional sources of economic structure, 1840-1920. *Research in Organizational Behavior*, *8*, 53–111.

ENDNOTE

[1] Though telemedicine has been practiced for over forty years in the U.S., it has mainly been implemented in niche areas of medicine and for telemonitoring of specific (usually chronic) health conditions (Brennan, Holtz, Chumbler, Kobb, & Rabinowitz, 2008; Mair & Whitten, 2000; Williams, May, & Esmail, 2001).

This work was previously published in International Journal of Healthcare Information Systems and Informatics, Vol. 4, Issue 4, edited by J. Tan, pp. 37-56, copyright 2009 by IGI Publishing (an imprint of IGI Global).

Chapter 5.18

Disability Determinations and Personal Health Records

Elaine A. Blechman
University of Colorado at Boulder, USA

ABSTRACT

Newly disabled workers are often unemployed, uninsured, and indigent. They are in desperate need of Social Security OASDI monthly benefits, and the Medicare health insurance that follows 24 months after benefits begin. Applicants must prove that their medical conditions (excluding drug and alcohol abuse) have resulted in severe functional limitations that prevent them from any gainful employment. Delays and denials of benefits result when applicants cannot find or retrieve medical records from providers familiar with their medical history, health status, and functional limitations. The disability application workflow is complex, particularly for applicants with cognitive and mental health impairments. Health information technology (HIT) has been used to automate care delivery workflow through provider-controlled, electronic health record systems (EHRs). Disability applicants' workflow could, just as well, be automated through consumer-controlled, unbound, and intelligent personal electronic health record systems (PHRs), which are not tethered to a health plan or employer network, and which automatically exchange information updates with authorized providers' EHRs. Applicants' PHRs may later prove helpful with self-management of chronic conditions prior to Medicare coverage and with periodic reevaluations of their medical status.

INTRODUCTION

"A 20-year-old worker has a 3 in 10 chance of becoming disabled before reaching retirement age" (http://www.socialsecurity.gov) by a condition that prevents work or that limits the kind or amount of possible work (Burkhauser & Houtenville, 2006). In 2004, an estimated 7.9% (or about one in 13) civilian noninstitutionalized, men and women, aged 18-64 in the United States reported a disability that limits work; about one in four people with disabilities lived in families with incomes below the poverty line (Houtenville, Erickson, & Lee, 2005).

DOI: 10.4018/978-1-60566-016-5.ch005

About 46.6 million people or 15.9 percent of the U.S. population have no health insurance (Hadley, 2007). Approximately 18,000 Americans die prematurely each year because they lack health insurance (DeNavas-Walt, Proctor, & Lee, 2006). A telephone survey of people with disabilities found that those who were uninsured were more likely than others to do without or delay necessary care, including prescription drugs and preventive healthcare services that would reduce their future need for healthcare (Hanson, Neuman, Dutwin, & Kasper, 2003). Newly disabled and unemployed workers who no longer have private health insurance coverage are exceptionally vulnerable to deteriorating health and untimely death. If they qualify for Social Security disability benefits, they get a modest income for themselves and their dependents and, after 24 months, Medicare Part A (http://www.socialsecurity.gov/disability/3368).

Disability benefits have expanded and contracted since their institution during the Great Depression (http://www.ssa.gov/history/briefhistory3.html). In 1935, President Roosevelt signed the Social Security Act (SSA), creating a contributory system in which workers prepared for their retirement through taxes that they paid while employed. In 1956, an amendment to the Act provided benefits to disabled workers aged 50-64 and disabled adult children. In 1960, President Eisenhower signed an amendment permitting SSA disability benefits for disabled workers of any age and their dependents. In 1996, President Clinton signed a bill (P.L. 104-121) that changed eligibility for SSA disability benefits from a medical condition that prevents work, to a medical condition other than drug addiction or alcoholism that prevents work.

About 48.4 million people received Old Age, Survivors, and Disability Insurance (OASDI) monthly benefits in December 2005. Disabled workers and their dependents were 17% of OASDI beneficiaries, their average monthly benefits were $938. In 2005, OASDI payments exceeded $44 billion a month, approached $521 billion for the year, and represented 4.2% of the U.S. gross domestic product. At the same time, employees, self-employed workers, and employers contributed $593 billion to the OASDI trust funds (SSA, 2007).

Two recent studies indirectly suggest the importance of SSA disability benefits. In Sweden, 197 individuals granted disability pensions reported less illness, larger social networks, and less work and family role limitations than 96 individuals who did not receive disability pensions (Ydreborg, Ekberg, & Nordlund, 2006). In the U.S., a survey of 4,918 veterans found that their odds of impoverishment were reduced considerably if they applied for and received VA benefits for posttraumatic stress disorder (Murdoch, van Ryn, Hodges, & Cowper, 2005).

The findings of a third study (McWilliams, Meara, Zaslasvky, & Ayanian, 2007) are directly relevant to the impact of Medicare coverage following (by 24 months) qualification for SSA disability benefits. McWilliams et al. (2007) used longitudinal data from the nationally representative Health and Retirement Study to assess self-reported healthcare use and expenditures from 1992 through 2004 among 5,158 adults who were privately insured or uninsured before age 65 and of Medicare eligibility. Previously uninsured Medicare beneficiaries with hypertension, diabetes, heart disease, or stroke required more intensive and costly healthcare, and died earlier than previously insured Medicare beneficiaries with these same chronic conditions. There were no differences in morbidity or mortality between previously uninsured and insured Medicare beneficiaries without chronic conditions.

Chapter Overview

Newly disabled workers are often unemployed, uninsured, and indigent. They are in desperate need of Social Security OASDI monthly benefits and the Medicare health insurance that follows 24 months after benefits begin. Applicants must prove that their medical conditions (excluding drug and alcohol abuse) have resulted in severe functional limitations that prevent them from any gainful employment. Delays and denials of benefits result when applicants cannot find or retrieve medical records from providers familiar with their medical history, health status, and functional limitations. The disability application workflow is complex and obscure (Pransky & Dempsey, 2004), particularly for applicants with cognitive and mental health impairments (Banks & Lawrence, 2005).

Health information technology (HIT) has been used to automate care delivery workflow through provider-controlled, electronic health record systems (EHRs). For example, providers can use capabilities of their EHR systems to automate scheduling of patient encounters, e-prescribing, ordering of laboratory tests and import of laboratory results, and production and export of health insurance claims for reimbursement of their services.

Disability applicants' workflow could, just as well, be automated through consumer-controlled, unbound, and intelligent personal electronic health record systems (PHRs), which are not tethered to a health plan or employer network and which automatically exchange information with authorized providers' EHRs. For example, consumers could use their PHRs to automate transmission of requests for medical records, autofilling of SSA forms, importing of requested data and documents from providers' EHRs, and exporting of the completed application portfolio to SSA interviewers and evaluators in formats they require. Applicants' PHRs may later prove helpful with self-management of chronic conditions prior to Medicare coverage, and with periodic reevaluations of their medical status.

In the remainder of this chapter, I suggest how newly disabled workers could use PHRs to ease the disability benefits application process. First, I describe some of the workflow requirements confronting newly disabled workers applying for SSA benefits. Next, I present the conventional assumption that a National Health Information Network (NHIN), scheduled for rollout in 2014, should be composed of provider-controlled EHRs networked in regional health information exchanges (HIEs) with limited consumer access via tethered PHRs.

A provider-controlled NHIN simply cannot satisfy the workflow requirements of low-income, unemployed consumers with chronic conditions, such as applicants for SSA benefits. And so, I recommend that the NHIN architecture make room for consumer-controlled, unbound, intelligent personal electronic health record systems (PHRs), which are capable of automating data exchange across the NHIN with provider-controlled EHRs, are not tethered to employer or health plan networks, and automate the workflow required to compile, update, and selectively share an electronic disability benefits application portfolio.

PROBLEM: APPLYING FOR SSA DISABILITY BENEFITS

The applicant for SSA disability benefits must satisfy SSA's five-step disability application process. Applicants must meet an earnings requirement including a duration-of-work test to show sufficient length of work under Social Security. And, they must prove that they are unable to work due to limitations associated with medical conditions other than drug addiction or alcoholism. Decisions about eligibility, according to various SSA documents, can take from three months (for applicants with confirmed disabilities on the SSA list) to five years (for applicants who contest denial of their initial application and await the ruling of an administrative law judge). The application process, with its various permutations, is depicted on the SSA Web site in a 15-page-long flow chart.

SSA deems applicants eligible for benefits if they:

1. Are not working or have monthly earning in an acceptably low range;
2. Have a severe medical condition that "significantly limits your ability to do basic work activities—such as walking and remembering—for at least one year";
3. Have medical conditions on the SSA list of impairments (http://www.ssa.gov/disability/professionals/bluebook/AdultListings.htm) that are automatically considered disabilities as defined by law; or
4. Have medical conditions that the state agency decides prevents applicants from being able to do the work they did before; and
5. Are judged by a state agency unable to do other work than before.

SSA 3368: The process usually begins at the applicant's local Social Security office where the applicant, assisted by an SSA interviewer, completes SSA Disability Application 3368, Adult Disability and Work History Report (http://www.socialsecurity.gov/disability/3368). SSA 3368 includes 275 data fields covering illnesses, injuries, conditions; work; medical records; medications; tests; education and training; vocational rehabilitation; and employment. SSA 3368 is available online so that applicants can print it out and use it to prepare for the interview at the local SSA office. (Although the SSA Web site indicates that online submission is an option, my several attempts to initiate an online submission failed).

Other applicant forms: In addition to the basic SSA 3368 application form, applicants must complete other forms which describe their medical conditions and explain how it affects their ability to work, and which give permission to doctors, hospitals, and other healthcare professionals to release applicant information and records to the SSA. (These forms are mentioned on the SSA Web site, but my repeated attempts to find these forms failed).

Supporting documents and medical records: SSA requires applicants to supply documents and medical records that support claims made in SSA 3368 forms including:

- The Social Security number and birth certificate or other proof of age for each person applying for benefits (including your spouse and children, if they are applying for benefits);
- Names, addresses, and telephone numbers of doctors, hospitals, clinics, and institutions that treated you and dates of treatment;
- Names and prescribed dosage of all medications you are taking;
- Medical records from your doctors, therapists, hospitals, clinics, and caseworkers;
- Laboratory and test results;
- A summary of where you worked in the past 16 years (company names, addresses, supervisors' telephone numbers) and the kind of work you did;
- A copy of your W-2 Form (Wage and Tax Statement), or if you are self-employed, your federal tax return for the past year; and
- Dates of your current and any prior marriages, if applicable

The SSA Blue Book (SSA, 2006a) recommends that applicants request medical records documenting their medical condition (including prescribed medications and lab test results) from healthcare providers who are familiar with them and able to provide *a detailed longitudinal picture of the claimant's impairments.* Many applicants cannot retrieve medical records from the healthcare providers who diagnosed and treated them in the past. Their past providers may be unresponsive to requests for medical records. Or, they may not be able to recall the identity or location of the many past providers with whom they have had diagnostic and treatment encounters. Applicants who are unable to retrieve sufficient documentation from their own healthcare providers must submit to a one-time examination by an SSA-appointed examiner. SSA examiners are unfamiliar with applicants' medical history and health status; and, they are probably less inclined than applicants' own physicians to find in the applicant's favor.

If an applicant's claim is denied by the state agency, the applicant may request a hearing before an administrative law judge involving reconsideration of application evidence by a vocational or medical expert. The waiting time for hearings ranges from 90 days to 18 months. When a judge issues a partially favorable or unfavorable decision, the claimant may appeal to Social Security's Appeals Council, whose response time ranges from 12 weeks to three years.

The SSA disability application process requires applicants to procure, store, and share a comprehensive and up to date portfolio of medical records, lab tests, and evaluation reports. Applicants must make copies of items in this portfolio available to any number of SSA employees and subcontractors involved in the applicant's case for as many as five years from start to finish of the application process. Most applicants who are awarded benefits must be prepared for periodic re-evaluations of their status by continuously updating their medical records portfolios.

The SSA publishes annual statistical reports (e.g., SSA, 2007) enumerating the proportion of applicants who are denied benefits and the reasons for denial such as "Impairment is not severe." An unknown number of applicants pay doctors and lawyers to prepare, submit, and appeal their applications. It is not clear how many applicants are improperly denied benefits, because they lack the human or financial resources required for continuous, long-term exchange of records and information with providers, vocational and medical experts, lawyers, administrative law judges, and appeals councils. Nor, is it clear how many applicants make substantial investments in this process, but die before they become eligible for benefits.

It seems likely that a substantial number of genuinely eligible applicants cannot find and supply the required data and supporting documents, due to the presence of medical conditions (such as traumatic brain injury) and associated cognitive and mental health disabilities (such as dementia and PTSD), and due to the absence of capable, informed family caregivers. Many beneficiaries, similarly unprepared for SSA reevaluation of their status, may lose their benefits.

Controversy: A Provider-Centered National Health Information Network

For about two decades, health information technology (HIT) has been employed to automate healthcare providers' workflow, including records management, scheduling of patient encounters, and submission of claims to health insurance payers. No noticeable attention has been directed to automation of workflow of consumers with chronic conditions and their family caregivers who spend hours each week managing health-care records, scheduling appointments with providers, and contending with healthcare financing problems. Lessons learned from automation of providers' workflow could readily be applied to consumers such as SSA disability benefits applicants or SSA beneficiaries undergoing reevaluation of status. HIT might just as well be used to automate the SSA disability application workflow, making it easier for deserving applicants to speedily and successfully submit applications and qualify for benefits.

Health Information Technology Policy Recommendations

The Institute of Medicine (IOM) of the National Academies of Science is a nongovernmental body established to advise the U.S. Congress about healthcare policy. The IOM has repeatedly recommended the use of HIT to automate the workflow of healthcare providers with the expectation that the results would benefit consumers, particularly those with chronic illnesses and disabilities.

In 1991, the IOM proposed, "The Computer-Based Patient Record," as an essential technology solution for inadequacies in U.S. healthcare (IOM, 1991). In 2000, the IOM reported that, "More people die in a given year as a result of medical errors than from motor vehicle accidents (43,458), breast cancer (42,297), or AIDS (16,516)" (IOM, 2000, pp. 1), and in 2001, recommended the use of HIT to make healthcare more safe, effective, patient-centered, timely, efficient, and equitable (IOM, 2001). In 2003, the IOM described the key care delivery functions with which an electronic health record system or EHR could promote patient safety in hospitals, ambulatory care settings, nursing homes, and the community (IOM, 2003). In 2006, the IOM recommended the use of HIT to improve the coordination of care for cancer survivors (IOM, 2006). In 2007, the IOM recommended e-prescribing in order to prevent an estimated 1.5 million adverse drug events each year (IOM, 2007).

Building a National Health Information Network

The U.S. is a decade or so behind other economically developed countries in the design and deployment of a nationwide health information network and in network inclusion of disabled, uninsured, and indigent individuals (Anderson, Frogner, Johns, & Reinhardt, 2006).

With bipartisan support, President Bush, in 2004, ordered nationwide implementation of an interoperable health information technology infrastructure to improve the quality and efficiency of healthcare by 2014. David Brailer (2005), the first national health information technology coordinator, predicted that a National Health Information Network (NHIN) composed of interoperable electronic health records (EHRs) would "not only transform but become healthcare," with regional health information organizations (now called health information exchanges or HIEs) as likely local NHIN hubs (Halamka, Aranow, Ascenzo, Bates, Debor, Glaser, Goroll, Stowe, Tripathi, & Vineyard, 2005).

Kaushal, Blumenthal, Poon, Jha, Franz, Middleton, Glaser, Kuperman, Christino, Fernandopulle, Newhouse, Bates, and the Cost of National Health Information Working Group (2005) estimated NHIN roll out over five years would cost $156 billion, assuming that physicians, hospitals, skilled nursing facilities, home health agencies, laboratories, payers, and pharmacies acquire interoperable EHRs. Walker, Pan, Johnston, Adler-Milstein, Bates, and Middleton (2005) estimated the costs of interoperability between physicians, hospitals, laboratories, radiology centers, pharmacies, payers, and public health departments at $320 billion if nonstandardized (i.e., dependent on customized adapters to translate data between EHRs), and at $276 billion if standardized (i.e., based on common standards for data exchange).

Efforts are underway to build sustainable business models (e.g., Yasnoff, Humphreys, Overhage, Detmer, Brennan, Morris, Middleton, Bates, & Fanning, 2004) that would leverage private healthcare enterprise funding for the NHIN with federal contributions for research and development but not for ongoing operations. Private funding for the NHIN would come from providers who adopt interoperable EHRs and from regional HIEs, which provide the infrastructure for data exchange among EHRs across the NHIN. How a private enterprise NHIN business model would impact uninsured, unemployed, and indigent consumers has been given little consideration to date.

So far, only 9-15% of physician offices have adopted EHRs (Kaushal et al., 2005). To motivate provider adoptions, vendors are enhancing EHRs in ways presumed to build patient loyalty and simplify practice workflow. One such EHR enhancement gives consumers limited views of their records through patient portals or tethered personal electronic health record (PHRs). Tethered PHRs ease the workflow of providers and office staff by encouraging consumers to report information (e.g., allergies, family medical history, complaints), schedule appointments, and otherwise self-manage their healthcare—online. For healthy, employed, and insured consumers, who encounter their primary care providers perhaps once a year, tethered PHR are a pleasant convenience.

For disabled, unemployed, and uninsured consumers, who frequently visit many providers, tethered PHRs are not particularly convenient because they display partial views of fragments of consumer information and do not permit aggregation of data across tethered PHRs or exchange of aggregate data with other EHR systems. Applicants for disability benefits need both options. Regardless of the capabilities of tethered PHRs, disabled workers are unlikely to encounter many publicly funded providers who are equipped with EHRs and associated tethered PHRs.

Efforts are underway to select and harmonize technical standards (Hammond, 2005) for information exchange across the NHIN. The search for interoperability standards is largely focused on the exchange of patient information among provider-controlled EHRs within and across regional HIEs. The expected result is that the NHIN will be implemented as a network of networks that joins national technical interoperability standards to state or local control and funding.

In order to implement the NHIN, the Office of the National Coordinator of Health information technology (ONC), in the U.S. Department of Health and Human Services, established the American Health Information Community (AHIC) and the Health information technology Standards Panels (HITSP). AHIC's role is to develop high-level use cases related to information exchange across the NHIN. The role of HITSP's four technical committees—public health, care delivery (EHRs), consumer empowerment (PHRs), and security and privacy—is to develop interoperability standard specifications for the AHIC use cases.

How the architecture of the NHIN will impact uninsured, unemployed, and indigent consumers, who are not profitable customers of privately financed healthcare, has been given little consideration to date.

Recommendation: Room at the NHIN for Consumers with Disabilities

There needs to be room at the NHIN for consumers without primary-care provider advocates. Newly disabled workers exemplify the consumers who most need NHIN data-exchange capabilities but who are least able to get what they need for their disability benefits applications from provider-controlled EHRs.

Delays and denials of benefits result when applicants cannot find or retrieve medical records from providers familiar with their medical history, health status, and functional limitations. The disability benefit application workflow is complex, particularly for applicants with cognitive and mental health impairments. Health information technology (HIT), which is routinely used to automate care delivery workflow through provider-controlled EHRs might just as well be used to automate the workflow of benefit applicants through consumer-controlled PHRs. For this purpose, applicants would need unbound, intelligent PHRs.

Unbound PHR systems are not tethered to a health plan or employer network; they supply the utility infrastructure services required for current point-to-point exchange with diverse providers' EHRs and for future participation in the NHIN. Intelligent PHRs automate the workflow of applicants including the automated exchange of new and updated information with authorized providers' EHRs, eliminating the necessity for manual data entry, without reimbursement, by providers' office staff.

Tethered PHRs, which give consumers selected glimpses into providers' EHRs, represent the first generation of PHRs. Consumer-controlled and unbound PHRs, which enable consumers to control the exchange of data with providers' EHRs represent the second generation of PHRs. Consumer-controlled, unbound, and intelligent PHRs (or smart PHRs), which automate consumers' healthcare workflow such as applying for SSA disability benefits, represent the third-generation of PHRs (see for example, http://www.thesmartphr.com).

For disability applicants, smart PHRs would seem to offer several advantages including facilitation of the initial benefits application and of periodic reevaluations of their medical status, self-management of chronic conditions prior to Medicare coverage, and ongoing preparedness for medical emergencies and Hurricane Katrina-like disasters.

Instead of prolonged speculation about potential advantages, we need randomized field trials with large samples of disability applicants. The first research step would be to examine usage rates, and self- and provider-perceived utility for various PHR types with and without assistance from patient navigators. (What type of PHR with what kind and amount of assistance is used most and perceived as most useful by all or some applicants?) The next step would be to examine impact on the disability application process of a frequently used, and apparently useful PHR. (Are PHR-equipped applicants more successful at getting benefits than PHR-unequipped applicants?) A third, and particularly important, research step would be to examine the impact of PHR usage on perceived and objective measures of applicant health. (Do beneficiaries with high rates of PHR usage evidence better health in the two years before Medicare coverage than beneficiaries with lower rates of PHR usage, controlling for pre-existing differences between high-usage and low-usage beneficiaries?)

FUTURE TRENDS

Due to Google, consumers expect to have information about every imaginable topic immediately available. Yet, consumers' own medical records are inaccessible, locked away in providers' paper and electronic files. Educated and affluent consumers, aware of the fallibility of the healthcare establishment, are primed for advances in information technology that give them increased control over the healthcare workflow. The purchasing decisions of these opinion leaders may make consumer-controlled PHRs as ubiquitous as cell phones and affordable even to newly disabled workers applying for SSA benefits.

CONCLUSION

A National Health Information Network can be accessible to providers via interoperable EHRs supported by regional HIE networks and to consumers via interoperable, unbound, and intelligent PHRs with HIE infrastructure inside. Disabled workers applying for SSA benefits or undergoing periodic reevaluations of their status could use this consumer-centered information technology to avoid delays and denials of essential income and Medicare coverage. Evaluations of adoptions, usage, and consequences of this technology among SSA applicants and beneficiaries are in order. At the end of the day, health information technology has value only if it benefits the disabled consumers who "pay the price for America's healthcare crisis" (Cohn, 2007).

REFERENCES

Anderson, G. F., Frogner, B. F., Johns, R. A., & Reinhardt, U. E. (2006). Healthcare spending and use of information technology in OECD countries. *Health Affairs*, *25*, 819–831. doi:10.1377/hlthaff.25.3.819

Banks, P., & Lawrence, M. (2005). Transparent or opaque? Disabled people in Scotland describe their experience of applying for disability living allowance. *Journal of Social Work*, *5*, 299–317. doi:10.1177/1468017305058937

Brailer, D.J. (2005). Interoperability: The key to the future healthcare system. *Health Affairs, Web Exclusive, W5-19-W5-21*.

Burkhauser, R. V., & Houtenville, A. J. (2006). A guide to disability statistics from the current population survey. *Annual Social and Economic Supplement (March CPS).* Rehabilitation Research and Training Center on Disability Demographics and Statistics, Cornell University, Ithaca, NY. Retrieved May 21, 2008, from http://digitalcommons.ilr.cornell.edu/edicollect/1233/

Bush, G. W. (2004). *Executive order: Incentives for the use of health information technology and establishing the position of the national health information technology coordinator*. Washington D.C.: The White House.

Cohn, J. (2007). *Sick*: *The untold story of America's healthcare crisis---and the people who pay the price*. NY: Harper Collins.

DeNavas-Walt, C., Proctor, B. D., & Lee, C. H. (2006). U.S. census bureau, current population reports, P60-231, *Income, poverty, and health insurance coverage in the United States: 2005.* Washington D.C.: U.S. Government Printing Office.

Hadley, J. (2007). Insurance coverage, medical care use, and short-term health changes following an unintentional injury or the onset of a chronic condition. [JAMA]. *Journal of the American Medical Association*, *297*, 1073–1084. doi:10.1001/jama.297.10.1073

Halamka, J., Aranow, M., Ascenzo, C., Bates, D., Debor, G., & Glaser, J. (2005). Healthcare IT collaboration in Massachusetts: The experience of regional connectivity. [JAMIA]. *Journal of American Medical International Association*, *12*, 596–601. doi:10.1197/jamia.M1866

Hammond, W. E. (2005). The making and adoption of health data standards. *Health Affairs*, *24*(5), 1205–1213. doi:10.1377/hlthaff.24.5.1205

Hanson, K.W., Neuman, P., Dutwin, D., & Kasper, J.D. (2003). Uncovering the health challenges facing people with disabilities: The role of health insurance. *Health Affairs, Web Exclusive, W3-552-565.*

Houtenville, A. J., Erickson, W. A., & Lee, C. G. (2005). *Disability statistics from the current population survey (CPS)*. Cornell University Rehabilitation Research and Training Center on Disability Demographics and Statistics, Ithaca, NY (StatsRRTC). Retrieved May 21, 2008, from www.disabilitystatistics.org

Institute of Medicine. (2000). *To err is human: Building a safer health system*. In L.T. Kohn, J.M. Corrigan, & M.S. Donaldson (Eds.). Washington D.C.: National Academy Press.

Institute of Medicine. (2001). Crossing the quality chasm: A new health system for the 21st century. *Committee on Quality of Healthcare in America*. Washington D.C.: National Academy.

Institute of Medicine. (2003). *Key capabilities of an electronic health record system*. Committee on Data Standards for Patient Safety. Washington D.C.: National Academy Press.

Institute of Medicine. (2006). *From cancer patient to cancer survivor. Lost in transition*. In M. Hewitt, S. Greenfield, & E. Stovall (Eds.). Washington D.C.: National Academy Press.

Institute of Medicine. (2007). *Preventing medication errors*. In P. Aspden, J. Wolcott, J.L. Bootman, & L.R. Cronenwett (Eds.). Washington D.C.: National Academy Press.

Institute of Medicine (IOM). (1991). In R.S. Dick & E.B. Steen (Eds.), *The computer-based patient record: An essential technology for healthcare*. Washington D.C.: National Academy Press.

Kaushal, R., Blumenthal, D., Poon, E. G., Jha, A. K., Franz, C., & Middleton, B., & theCost of National Health Information Working Group. (2005). The costs of a National Health Information Network. *Annals of Internal Medicine*, *143*, 165–173.

McWilliams, J. M., Meara, E., Zaslavsky, A. M., & Ayanian, J. Z. (2007). Use of health services by previously uninsured Medicare beneficiaries. *The New England Journal of Medicine*, *357*, 143–153. doi:10.1056/NEJMsa067712

Murdoch, M., van Ryn, M., Hodges, J., & Cowper, D. (2005). Mitigating effect of department of veterans affairs disability benefits for posttraumatic stress disorder on low income. *Military Medicine*, *170*, 137–140.

National Health Interview Survey. (2006). *Public use data release. NHIS survey description.* Division of Health Interview Statistics. National Center for Health Statistics Hyattsville, Maryland Centers for Disease Control and Prevention U.S. Department of Health and Human Services. Retrieved May 21, 2008, from http://www.cdc.gov/nchs/about/major/nhis/quest_data_related_1997_forward.htm

Pransky, G. S., & Dempsey, P. G. (2004). Practical aspects of functional capacity evaluations. *Journal of Occupational Rehabilitation*, *14*, 217–229. doi:10.1023/B:JOOR.0000022763.61656.b1

Social Security Administration. (2006b). *Disability evaluation under social security. Blue book.* SSA Publication No. 64-039 ICN 468600. Retrieved May 21, 2008, from http://www.ssa.gov/disability/professionals/bluebook/

Social Security Administration. (2007). *Annual statistical supplement to the Social Security bulletin.* SSA Publication No. 13-11700. Social Security Administration, Office of Policy, Office of Research, Evaluation, and Statistics: Washington D.C. Retrieved May 21, 2008, from http://www.socialsecurity.gov/policy/docs/statcomps/supplement/2006/supplement06.pdf

Social Security Administration (SSA). (2006a). *Social Security disability benefits.* SSA Publication No. 05-10029. ICN 456000. Retrieved May 21, 2008, from http://www.ssa.gov/pubs/10029.html#part2

Walker, J., Pan, E., Johnston, D., Adler-Milstein, J., Bates, D.W., & Middleton, B. (2005). The value of healthcare information exchange and interoperability. *Health Affairs Web Exclusive, W5-10-W5-18.*

Yasnoff, W. A., Humphreys, B. L., Overhage, J. M., Detmer, D. E., Brennan, P. F., & Morris, R. W. (2004). A consensus action agenda for achieving the national health information infrastructure. *Journal of American Medical International Association*, *11*(4), 332–228. doi:10.1197/jamia.M1616

Ydreborg, B., Ekberg, K., & Nordlund, A. (2006). Health, quality of life, social network and use of healthcare: A comparison between those granted and those not granted disability pensions. *Disability and Rehabilitation*, *28*, 25–32. doi:10.1080/09638280500165179

This work was previously published in Patient-Centered E-Health, edited by E. Wilson, pp. 60-69, copyright 2009 by Medical Information Science Reference (an imprint of IGI Global).

Chapter 5.19

Active Patient Role in Recording Health Data

Josipa Kern
University of Zagreb, School of Medicine, Andrija Stampar School of Public Health, Croatia

Kristina Fister
University of Zagreb, School of Medicine, Andrija Stampar School of Public Health, Croatia

Ozren Polasek
University of Zagreb, School of Medicine, Andrija Stampar School of Public Health, Croatia

INTRODUCTION

The healing process can be viewed as a partnership between doctors and patients, nurses and physicians or, more generally, a partnership of health professionals and health care users (Anonymous, 2008, Graham, 2007). A patient-centered approach that empowers patients to participate in decisions about their treatment and health care options asks for active participation of patients themselves, specifically, in health information gathering and exchange of this information with their health or medical records (Bachman, 2007; Stolyar, Lober, Drozd, & Sibley, 2005).

DOI: 10.4018/978-1-60566-026-4.ch003

BACKGROUND

Medical or Health Record

Every physician has a number of patients in his or her care. Many patients also have a number of specialists taking care of their health. It is almost impossible for physicians to keep in mind all the information about even a single patient, let alone all patients in their care. Similarly, patients need to remember and comply with many recommendations communicated to them by their doctors. Recording patients' data is, today, a necessity, especially considering a large number of available diagnostic procedures and instruments producing information relevant for making medical decisions. One implication of such recording is the creation of medical records in health institutions; they are created and accessed by health professionals. According to the National Library of Medicine, the MeSH (medical subject heading) term "medical record" considers "recording of pertinent information concerning patient's illness or illnesses" (http://www.PubMed.com).

However, the medical data gathered by health professionals are not enough for making good medical decisions. Information that is not strictly medical can be added to medical data. We therefore usually talk about a *health record*, consisting of data and information that affect or could affect the patient's health status, or simply describe it. A health record is a more general term than a medical record, nursing record, or dental record, and should be used as an immediate superior term to them. Keeping all the information pertaining to a particular patient in one place, and making it accessible at any time to authorized professionals, is a challenge. In seeking solutions, the information and communication technology should be consulted.

Personal Health Record

In trying to encourage people to take an active interest in their own health, patients are supported to manage their own personal health records. A personal health record can contain copies of data from the health record, which is created by health professionals, and also information entered by patients themselves (for example, subjective information such as description of symptoms, and objective information such as values of self-measured blood pressure or blood glucose levels, etc., recorded in a personal health diary).

Thus far, the literature does not give an adequate definition of a personal health record. Wikipedia defines it as "a health record that is initiated and maintained by an individual," but it is unclear who the individual is, the health professional or the patient. According to Tang (2006), a personal health record includes health information managed by the *individual*, who is not necessarily a *patient,* an ill person. This distinction emphasizes that the personal health record is a tool used to care for health and wellness, not only illness.

CURRENT STATUS

Electronic Health Record and Personal Health Record

There are several definitions of the electronic health record and many descriptions of its characteristics and demands (Hayrinnen, 2007). According to ISO (2004), "the EHR means a repository of patient data in digital form, stored and exchanged securely, and accessible by multiple authorized users. It contains retrospective, concurrent, and prospective information and its primary purpose is to support continuing, efficient and quality integrated health care." One of the most exhaustive descriptions of electronic health records is given by the Advisory Committee on Health Infostructure of Canada (2001). According to the description in their Tactical Plan for a pan-Canadian Health Infostructure, an electronic health record is "a longitudinal collection of personal health information of a single individual, entered or accepted by health care providers, and stored electronically. The record may be made available at any time to providers, who have been authorized by the individual, as a tool in the provision of health care service. The individual has access to the record and can request changes to its content. The transmission and storage of the record is under strict security." This means that an electronic *health* record also incorporates electronic *medical* records, including digital medical images (computer tomography or similar) and biomedical signals (electrocardiography or similar), laboratory findings, the interpretation of all such findings, and physicians' recommendations to patients. Hospital records, nursing records, dental records, and other similar records can also be parts of an electronic health record.

It is generally agreed that patients have the right to know who is collecting, storing, accessing, communicating, or processing the data in their electronic health records, for what purpose, where the data will be kept, to whom they will be communicated, and for what purpose (Kluge, 2004).

The definition of electronic personal health records as "electronic summaries of a patient's medical record that are often portable and easily accessed by the patient" (Endsley, Kibbe, Linares, & Colorafi, 2006) is not adequate, for it does not distinguish from electronic medical records. A better description of an electronic personal health record was given as "an electronic application through which individuals can access, manage and share their health information" (Pagliari, Detmer, & Singleton, 2007). We propose the most appropriate description of an electronic personal health record would be "a digitally (electronically) saved health information, created and accessible by both health professionals and the individual, respecting privacy, security and confidentiality."

Content of the Electronic Health Record

Today, electronic health records are used in many hospitals, primary care offices, and other health institutions. Each of these sites collects specific patient data particularly relevant to the type of health care received at the site, but all the data could, and should, be mutually communicated. Pulling together health data from different sources should help doctors make better diagnostic and therapeutic decisions. However, pulling information from several different sources will require a unique identifier (Mayor, 2007). This is the first demand on electronic health records.

Patient Identifier

Health systems of different countries define patient identifiers in different ways. Sometimes patients are identified by their health insurance number, other times by the social security number, and sometimes by biometric characteristics of a patient. As a general rule, all of these identifiers are unique (i.e., any two patients have different identifiers) and should have a check digit calculated by a defined algorithm. Table 1 shows an example of creating such an identifier.

Health and Medical Data

Structured electronic medical records can result in quicker data entry, improved quality of care, and improved usefulness of records for daily clinical practice (Kruger, 2007). Doctors and nurses prefer structured data entry; electronic nursing records are better, and databases with structured electronic patient records can be used on a large scale to develop treatment regimes and support quality assurance (Kruger, 2007). Integration of clinical decision support systems into electronic medical records holds a promise for more efficacious and cost-effective solutions in daily medical practice. However, designing and structuring the electronic health (or medical) record is a daunting task.

The starting point of the electronic health record should be *patient history*. Patient history is produced during a conversation between the patient and the health care professional. It is not a final product made by, for example, a general practitioner at the first appointment, but it should be resummarised, recontextualised, and recreated in the light of new information, possibilities, and changing priorities during patient care. Some of these data can be structured, but some should also be written as free text.

Laboratory data are mostly structured. Some are measured and recorded as numeric values (e.g., blood glucose 5.3 mmol/L), while some laboratory data are qualitative and usually coded (e.g.,

Table 1. Creating a patient identifier (algorithm: module 11)

Starting with: 10000001
Add ponders to each digit: 7 6 5 4 3 2 7 6
Calculate: 7*1+6*0+5*0+4*0+3*0+2*0+7*0*6*1=13
Calculate: 13∧:∧11∧=∧1, remnant∧=∧2*
Calculate: 11∧–∧2∧=∧9
Conclusion: 9 is a check digit and the created identification number is: 100000019
* in case of remnant∧=∧0 the 8 digit number should be omitted; in case of remnant∧=∧1 the check digit shoudl be 0
Following the same algorithm the next identifiers will be:
100000024
100000038
100000043
100000057
....#

blood groups: A, B, O, AB; proteins in urine: -, +, ++, +++).

Radiological data (medical images) and *biomedical signals* can be recorded digitally, and described (interpreted) by a radiologist or another appropriate specialist in the form of free text.

Diagnoses are coded according to an adequate coding system (International Classification of Diseases – ICD-10, SNOMED-CT, etc.), and *drugs* usually by the ATC classification.

Procedures are also coded, usually by using a specific coding system, depending on the country, health sector (hospitals, primary health care, etc.), and the purpose of such data. A diagnosis-related group (DRG) is based on the major diagnosis, length of stay, secondary diagnosis, surgical procedure, age, and types of services required. It is internationally accepted for acute cases in hospitals in order to determine the fixed payment per case (Hammond & Cimino, 2001), but it can be locally adjusted.

Patient *discharge letter* could be partially structured (parts including numeric and coded data), but it also includes some descriptions (free text).

Other Data

The electronic health record can contain other data such as personal data, socio-demographic and administrative data (e.g., name of the individual, date of birth, gender, education, insurance data, etc.).

Characteristics of an Electronic Health Record

Electronic health records should support the delivery of good quality patient care and improve decision making in all daily clinical situations. It should be standardized (e.g., EN 13606). In particular, an electronic health record should improve the management of chronic conditions and help maintain immunization records.

Specific characteristics of digitally recorded data are:

- They can be viewed from a variety of locations (general practice office, specialist practice, laboratory, hospital, etc.) at any moment, when needed,
- For viewing the data as a specific output (e.g., tables or graphs), a specific software is needed; viewing is not static and final, but is instead continuously modifiable,
- Users' authorization levels determine which parts of electronic health record they can access and which actions they can perform (security and protection),
- It is possible to trace who entered the data and who has seen the data, and when (any action can be recorded for the sake

of patient safety and responsibility of the health professional),

- Periods of nonavailability of electronic health record data can be known (criterion for usability of the particular system).

Opposite to this, paper-based medical data can be viewed from only one location, they can be seen unconditionally, there is no possibility to specify which part of the document can be read (all or nothing), it is not possible to know who has seen the data and when (it is not recorded), and periods of nonavailability are unknown.

An electronic health record can be used not only for patient management, but also for reporting, quality assurance processes, research, and administrative processes, such as scheduling and billing. A standardised electronic health record is a prerequisite for good communication in the health care system (examples of standards relevant for electronic health record and communication are EN 13606, DICOM, LOINC and HL7).

Benefits of the Electronic Health Record

Electronic health records increase patients' confidence in their health care providers. They save patients and health care providers the repetition of various information (such as personal information – name, address, etc., previous course of the disease, test results) in different health institutions. At the same time, patients are assured that all health professionals caring for them have access to all the relevant parts of their health history. Also, online communication between health care providers in different institutions speeds up health service. There is no need to wait for discharge letters or test results, and the number of lost test results is markedly reduced. Quality of care is improved as the electronic health record (and data in it) makes the communication with experts much easier. Consequently, another benefit of an electronic health record can be a reduction in the number of medical errors.

Content of the Electronic Personal Health Record

Individual patients have their own documents about their health, their own personal health records. These could be copies of medical documents in paper or in electronic format, for example, laboratory findings or x-ray images (Fig. 1), or even hospital discharge letters. These could also be data on drugs, herbal medications, diet, or

Figure 1. Example of the copy of a medical document

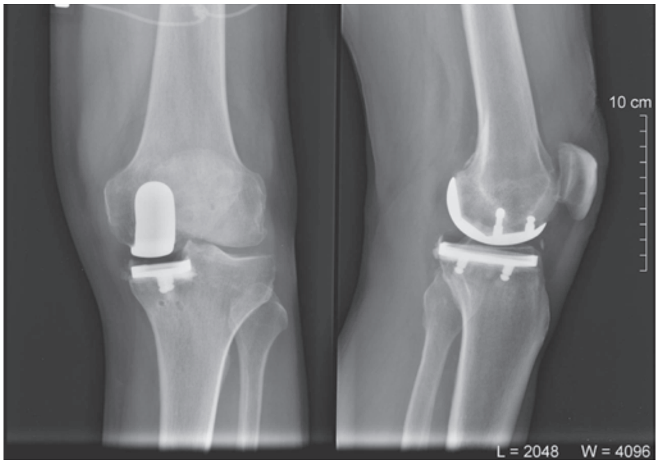
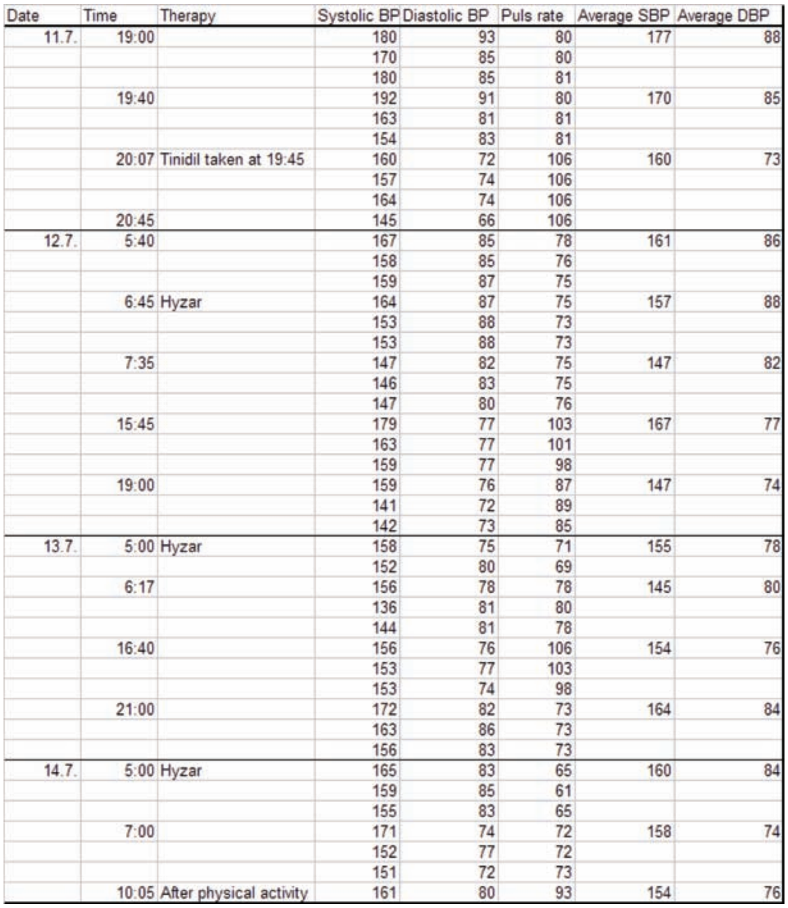


Figure 2. Example of a personal health record maintained by a person with hypertension



Date	Time	Therapy	Systolic BP	Diastolic BP	Puls rate	Average SBP	Average DBP
11.7.	19:00		180	93	80	177	88
			170	85	80		
			180	85	81		
	19:40		192	91	80	170	85
			163	81	81		
			154	83	81		
	20:07	Tinidil taken at 19:45	160	72	106	160	73
			157	74	106		
			164	74	106		
	20:45		145	66	106		
12.7.	5:40		167	85	78	161	86
			158	85	76		
			159	87	75		
	6:45	Hyzar	164	87	75	157	88
			153	88	73		
			153	88	73		
	7:35		147	82	75	147	82
			146	83	75		
			147	80	76		
	15:45		179	77	103	167	77
			163	77	101		
			159	77	98		
	19:00		159	76	87	147	74
			141	72	89		
			142	73	85		
13.7.	5:00	Hyzar	158	75	71	155	78
			152	80	69		
	6:17		156	78	78	145	80
			136	81	80		
			144	81	78		
	16:40		156	76	106	154	76
			153	77	103		
			153	74	98		
	21:00		172	82	73	164	84
			163	86	73		
			156	83	73		
14.7.	5:00	Hyzar	165	83	65	160	84
			159	85	61		
			155	83	65		
	7:00		171	74	72	158	74
			152	77	72		
			151	72	73		
	10:05	After physical activity	161	80	93	154	76

results of home testing (blood pressure, medication, etc.) (Fig. 2). Some patients can analyze their health data (e.g., visualization of time series of blood pressure) (Fig. 3) and change their behavior accordingly. Personal health record can also contain various administrative data, such as the name of the person's physician or data related to health insurance.

Characteristics of the Electronic Personal Health Record

There is no standard for electronic personal health record, but there are many electronic applications offered for this purpose (MyPHR, iHealthRecord, etc).

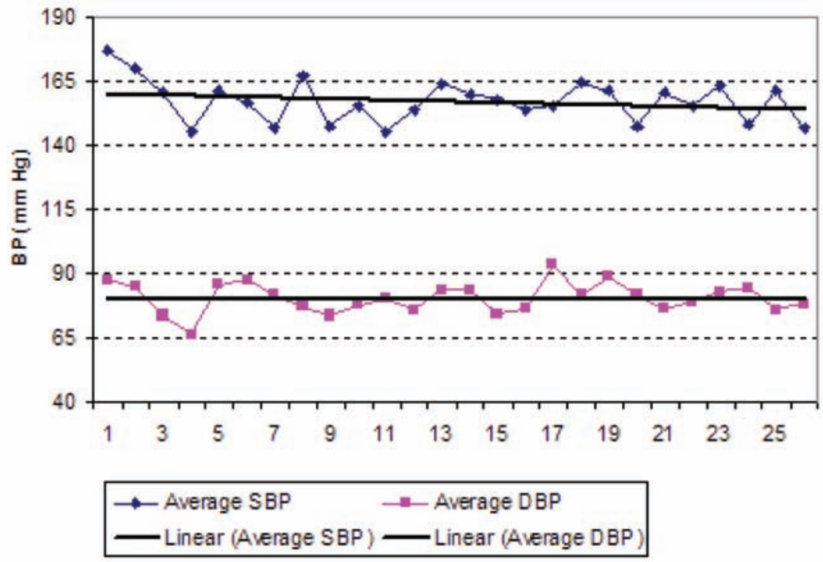
Benefits of the Personal Health Record

Without doubt, the two leading benefits of personal health records are patients' empowerment and promotion of active partnership between patients and caregivers.

FUTURE TRENDS

Electronic health records have been successfully implemented in many settings. Still, they all need further development and improvement, usually linked to rapidly changing technologies. Other aspects of improvement deal with the contents

Figure 3. Example of visualization of blood pressure measurements as a part of an electronic personal health record



and the way in which the data are recorded (such as classifications or coding systems).

Electronic personal health records are emerging and have much room for further growth. Simpler models of personal health records include passive access to data written on a compact disc or a smart card, or possibly at a Web site. Interactive systems of personal health records demand the integration of a personal health record with health providers' record systems (i.e., electronic health records). Ensuring the security of such systems remains a challenge. According to Pagliari (2007), views on values vs. risks of electronic records are highly polarized. Still, as all new initiatives take time to become fully developed and accepted by its users, this polarization is likely to be only temporary.

CONCLUSION

Electronic health records are the present and the future of contemporary health care systems. Electronic personal health records should be developed in accordance to the needs of all the participants in the health care (health care providers and health care users). It could be expected that the electronic personal health record and electronic health record will interact while not threatening privacy, security, and confidentiality. Both types of records are only parts of the same system, and both need more development and improvement. The ultimate goal of high interactivity, accuracy, and safety can be assured by the information and communication technologies, but both health care professionals and health care users need to accept such a system and become partners in using it, in order to benefit from it.

REFERENCES

American Health Information Medical Association. (n.d.). *MyPHR personal health record. A guide to understanding and managing your personal health information*. Retrieved November 16th, 2007 from http://www.myphr.com/your_record/index.asp

Anonymous, . (2007). Good patient-doctor communication is vital. The healing process can be viewed as a doctor-patient partnership, facilitated and enhanced by good interaction. *Health News (Waltham, Mass.)*, *13*(12), 3–4.

Bachman, J. (2007). Improving care with an automated patient history. *Family Practice Management*, *14*(7), 39–43.

Endsley, S., Kibbe, D. C., Linares, A., & Colorafi, K. (2006). An introduction to personal health record. *Family Practice Management*, *13*(5), 57–62.

F/P/T Advisory Committee on Health Infostructure. (2001). *Tactical plan for a pan-Canadian health infostructure. Update*. Office of health and the information highway, Health Canada, November 2001. Retrieved September 11th, 2007, from http://www.hc-sc.gc.ca/hcs-sss/alt_formats/iacb-dgiac/pdf/pubs/2001-plan-tact/2001-plan-tact_e.pdf

Graham, I. W. (2007). Consultant nurse-consultant physician: A new partnership for patient-centred care? *Journal of Clinical Nursing*, *16*(10), 1809–1817. doi:10.1111/j.1365-2702.2007.01816.x

Hammond, W. E., & Cimino, J. J. (2001). Standards in medical informatics. In E. H. Shortliffe et al. (Eds), *Medical informatics. Computer applications in health care and biomedicine* (p. 226). New York: Springer.

Häyrinen, K., Saranto, K., & Nykänen, P. (2007). (in press). Definition, structure, content, use and impacts of electronic health records: A review of the research literature. *International Journal of Medical Informatics*. doi:.doi:10.1016/j.ijmedinf.2007.09.001

ISO/DTR 20514. (2004). *Health informatics – Electronic health record – Definition, scope, and context.*

Kluge, E.-H. W. (2004). Informed consent and the security of the electronic health record (EHR): Some policy considerations. *International Journal of Medical Informatics*, *73*(3), 229–234. doi:10.1016/j.ijmedinf.2003.11.005

Krüger, K. (2007). Electronic medical records should be structured. *Tidsskrift for Den Norske Laegeforening*, *127*(16), 2090–2093.

Mayor, S. (2007). NHS IT system must use unique patient identifiers to achieve research potential. *BMJ (Clinical Research Ed.)*, *334*(7606), 1238.

Pagliari, C., Detmer, D., & Singleton, P. (2007). Potential of electronic personal health records. *BMJ (Clinical Research Ed.)*, *335*(7615), 330–333. doi:10.1136/bmj.39279.482963.AD

Record, I. H. (n.d.). *iHealthRecord.* Retrieved November 16th, 2007, from http://www.ihealthrecord.org/faq.html

Stolyar, A., Lober, W. B., Drozd, D. R., & Sibley, J. (2005). Feasibility of data exchange with a patient-centered health record. In *AMIA 2005 Symposium Proceedings* (p. 1123). Retrieved February 25th, 2008, from http://www.pubmedcentral.nih.gov/picrender.fcgi?artid=1560649&blobtype=pdf

Tang, P. C., Ash, J. S., Bates, D. W., Overhage, J. M., & Sands, D. Z. (2006). Personal health records: Definitions, benefits, and strategies for overcoming barriers to adoption. *Journal of the American Medical Informatics Association*, *13*(2), 121–126. doi:10.1197/jamia.M2025

Wikipedia. Personal health record. (n.d.). Retrieved October 16th, 2007, from http://en.wikipedia.org/wiki/Personal_health_record#_note-FIRST

KEY TERMS

Active Patient: is an emerging term describing patients' active participation in the management of their health and wellness.

Electronic Health Record (EHR): A health record stored electronically.

Electronic Medical Record (EMR): A medical record stored electronically.

Electronic Personal Health Record (EPHR): A personal health record stored electronically.

Health Record (HR): A longitudinal collection of personal health information of a single individual, entered or accepted by health care providers.

Medical Record (MR): A longitudinal collection of personal data concerning patient's illness or illnesses.

Personal Health Record (PHR): A longitudinal collection of personal health information of a single individual containing copies of parts of health records, health related data measured and/or noticed by the individual, and administrative data.

This work was previously published in Encyclopedia of Information Science and Technology, Second Edition, edited by M. Khosrow-Pour, pp. 14-19, copyright 2009 by Information Science Reference (an imprint of IGI Global).

Chapter 5.20

Using Stakeholder Analysis to Identify Users in Healthcare Information Systems Research:

Who is the Real User?

Alexander J. McLeod Jr.
University of Nevada, USA

Jan Guynes Clark
The University of Texas at San Antonio, USA

ABSTRACT

Applying IS research to the healthcare context is an important endeavor. However, IS researchers must be cautious about identifying individual roles, the context of the setting, and postulating generalizability. Much of IS theory is rooted in organizations, their business processes, and stakeholders. It is not a simple matter to generalize healthcare IS research, assuming that it is equivalent to organizational IS research. Hospitals, emergency rooms, and laboratories are different from the "business environment", and "healthcare users" vary considerably in their roles. Therefore, IS researchers need to understand the healthcare setting before they can appropriately apply IS theory. Obviously, if we are studying the wrong person, or group of people, we cannot expect to get relevant results. In order to alleviate confusion regarding "who is the user?" in healthcare IS research, we provide examples of healthcare scenarios, perform simplified stakeholder analysis for each scenario, and identify the stakeholders.

INTRODUCTION

Information systems continue to make inroads into the healthcare industry as more of those in medicine adopt computer technologies (Goldschmidt, 2005; Huston & Huston, 2000; Khoumbati, Themistocleous, & Irani, 2006). Innovative technologies support healthcare by maintaining or reducing costs, distributing care to geographically distant patients, and providing consulting specialists where expertise is limited or not available (Field, 1996; LeRouge, Hevner, & Collins, 2007; Login & Areas, 2007). Emphasizing the needs and abilities of those who are using the technology improves the quality of health information systems research.

Crafting Information Systems (IS) research for the healthcare context is an important endeavor. However, IS researchers must be accurate when identifying individual roles (Kling, 2003; Reponen, 1994), the setting context, and postulating generalizability (Avgerou, 2001; DeLone & McLean, 2003; Rawstorne, Jayasuriya, & Caputi, 2000). One of the most important principles for IS researchers is "know your user" (Norman, 2005). This principle should also apply to those performing healthcare information systems research. However, this is often not the case.

Much of IS theory is rooted within the organization, its business processes, and stakeholders (Ginsberg & Venkatraman, 1985; Magni & Pennarola, 2008; Massa & Testa, 2008; Van de Ven, 2005). One well accepted definition of a stakeholder is "Any group or individual who can affect or is affected by the achievement of the organization's objectives" (Freeman, 1984). In order to understand "who really counts", we need to systematically evaluate stakeholder relationships (Mitchell, Agle, & Wood, 1997). IS stakeholders within a business context generally fall within one of three groups – users, managers, and IS professionals. Although this distinction is fairly clear in healthcare administration (the business side of healthcare), it is not nearly as clear-cut in patient healthcare.

Hospitals, emergency rooms, and laboratories are very different from the normal "business" environment, and healthcare stakeholders vary considerably in the role they play (patient, attending physician, specialist, intern, resident, nurse, clinician, administrator, etc.). Depending upon the situation, any or all of these stakeholders can be users of a healthcare IS system. Therefore, definitions originating from the business environment involving business users and processes may not apply in the healthcare setting. For example, attempting to apply an IS theory such as the Technology Acceptance Model (TAM) to telemedicine requires that the investigator realize the differences in stakeholders. All stakeholders are not users. A physician who reads a report generated by a clinician that operated some technology is not the "user" of the technology. It would therefore be inappropriate to survey the physician's user acceptance or usability of the technology. The clinician, not the physician, is the "user". In addition, a patient who obligingly reports for an examination and passively participates in a televideo consultation is not a "user". The technician who operates the equipment is the user, and the technician's acceptance of the technology is important to IS researchers.

We contend that IS researchers should understand the healthcare setting and the role of its stakeholders before applying IS theory. In addition, networks of patients and practitioners using information technology create very different interrelated user and interorganizational processes. Healthcare processes are considerably different. These processes may involve life and death situations that depend on extremely important and often time sensitive data and information. Most patients facing illness or injury are sick and stressed. Ignoring these contextual differences in favor of generalizability simply dilutes or negates the effects of human computer interactions in the unique healthcare environment.

A recent meta-analysis of patient satisfaction revealed that a) few studies adequately defined terms, b) most studies lack explanation of interaction effects of the physician-patient relationship, and c) in general, studies lack data correctly examining the perceptions of the users (Mair & Whitten, 2000). These studies were performed by medical and/or information systems researchers. The very division of healthcare into medical/clinical and socio/technical entities begs for a duality of understanding when applying theoretical constructs.

Conceptualization of the user is fundamental to healthcare and IS research (Lamb & Kling, 2003). Those researching the "IS user" in healthcare must have insight into the triad of physician, clinician, and patient in order to correctly apply IS theory in the healthcare setting. Arguably, inadequate definitions, missing relationships, and erroneous perceptions cast doubt over the generalizability of healthcare information systems research.

Some readers may view this as "simply stating the obvious". However, as former healthcare professionals, we have identified several IS/healthcare research articles in which the user was not properly defined. The researchers, as well as the reviewers of their research, simply did not understand the complexity of healthcare and IT. It is not our intent to embarrass any healthcare researchers or publishers. Therefore, we will discuss known errors in a generic fashion. The vast majority of healthcare IT user research focuses on either the patient or the primary physician. In many cases, neither the patient nor the primary physician was the actual user of the technology. For example, one recent IS healthcare article surveyed patients on user satisfaction. However, the patients did not use the technology. Instead, they provided medical data input to a system that was used by either clinicians or physicians. Although patient satisfaction is important, it does not always equate to IS user satisfaction. In other prior research, physicians were surveyed to determine ease of use of a medical technology that rarely, if ever, is actually "used" by a physician. Instead, clinicians "use" the technology and send reports to the physician. Other researchers have studied the wrong physician, focusing on primary physicians, rather than the medical specialist, such as a cardiologist, who actually used the IS healthcare technology. Obviously if researchers do not properly define the user, the validity of the research is in question.

In order to facilitate "IS user" research in healthcare, we propose performing a simplified stakeholder analysis of the decision or implementation in order to better define the users of the technology. The next section provides a brief review of research that focuses on the "IS user". This is followed by a discussion of stakeholder analysis as it applies to information systems research in the patient healthcare setting.

IS USER LITERATURE

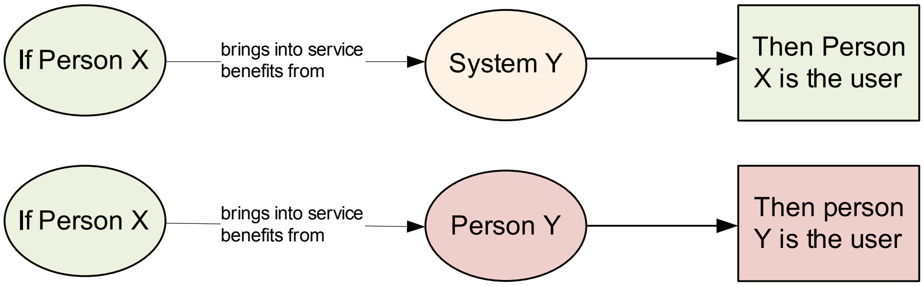
To understand the user concept, it is necessary to first define the user within the context of IS research. Historically, user definitions are scarce, and even fewer definitions exist within specific contexts. Davies (2002) conceptualizes the user from four theoretical perspectives: distributed cognition, situated action, activity theory and as social actors. In defining the user via these perspectives, Davies suggests the following relationships.

1. X causes Y to act or serve a purpose.
2. X brings Y into service.
3. X avails himself of Y.

If X brings Y into service, then X benefits from Y. One could assume that if X benefits from Y, then X is automatically the user. However, that is dependent upon whether Y is a person or an object. For example, assume data is needed. Someone can retrieve the data for you, or you can retrieve it yourself, from an online database. If you ask Person Y to provide you with the data, then Person Y is the user. You are the data recipient and a stakeholder but not the user. However, assume that Y is a system. You bring System Y into service by entering the commands to retrieve the data. In this situation, you are a stakeholder, the user and the data recipient. Figure 1 details the User Definition. If Person X brings Person Y into service, Person X benefits (indirectly) from Person Y. Therefore, Person Y is the User. If Person X brings System Y into service Person X benefits (directly) from System Y. Therefore, Person X is the User.

Note that these definitions are presented in the simplest form. As complexity increases, the

Figure 1. User definition diagram



true definition of the user becomes blurred. For example, if Person X requests data from Person Y, who then passes on the request to Person Z, Person Z becomes the user. In other situations, Person X may receive data indirectly, but still be a user of the system. For example, assume an EKG technician performs an EKG on a patient and transmits results electronically to a physician. If the physician signs on to the system and retrieves and analyzes the EKG data, the physician is also a user of the technology. However, if the physician simply receives a hard copy of the EKG, the physician is only a data recipient. Therefore, for the purpose of this paper, a user is anyone who manipulates a system in order to perform a given task.

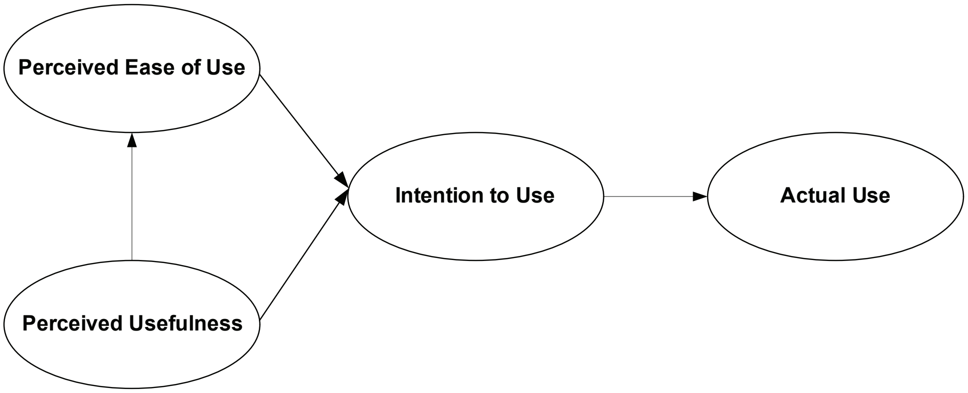
As would be expected, there is an abundance of research related to the user construct in IS literature. A review of the top five ranked journals listed on IS World revealed over 350 "user" titled articles (ISWorld, 2006). This exemplary review was not exhaustive but did supply an adequate number of articles with which to classify the user construct for further analysis. The primary user concepts in these articles included user acceptance, user participation, user satisfaction, user training, user performance, user interfaces, and end user computing. We examined the user construct in each of these areas to see how IS researchers conceptualized the user.

User Acceptance

User acceptance is one of the most studied areas of information systems research (Hu, Chau, Sheng, & Tam, 1999; Ma & Liu, 2004). In this area, IS research examines how and why people adopt and use information technology (Venkatesh, 2000). The importance of user acceptance is its potential relationship to system success. System success in IS research is often dependent upon many independent variables, one of which is user acceptance (DeLone & McLean, 1992). Often, user unwillingness to accept technology obstructs implementation and use. In IS research, the user's perceived ease of use and perceived usefulness provided the starting point for measuring acceptance (Davis, 1989). Figure 2 shows the user acceptance model as originally proposed and its relationship to use.

Many researchers extended and modified this model adding mediating and moderating variables, resulting in a variety of possible user acceptance conceptualizations. Venkatesh et al. (2003) attempted to unify this diverse topic by discussing, empirically comparing and consolidating eight prominent models of user acceptance. The unified model maintains the dependent variable as originally conceived. The basic concept underlying the user acceptance model is the individual's "**Actual Use**" of information technology. Actual use can be seen in the model as suggested by Venkatesh (2003) in Figure 3. As

Figure 2. User acceptance model (Davis 1989)



conceptualized, "Actual Use" conforms to the Davies (2002) user definition test. The individual causes the computer to act or serve a purpose, brings the computer into service, and benefits from using the system. Obviously, "Actual Use" of the information technology is a requirement in IS research involving user acceptance theory. Those performing healthcare related acceptance research need to ascertain if the participants are "actually using" the information system.

User Participation

User participation is another important area of IS research. System analysis and design has been the primary context for studying user participation (Ives & Olson, 1984). Many authors use the term 'user involvement" interchangeably with "user participation" (McKeen, Guimaraes, & Wetherbe, 1994). This led to confusion in user participation research, causing Barki and Hartwick (1989) to define user participation as taking part or playing a role in the development of a system. They also refined the term "user involvement" to mean the psychological state in which the user considers a system important and personally relevant. Thereafter, a distinction in "user involvement" and "user participation" existed for IS researchers.

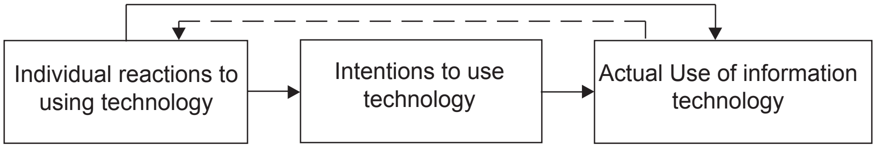
User participation deals with the primary users of the system, or those who use the output of the system (Ives & Olson, 1984). This is supported by Powers and Dickson (1973) who suggest that the actual users are those who receive and use the products of a project rather than the development personnel. From this, it can be seen that IS user participation theory is concerned with the primary users of the information technology product.

In an analysis of user participation, McKeen, Guimaraes and Wetherbe (1994) looked at 19 articles. They examined the nature and role of user participation, concluding that IS development requires the appropriate user's participation at a stage and in a manner that supports significant contribution. These concepts support the Davies (2002) definition. The appropriate user participates and contributes by bringing knowledge concerning how the system must act or serve a purpose, be brought into service, or be available for use. Therefore, actual use of the product and output rather than development of the system is a requirement in IS research involving user participation theory.

User Satisfaction

User satisfaction is another concept widely explored by IS researchers. DeLone and McLean

Figure 3. Actual use concept of technology acceptance (Venkatesh, Morris et al. 2003)



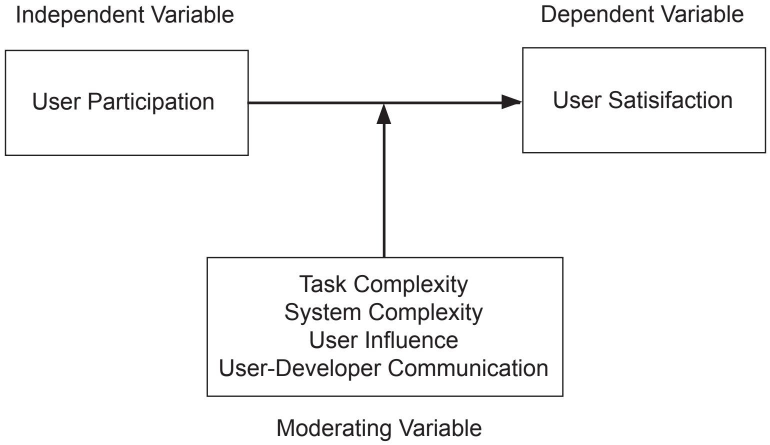
(1992) theorize that system success variables include system quality, information quality, use, user satisfaction, individual impact, organizational impact. User satisfaction is often a surrogate for system success. Successful implementation leads to greater user satisfaction and in this line of research, user satisfaction is the dependent variable. Participation has been postulated to be a predictor of user satisfaction (McKeen et al., 1994). Figure 4 shows these relationships. Unfortunately, user satisfaction weakly predicts system usage (Wixom & Todd, 2005). This is understandable. Some people use a technology because it is a requirement of their job, rather than because they like it and want to use it. There is little "voluntariness" for most health care systems users who are employees performing professional tasks (Agarwal & Prasad, 1997). We would argue that there is also little "voluntariness" for patients using health care systems in their medical treatment.

The system use literature takes a different view of user satisfaction. For example, Shneiderman (1987) believes that interface design makes a substantial difference in user satisfaction. In this line of research, system interaction affects the attitude of the user (Hiltz & Johnson, 1990). Satisfaction is derived from the person's feelings or attitudes about system characteristics (Wixom & Todd, 2005). Thus, healthcare information system researchers working with user satisfaction should take note that stakeholders who do not actively interact with the system should not be considered users. In most situations, patients are data providers and stakeholders, but not users. However, if they are required to manipulate the system in some manner, they are users.

Users in Healthcare

Early technology adoption took place in business settings with employees using mainframe systems to accomplish major business processes such as accounting, payroll, and budgeting. Users were typically employees using transaction-processing systems to accomplish routine business operations. Although healthcare delivery systems vary considerably from traditional business settings, many of the traditional IS theories are making their way into healthcare information systems research (Chiasson & Davidson, 2004). Unfortunately, many researchers simply fail to provide enough detail to ascertain the true users of the system. For example, research in telemedicine involves user satisfaction, cost and acceptance (Huston & Burton, 1997; Huston & Huston, 2000). The focus of some telemedicine research involves the perceptions of the patient, although the patient is not using the technology. In most cases, the physician and/or the clinician are the users during telemedicine. If the focus is user satisfaction or acceptance of a given technology, it is more appropriate to survey the clinician or physician, not the patient. Often, patients are surveyed for their acceptance of tele-video systems when they are non-using medical participants or simply social actors (Lamb & Kling, 2003; Wong, Hui, & Woo, 2005). Other researchers have studied patients as users when their intent was to determine the accuracy of a given technology (Baba, Seckin, & Kapdagli, 2005). In most cases, the patients would have no knowledge of the accuracy of the technology. Instead, they are simply the data source. Healthcare IS researchers must bear in

Figure 4. User Participation Model (McKeen, Guimaraes et al. 1994)



mind that not all stakeholders are users. Some may participate in a given act or action, but they are not necessarily users within that given context or time period.

Another common research topic in telemedicine research is user involvement. In an examination of tele-radiology, Chau (1996) argues that user acceptance is highly dependent on user involvement. In his study, physicians were correctly identified as users of the technology. There was little mention of patients except from the standpoint of patient care, patient management, and patient images. Clearly, the patient's role was that of stakeholder and data source, not user.

USING STAKEHOLDER ANALYSIS TO IMPROVE USER IDENTIFICATION

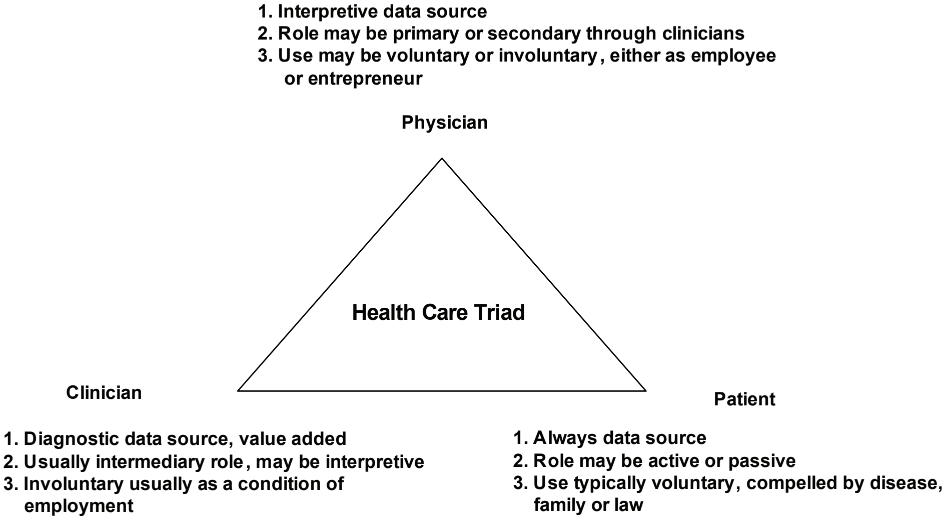
We contend that those conducting IS-related research in the healthcare setting should undertake a comprehensive study of stakeholders. Stakeholder analysis is an approach used to improve understanding of the "behaviour, intentions, interrelations and interests" (Varvasovszky & Brugha, 2000) of individuals and/or organizations as they relate to a given decision or implementation. This information will satisfy a variety of needs. For example, it could be used to develop objectives, strategies, or policies, or to aid in evaluating or implementing a given technology. Our primary intent for utilizing stakeholder analysis is to determine the actual healthcare user in IS related research. For example, in patient treatment, the three primary stakeholders are physicians, clinicians, and patients. Depending upon the situation, the user can consist of one or more individuals from any or all of these categories. Obviously, if we are researching the wrong person, or group of people, we cannot expect to get relevant or valid results.

When applying stakeholder analysis, it is useful to view the triad of patient, clinician, and physician to establish their individual roles. Figure 5 depicts the relationships between these actors, as well as possible roles.

Pouloudi (1999) proposed the following principles of stakeholder behavior, suggesting that these fundamentals can assist in identifying inter-organizational stakeholders within a given context:

1. The group and number of stakeholders are time and context dependent.
2. Stakeholders should not be isolated from others when determining their role.

Figure 5. Health care triad



3. The role of a given stakeholder may change with time.
4. A stakeholder may have multiple roles within a given context or time period.
5. Stakeholders do not have the same perspectives or wishes.
6. Stakeholders may change their perspectives or wishes over time.
7. Stakeholders may not be able to satisfy their needs or desires.

When conducting IS-related research in the healthcare setting, all participating stakeholders need to be evaluated. The technology, what the group is trying to achieve, and how they interact with each other dictates their activities and aid in determining if they are, in fact, users of the technology. For example, a physician providing a cardiac consult might enlist several clinicians to evaluate a patient. One clinician may perform an echocardiogram, another electro-cardiogram. The results of both of these procedures may feed data into an information system. The consulting physician may in turn interact with an aggregating software package that combines several data inputs in order to diagnose the patient. This situation involves a minimum of four stakeholders: the consulting physician, two clinicians, and the patient. However, they are not all users. If the physician actually utilizes the software to aid in diagnosing, or if the diagnostic results are presented in a format, or time basis different than if the system were not available, the physician is considered a user. However, if there is no difference in regard to time or context, the physician is not a user. If the clinicians need to perform some task in order to move the data from the medical equipment to the information system, they are users. For example, technicians may have to physically move data from the EKG monitor to the Information System. If this is done transparently, (i.e. with no clinician intervention), the clinicians are not considered users. In each of these situations, the patient is a data source, and not a user.

Researchers also need to be aware of which physician they are researching. In the above example, the cardiac consult physician may, or may not, be a user. However, the patient's primary physician is most likely a recipient of the data, and has very little knowledge of the technology used to obtain and/or diagnose the data from the patients.

At different time periods, a patient may play the role of both data source and user. Take the case of a diabetic patient recently diagnosed. Initially, a technician will draw some blood from the patient (data source) and insert the sample into a blood glucose analysis system to analyze the patient's blood glucose level. In this situation, the clinician (or maybe the physician) is the user, and the patient is the data source. Eventually, the patient may learn to monitor his or her own glucose levels. The patient may draw the blood, use the glucose analyzer, and enter the reading into an information system. In this situation, the patient is both a data source and the user. Varvasovszky and Brugha (2000) suggest the following be reviewed before performing a stakeholder analysis:

1. Purpose and time dimension (past, present, or future) of the stakeholder analysis
2. Time frame and available resources
3. Culture and context
4. Level (local, regional, national, international) of the analysis

Depending upon time and resource constraints, the stakeholder analysis can be performed by an individual, or group. Data related to the decision or implementation is collected. The analysts can learn not only more about the process at hand, but also more information related to potential stakeholder conflict and/or alliances.

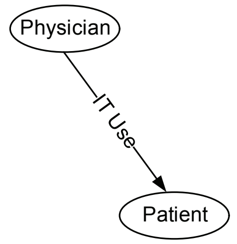
Patient Healthcare Examples for Identifying the User(s)

Utilizing Varvasovszky and Brugha's (2000) suggestions for stakeholder analysis, we provide examples of situations in which the patient, clinician, and/or the physician are users in healthcare information systems (Figures 6-11). The researcher must also be aware of Pouloudi's (1999) principles, remembering that purpose, time, context and level of analysis are important. In essence, before conducting user research, the researcher must first answer the questions of who, what, where, when, and how. Who are the stakeholders? What role do they play? Are there any circumstances in which their role (user, data provider, data recipient, etc.) may change? If so, what are these circumstances? Where are the stakeholders located (local, regional, global)? Does their stakeholder role change if their location changes? When are they doing this? Are all stakeholders involved in real-time? How do the stakeholders interact with each other? How does the stakeholder role change with changes in technology?

Stakeholder Analysis 1: Two Stakeholders: One User

Figure 6 is an example of two stakeholders, the physician and the patient, but only one user, the physician. In this case, the physician uses telemedi-

Figure 6. Physical Exam via Tele-Technology: Two Stakeholders - One User



Purpose: Perform a physical exam via tele-technology.
Time dimension: Present.
Time frame: Short term.
Available resources: The technology used for telemedicine.
Culture and context: Physician-patient relationship. Physician needs to extract information from the patient.
Level of analysis: Not local. Could be regional, national or international.
Stakeholders: Physician and patient.
User: Physician.

cine technology in the present (real time) to extract information from a patient. The remote physician might be regional, national or international but not in the same location as the patient. According to Pouloudi's (1999) principles, both the remote physician and the local patient are stakeholders. Applying the Davies (2002) definition, the physician is the only valid user for IS research. The patient is the data source.

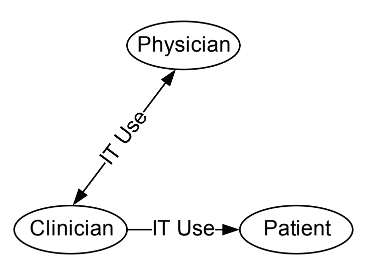
Stakeholder Analysis 2:
Three Stakeholders: One or Two Users

Another example might be the physician who diagnoses a cardiac arrhythmia over the Internet. This could occur in either real time or a store-and-forward time dimension. The clinician would use technology to obtain an electro-cardiogram (EKG) from the patient and transmit it to the physician. The patient would merely be a data source for the exam. In this example, three stakeholders interact with one another and the technology to provide healthcare delivery. The patient is the data source and the physician is a user. The clinician may, or may not, be a user. If there is no change in the manner in which the EKG is conducted, and it is transparently sent to the physician, the clinician is not a user. However, if the clinician needs to perform a different function in order to transmit the EKG, he is also a user. The IS researcher must know more about both the technology and procedure in order to determine the user(s).

Stakeholder Analysis 3:
Three Stakeholders: Up to Three Users

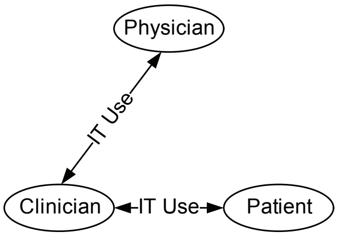
Assume the diabetic patient is now hooked up to a wireless blood glucose continuous monitoring device that transmits data to the clinician over the Internet, who aggregates results and transmits them along with clinical interpretation to the physician. As shown in Figure 8, all three members of the healthcare triad are stakeholders and may be users. The patient's role occurs in the present, while the clinician and physician's roles occur in the present and/or future. The patient is local, but the clinician and physician might be regional, national, or international. All three are considered stakeholders. In this scenario, all three are also considered users for IS research. As previously discussed, time could change the relationship of the users. Initially, the clinician and physician may be users, with the patient only being a data source. Over time, the patient may actually self-monitor and adjust medication accordingly. In this case, all three stakeholders are users. Later, there may be no need for the clinician, or the patient may not be healthy enough to play the role of user. As shown, IS researchers need to be aware of Pouloudi's principles (1999).

Figure 7. Diagnosis via Internet: Three Stakeholders – One or Two Users



Purpose: Diagnose a cardiac arrhythmia via the internet.
Time Dimension: Present or past.
Time Frame: Intermediate term.
Available Resources: Cardiac monitor, web interface.
Culture and Context: Physician-clinician, clinician-patient relationships, Clinician needs to extract EKG, Physician needs to diagnose arrhythmia.
Level of Analysis: Physician not local. Could be regional, national, or international. Clinician local.
Stakeholders: Physician, clinician, patient.
Users: Physician and clinician.

Figure 8. Wireless Continuous Blood Glucose Monitoring: Three Stakeholders – Up to Three Users



Purpose: Check and report blood glucose level.
Time Dimension: Present and/or future.
Time Frame: Short term.
Available Resources: Wireless glucose monitor, online access to reporting facility, web interface.
Culture and Context: Physician-clinician, clinician-patient relationships, Physician and Clinician need access to patient's glucose level, Patient needs to adjust meds.
Level of Analysis: Physician and Clinician not local. Could be regional, national, or international. Patient local.
Stakeholders: Physician, clinician, patient.
Users: Physician, clinician and patient.

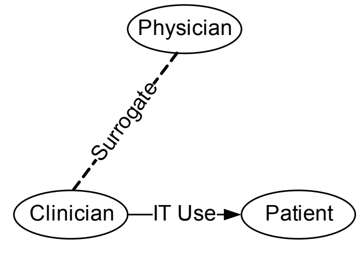
Stakeholder Analyses 4 and 5: Physician as Stakeholder, but not User

Physicians often employ specialists to serve their clinical needs. In Figures 9 and 10, the physician serves the role of manager or employer using a surrogate clinician to deliver healthcare services. In both of these scenarios, the physician is a stakeholder, but not a user. In Figure 9, the clinician secures a medical history from the patient, inputting the information into a wireless tablet PC. This medical history is acquired for the physician, the employer. The patient is the data source. All three are stakeholders in this system. However, the clinician is the sole user.

In Figure 10, a similar surrogate relationship exists. An outpatient is required to perform pulmonary function tests twice daily. The pulmonary function monitor is wirelessly connected to technology which creates graphs of the patient's pulmonary functions and transmits results to a remote location in real-time. Both the clinician and the patient interact with the diagnostic technology. The clinician is an employee of the physician, and only contacts the physician if pulmonary function results are not within expected limits.

In this example, it would be inappropriate to apply IS user theories to the physician. All three are stakeholders, but only the clinician and the patient are users.

Figure 9. Obtain Patient History: Three Stakeholders - One User



Purpose: Obtain patient history for electronic record.
Time Dimension: Present.
Time Frame: Short term.
Available Resources: Wireless tablet PC, secured wireless network, health care information system.
Culture and Context: Physician-clinician, clinician-patient relationships, Physician surrogates clinician to obtain patient's medical history.
Level of Analysis: Physician not local. Could be regional, national, or international. Clinician and patient local.
Stakeholders: Physician, clinician, patient.
User: Clinician.

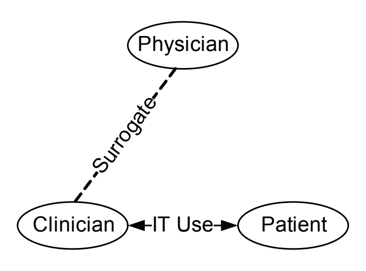
Stakeholder Analysis 6: Network of Stakeholders

While all of these examples are potentially real, in many cases healthcare delivery requires a network of stakeholders. Figure 11 represents such a setting. In this example, a seriously injured patient is admitted to an emergency room (ER) after an accident. The patient is immediately seen by an ER triage nurse and ER physician to evaluate the degree of injury. X-rays are ordered and while the patient is waiting, an admitting clerk obtains needed identification and insurance information using a wireless tablet PC. The ER nurse enters the initial signs and symptoms of the patient into the system that aggregates medical history and personal information. The patient's primary physician is notified and an orthopedic physician evaluates the patient's musculoskeletal injuries prior to the X-ray. The X-ray technician arrives and shoots a set of ordered X-rays that are then transmitted to a radiologist who diagnoses a fracture. The patient uses none of the technologies involved in triage, diagnosis, treatment or documentation. Instead, the patient is merely the data source. The patient, ER nurse, admitting clerk, X-ray technician, ER physician, and orthopedic physician are local. The radiologist is remotely located regionally, nationally or internationally. Most processes are in real time. It is possible that the orthopedic physician will diagnose the fracture and store-and-forward the X-rays to the radiologist for evaluation in the near future. In this scenario, there are eight stakeholders, and only four of which are users - the radiologist, emergency room nurse, the x-ray technician and the admitting clerk. The patient, ER, Orthopedic and primary physicians are data sources – and in most cases data recipients, but they are not users of any of the technologies.

The network example is more representative of a "real world" case, where multiple stakeholders share the responsibility of healthcare, play a variety of interacting roles, and function in a particular setting over time.

Note that the environment in which the technology is utilized may also influence user definition. Hospital policy may dictate how technology is used, and therefore how the user is to be identified. We have provided examples related primarily to telemedicine. The general assumption is that the two environments involve two hospitals or a hospital and a physician's office. However, it is often more complex. Technology may cross boundaries such as emergency medical care, extended care, and specialty clinics. The stakeholders and users of each of these facilities must be properly identified and considered.

Figure 10 . Three Stakeholders - Two Users



Purpose: Pulmonary function test.
Time Dimension: Present.
Time Frame: Short term.
Available Resources: internet access, information system
Culture and Context: Physician-clinician-patient relationships, Physician surrogates clinician to analyze test and inputs results. Patient reads.
Level of Analysis: Physician not local. Could be regional, national, or international. Clinician local. Patient local and regional, national or international.
Stakeholders: Physician, clinician, patient.
Users: Clinician and patient

CONCLUSION

Major problems associated with applying IS-related research to healthcare include the lack of understanding of the nuances of the healthcare concept and its context. One of the most important principles for those doing research in information systems is “know your user”. This principle should apply to those doing research in healthcare as well. However, this is often not the case, leading to unrealistic assumptions associated with user identification. We presented how a simplified stakeholder analysis can aid the IS healthcare researcher in identifying the appropriate user or users.

It was not our intention to identify prior research in which the user was inaccurately defined. Instead, we propose a way in which future research may be improved. As shown, not all stakeholders are users, and a user in one situation is not necessarily a user when time dimensions, resources, and/or the levels of analysis differ. This is especially evident in healthcare. Some physicians are actual users of technology, whereas other physicians rely upon technicians to use the technology. This varies among both physicians and procedures.

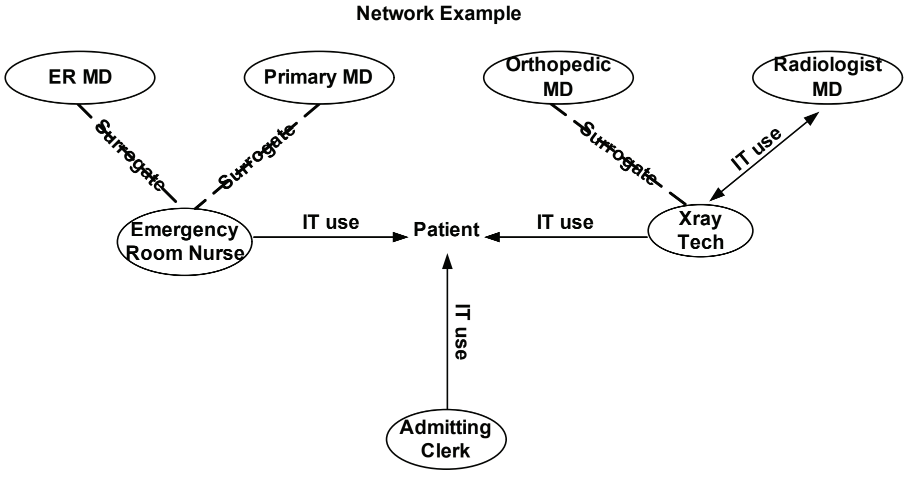
Each of the healthcare stakeholders plays an important role. It is our responsibility to assure that we properly identify that role and conduct research accordingly. Another important area of research in healthcare is client acceptance or satisfaction. The client generally will not manipulate the system, but may be heavily impacted by the system. Therefore, we encourage IS researchers both in healthcare and healthcare administration to develop instruments that focus on client acceptance and satisfaction.

The healthcare industry is becoming increasingly dependent upon technology, and it is imperative that research in IS/healthcare be conducted properly. Prior studies (Shah & Robinson, 2007) have shown conflicting results regarding the importance of user involvement when evaluating and developing medical devices. Perhaps these results could be attributed to improperly defining the true user of the technology.

REFERENCES

Agarwal, R., & Prasad, J. (1997). The role of innovation characteristics and perceived voluntariness in the acceptance of information technologies. *Decision Sciences, 28*(3), 557-582.

Figure 11. Network Example - Eight Stakeholders - Four Users



Avgerou, C. (2001). The significance of context in information systems and organizational change. *Information Systems Journal, 11*(1), 43-63.

Baba, M., Seckin, D., & Kapdagli, S. (2005). A comparison of teledermatology using store and forward methodology alone, and in combination with web camera videoconferencing. *Journal of Telemedicine and Telecare, 11*(7), 354-361.

Barki, H., & Hartwick, J. (1989). Rethinking the concept of user involvement. *MIS Quarterly, 13*(1), 52-63.

Chau, P. Y. (1996). An empirical assessment of a modified technology acceptance model. *Journal of Management Information Systems, 13*(2), 185-204.

Chiasson, M. W., & Davidson, E. (2004). Pushing the contextual envelope: Developing and diffusing is theory for health information systems research. *Information and Organization, 14*(3), 155-188.

Davies, G. (2002). *A user by any other name*. Paper presented at the Theoretical Perspectives in Human Computer Interaction.

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly, 13*(3), 319-340.

DeLone, W. D., & McLean, E. R. (1992). Information system success: The quest for the dependent variable. *Information Systems Research, 3*(1), 60-95.

DeLone, W. D., & McLean, E. R. (2003). The Delone and Mclean model of information system success: A ten year update. *Journal of Management Information Systems, 19*(4), 9-30.

Field, M. J. (1996). *Telemedicine: A guide to assessing telecommunications in health care.* Washington, D.C.: National Academy Press.

Freeman, R. E. (1984). *Strategic management: A stakeholder approach*. Boston: Pitman.

Ginsberg, A., & Venkatraman, N. (1985). Contingency perspectives of organizational strategy: A critical review of the empirical research. *Academy of Management Review, 10*(3), 421-434.

Goldschmidt, P. G. (2005). Hit and MIS: Implications of health information technology and medical information systems. *Communications of the ACM, 48*(10), 68-74.

Hiltz, S., & Johnson, K. (1990). User satisfaction with computer mediated communication systems. *Management Science, 36*(6), 739-764.

Hu, P. J., Chau, P. Y. K., Sheng, O. R. L., & Tam, K. Y. (1999). Examining the technology acceptance model using physician acceptance of telemedicine technology. *Journal of Management Information Systems, 16*(2), 91-112.

Huston, J. L., & Burton, D. C. (1997). Patient satisfaction with multispecialty interactive teleconsultations. *Journal of Telemedicine and Telecare, 3*(4), 205-208.

Huston, T., & Huston, J. (2000). Is telemedicine a practical reality? *Communications of the ACM, 43*(6), 91-95.

ISWorld. (2006). MIS journal rankings. Retrieved February 20, 2006, from http://www.isworld.org/csaunders/rankings-0517.htm

Ives, B., & Olson, M. (1984). User involvement and MIS success: A review of research. *Management Science, 30*(5), 586-603.

Khoumbati, K., Themistocleous, M., & Irani, Z. (2006). Evaluating the adoption of enterprise application integration in health-care organizations. *Journal of Management Information Systems, 22*(4), 69-108.

Kling, R. (2003). Reconceptualizing users as social actors in information systems research. *MIS Quarterly, 27*(2), 197-235.

Lamb, R., & Kling, R. (2003). Reconceptualizing users as social actors in information systems research. *MIS Quarterly, 27*(2), 197-236.

LeRouge, C., Hevner, A. R., & Collins, R. W. (2007). It's more than just use: An exploration of telemedicine use quality. *Decision Support Systems, 43*(4), 1287-1304.

Login, A., & Areas, S. (2007). An empirical examination of patient-physician portal acceptance. *European Journal of Information Systems, 16*, 751-760.

Ma, Q., & Liu, L. (2004). The technology acceptance model: A meta-analysis of empirical findings. *Journal of Organizational and End User Computing, 16*(1), 59-72.

Magni, M., & Pennarola, F. (2008). Intra-organizational relationships and technology acceptance. *International Journal of Information Management*.

Mair, F., & Whitten, P. (2000). Information in practice: Systematic review of studies of patient satisfaction with telemedicine. *British Medical Journal, 320*, 1517-1520.

Massa, S., & Testa, S. (2008). Innovation and SMES: Misaligned perspectives and goals among entrepreneurs, academics, and policy makers. *Technovation*.

McKeen, J., Guimaraes, T., & Wetherbe, J. (1994). The relationship between user participation and user satisfaction: Investigation of four contingency factors. *MIS Quarterly, 18*(4), 427-452.

Mitchell, R. K., Agle, B. R., & Wood, D. J. (1997). Toward a theory of stakeholder identification and salience: Defining the principle of who and what really counts. *Academy of Management Review, 22*(4), 853-886.

Norman, D. (2005). Human centered design considered harmful. *Interactions, 12*(4), 14-19.

Pouloudi, A. (1999). *Aspects of the stakeholder concept and their implications for information systems development.* Paper presented at the Proceedings of the 32nd Hawaii International Conference on System Sciences, Hawaii, HA.

Powers, R., & Dickson, G. (1973). MIS project management: Myths, opinions, and reality. *California Management Review, 15*(3), 147-156.

Rawstorne, P., Jayasuriya, R., & Caputi, P. (2000). *Issues in predicting and explaining usage behaviors with the technology acceptance model and the theory of planned behavior when usage is mandatory.* Paper presented at the International Conference on Information Systems, Brisbane, Queensland, Australia.

Reponen, T. (1994). Organizational information management strategies. *Information Systems Journal, 4*(1), 27-44.

Shah, S. G., & Robinson, I. (2007). Benefits of and barriers to involving users in medical device technology development and evaluation. *International Journal of Technology Assessment in Health Care, 23*(1), 131-137.

Shneiderman, B. (1987). *Designing the user interface: Strategies for effective human computer interaction*. Reading, MA: Addison Wesley.

Van de Ven, A. H. (2005). Advancing research in organizations through learning communities. *Research in Organizations: Foundations and Methods of Inquiry*.

Varvasovszky, Z., & Brugha, R. (2000). How to do (or not to do)...A stakeholder analysis. *Health Policy and Planning, 15*(3), 338-345.

Venkatesh, V. (2000). Determinants of perceived ease of use: Integrating control, intrinsic motivation, and emotion into the technology acceptance model. *Information Systems Research, 11*(4), 342-365.

Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User acceptance of information technology: Toward a unified view. *MIS Quarterly, 27*(3), 425-478.

Wixom, B., & Todd, P. (2005). A theoretical integration of user satisfaction and technology acceptance. *Information Systems Research, 16*(1), 85-102.

Wong, Y. K., Hui, E., & Woo, J. (2005). A community based exercise programme for older persons with knee pain using telemedicine. *Journal of Telemedicine and Telecare, 11*(6), 310-316.

This work was previously published in International Journal of Healthcare Information Systems and Informatics, Vol. 4, Issue 3, edited by J. Tan, pp. 1-15, copyright 2009 by IGI Publishing (an imprint of IGI Global).

Chapter 5.21

Economic Efficiency and the Canadian Healthcare System

Asha B. Sadanand
University of Guelph, Canada

ABSTRACT

In this chapter the authors examine the compatibility of the objectives of universality and public funding which are two important pillars of the Canadian healthcare system, with the objectives of cost effectiveness and more generally economic efficiency. The authors note that under some very innocuous conditions, markets and other economic based mechanisms such as second price auctions are characterized by economic efficiency and cost effectiveness. For the particular case of healthcare, some additional features that must be considered in the design of the mechanism are that healthcare services and products are valuable if, when taken together they constitute the components of a needed procedure, and otherwise they are worthless to the individual; and timely completion of procedures is what is valued, delays and waiting not only prolong suffering but may eventually prove to be more costly to the system if the condition worsens. They recommend a market-based mechanism, encompassing these features, that utilizes mobile agents representing patients and their medical needs. In order to incorporate the basic goals of universality and public funding, the agents will participate in virtual auctions using a needs based ranking as the currency for making bids.

DOI: 10.4018/978-1-60566-772-0.ch002

INTRODUCTION

A universal, publicly funded healthcare system, such as the one in Canada, has many attractive features that have general appeal. The belief that healthcare is a basic necessity, which must be provided by the state for all the citizens, is the underlying principle for universality. Public funding ensures that all people, no matter how wealthy or poor, can rely on the government for their healthcare needs.

The system has been a source of great pride for Canadians, and a reason for envy by other nations.

For decades, it has served the Canadian people well in taking care of their health needs in a timely fashion and without a large financial burden. However, recent times have witnessed some dissatisfaction as the Canadian population is beginning to age and health costs have burgeoned. The costs, that have throughout been creeping upward, have now threatened to overtake the budget and the system has responded by lengthening waiting lists. In the case of some procedures the waiting lists have reached such proportions that patients are needlessly suffering by prolonged waiting, during the course of which, their conditions have often worsened, at times to the point where they must be treated on an emergency basis. Indeed, many patients have contracted further complications in addition to their original illness, and in rare cases died from the complications. Allowing the patient to worsen generally has irreversible implications on treatment, and ultimately on outcomes; quite perversely, it can also increase the total cost of treatment for the patient, further aggravating the budget problem of healthcare provision. This escalation of both cost and suffering for the patient could have been prevented had the patient been treated in a timely fashion.

In effect, the much touted public healthcare system is now forcing Canadians to accept a compromised level of service by requiring protracted waiting followed by late treatment, and possibly at higher cost. This is certainly not fitting of a world class standard of care, and it is certainly not what was envisioned by the founders that first drafted this policy.

In trying to find solutions, three main strategies arise, and ideally, all three strategies should be used in forming and maintaining the best healthcare programs. The first and most obvious is to increase the budget. This has proven to be quite difficult when taxpayers are already burdened with fairly high taxes. Nevertheless, a somewhat higher budget does seem inevitable in the present situation. Indeed, it should be expected that supplying healthcare for an aging population, should cost more. However, in the future, such demographics should be anticipated. A scheme should be instituted whereby rather than burdening the current work force of younger individuals with the large healthcare costs of the top heavy aging cohort, the healthcare system avoids periods of crisis and recovery as the population demographics swing from aging to youthful populations. To achieve this steady cost for healthcare, a fund must be developed which would accumulate a total for each person summing to the average expected lifetime healthcare costs. An important part of developing such a system would be to have access to accurate data on average lifetime health costs, and to be able to make accurate predictions of future average lifetime health costs.

Another direction is to reduce the demand for healthcare by urging the public to adopt healthier lifestyles. There are certainly many initiatives being taken in this direction by both private individuals and organizations, as well as through Canadian public policy. There is currently greater awareness in the general public about maintaining a healthy active lifestyle than ever before. The government has also been promoting healthy living through massive advertising campaigns and economic incentives, such as preferential tax treatment or deductions for the cost of children's fitness participation. However, these are long horizon initiatives, and the benefits of these efforts in terms of improved health and lower medical costs will only be realized much farther in the future.

Finally, there is the strategy of ensuring that, given the limited budget that does exist for healthcare, it is allocated in a manner that achieves the maximum benefit at the lowest possible cost. In this chapter we will focus on this last strategy. This is not to say that the other two directions are not worthwhile, but rather that we do not expect to see much immediate relief by utilizing them, although they definitely have a necessary role in the proper long term functioning of a carefully crafted healthcare program.

The concept of a universal publicly funded healthcare system is very idealistic, and as such there are some inherent difficulties that must be overcome in order that the scheme works smoothly. The first and foremost issue has to do with the limited budget. The reality, of a budget that is limited, is that we are immediately confronted with the difficult questions of choices: Which treatments are to have a priority, which procedures are covered and which ones are not; among all the different needy patients, which shall we treat first and which patients will be treated later, all become very relevant questions.

These difficult questions that must be answered, are not exclusively encountered in the healthcare sector, but are issues that arise for most goods and services. We are accustomed to resolving these questions (in the other contexts) by allowing markets to determine the allocation of who gets how much of each good. Individuals decide whether to buy a certain good based on the price and whether, given the price, it is worthwhile to buy the good as compared to the next best alternative purchase. Suppliers are willing to provide quantities of the goods at different prices based on their costs; generally prices cover cost and more because suppliers who may be providing specialized goods or services often have incurred some set-up costs that must be covered in the long run. It is competition that keeps in check the suppliers' motivation to obtain prices that exceed their costs. The price for a good adjusts depending on demand until the amount demanded is exactly equal to the amount that can be supplied at that price. At that point the market is said to be in equilibrium. Once the market is in equilibrium, the people that end up buying are those that value the good more than the price, and those who do not buy, value the good less. Thus, the market achieves an allocation where the people are neatly divided into two groups; the high valuation people who consume the good, and the low valuation people who do not; and we notice that this maximizes the sum over all people, of the value of having this good. Further, if we extend the market to all goods, then the overall value to all people for all goods is maximized.

We are interested in knowing whether the market allocation is a good allocation: that is, whether the right people end up with the right amounts of goods or whether one could redistribute to achieve a better allocation. Economists have explored this issue and come up with the notion of economic efficiency.[1] The idea here is that an allocation is good (efficient) if it is impossible to alter the allocation and find that all people are at least as happy with their situation as before, and some strictly happier. This is called allocative efficiency. Starting with an arbitrary allocation, if we had to go from person to person, asking about alternative allocations, to verify allocative efficiency of the initial allocation, it would be an almost impossible undertaking, particularly if the number of people were large: the sheer volume of people that must be consulted and the number of questions that must be asked about all the possible alternative allocations will be endless.

Happily there is another way to verify efficiency. Economic theory shows that given certain conditions[2] market equilibrium is always efficient.[3] To see this intuitively, suppose that initially the market determined the allocation of all goods. Now suppose one attempted to reallocate by taking a unit of a good away from a person and returning the price to them, and at the same time allowing another person who did not initially buy, to buy the one unit of the good at the market price. The first person would be able to spend the money on something else if they liked. But since they did not originally buy any alternative good, it must have been that their value for the alternative good was not as high as that for the good they actually bought, leaving them worse off as compared to how they were before the reallocation. Similarly, the new person to whom the good is being reassigned would not find it worthwhile to pay the price for the good, since, if instead they had found it worthwhile they would have bought it in the first place. We can see how the second person is also worse off from our reallocation. Any other attempt to reallocate will suffer the same fate. It can then be concluded that markets must achieve allocative efficiency.

In addition to allocative efficiency, one might be interested in productive efficiency: whether, for a given cost of production, the maximum amount of goods has been produced. Here, again, economic theory indicates that markets result in productive efficiency,[4] since producers wish to make the highest possible profit. If production were not efficient, producers could simply modify their choices of inputs, produce more, earn more revenue, while throughout, keeping their cost the same.

Finally, even if all existing products are allocated efficiently, and all production of these products is efficient, there can still be room for improvement. If our economy was producing the wrong sorts of goods that people didn't particularly want, for example, this would be an area for improvement. In very simplistic terms, if a list of goods was being produced, but the consumers would be willing to pay more if only there was a different mix of goods available, it will improve things to change to the different output mix. Now, in a market economy where firms are motivated to earn profit, if there could be more profit made by modifying the line up of products offered, then naturally firms would change their product lines to avail themselves of the higher profit.

Thus, we see that under certain required conditions[5] the market (price system) does result in allocations that satisfy all the different aspects of efficiency. And this maximization of efficiency as it turns out, is equivalent to the notion that markets maximize the sum of the value to all individuals of all the goods in the market.

Why can we not apply this approach to healthcare? The greatest stumbling block in utilizing the efficiency properties of the market for healthcare is that we would lose the claim to universality. Some people would not be receiving even basic healthcare because they cannot afford it. While we can enjoy the benefits of the market system, namely the efficiency, we see that simultaneously we must accept the vagaries of the market.

However, as it happens, the market system outcome leads us to only one of many possible economically efficient outcomes. To see what extreme situations are admitted as efficient, consider a situation where we allocate all the goods and services available in an economy to a single individual. This one individual has everything and all the others have nothing. We notice that this satisfies the definition of economic efficiency and indeed would be economically efficient, because there would be no possible reallocation that would improve or leave *everyone* as well off, since if we change anything, the one person that had everything will become worse off. Once we see that this is efficient, we can also see that all the other allocations where we give everything to another of the people and nothing for the rest would also all be efficient. And then we can imagine that there will be all the possibilities in between that gradually distribute more among all people in the economy, but at the same time maintain economic efficiency. How can we choose between all these different efficient allocations?

We know that the market system chooses one particular allocation from all of these possible efficient outcomes, and that allocation depends on the wealth distribution of the people. The drawback of such an allocation is that, although it would be efficient, the wealthy can afford much healthcare, and the poor, very little. Universal healthcare instead requires that all people have equal access to healthcare, whenever the need arises.

The main question that this chapter addresses is whether the efficiency qualities of the market can be harnessed while at the same time preserving the universality of healthcare. This will be a measure of how well we are able to achieve the maximum benefit for the greatest number of people, with a fixed healthcare budget.

A number of schemes have been proposed to utilize the market system in the context of healthcare. One such plan gives each person an equal sum of healthcare dollars annually that can be saved to form a fund, from which they can draw as a health need arises. Being market based it does have potential for being efficient. However, the argument against such a plan is that it *equalizes spending* rather than equalizing access to treatment. In particular then, if an individual was very unlucky in their health problems, through no fault of their own, they may risk running out of funds; while another person who is relatively healthy may have a surplus in their account. Therefore, this plan in biased in favor of individuals with a good genetic endowment in health factors and as well as individuals that have been lucky in their health outcomes. Another similar possible approach is to allow individuals to save tax-free in order build a fund to be used for health needs, much like an RRSP. Individuals who know that they are predisposed to certain conditions would have the ability to prepare for such a contingency and would benefit form the tax-free treatment of these funds. However, like the open market, this has the problem that wealthier individuals will be able to save more, and afford more healthcare than the less wealthy. Moreover, in our current fluctuating financial climate, bad luck or unwise investment decisions may render an entire lifetime of saving earmarked for healthcare completely worthless. Thus, in addition to the inherent uncertainty about health outcomes, we may end up imposing even more uncertainty on individuals with this scheme.

In addition, both of these policies have the problem that if individuals are not farsighted enough they may have long spent their budgets on negligible health issues, and underestimate their future healthcare needs. There are a few other variations on these basic themes, but the general conclusion about the market based policies that have been proposed is that they have some important drawbacks with regard to universality as well as farsightedness, but in their favour, they do have the efficiency properties gained by utilizing the market system.

In this chapter we propose an entirely new market based mechanism. The plan proposed here uses the efficiency of the market system and simultaneously allows the system to be needs based. In order to have a market based system, we need to have a virtual market working in the background that signals the cost and the value of each procedure. At the same time if we want the system to be needs based, we need to establish a priority of medical procedures, and also have a needs based sense of which patients should be treated first, and the order in which the rest would receive treatment.

For the system to be truly needs based, patients must be ranked according to which ones have the more serious need. In the Canadian system there is some rudimentary ranking of the patients belonging to a single specialist, and this is the waiting list. Patients are mostly ordered according to their arrival into the system. The specialist has some discretion in modifying rankings based on his/her own reassessment of the changing of urgency of the patients. However, there is no sense in how one physician's patients compare with another physician's patients. For a market type system to work, there must be something akin to a "master" waiting list that ranks patients nationwide (or at least within a region that is served by a geographic cluster of medical care facilities) for urgency and priority of treatment. Compiling such a list itself is a major undertaking, and approaches to how this can be effectively achieved will be discussed further and in greater detail in a later section.

Once the ranking has been established, it will influence how patients will propagate through the system. The actual scheduling will be done with mobile agents, each representing a patient in the system. The agents will participate in a mechanism that is similar to a market, which will allow the system to realize the efficiency properties of markets. Moreover, because need alone govern the capability of the agents to secure treatment in the schedule, there is no connection between the timing, or quality of treatment, and the patient's wealth. The allocation is not based on ability to pay, but rather on need, thus satisfying the goal of universality.

THE MECHANISM

The mechanism for scheduling elective procedures that we propose here will be achieved by representing each patient by a mobile agent. The agent will have assigned to it the detailed description of the patient's malady, and will be updated as there are changes in the patient's information. Based on the description of the patient's case, physicians will have some input in arriving at a ranking between 1 and 100, indicating the urgency for treatment of this patient. The mobile agent will be given this ranking and it will also be given information about the treatment the patient needs, including all the hospital and medical equipment and types of personnel necessary for the treatment. With the treatment information and the rankings the computer agent will search and obtain treatment for the patient as early as possible. The agent will essentially participate in a mechanism that is very similar to a market or auction. We will discuss in depth both the ranking process and the auction.

The system will have information about the availability of all the hospital facilities and staff at each point in time. These are the items that are being auctioned in our fabricated market. Each agent will have a list of items that are needed to complete their procedure. For example the procedure may be a hip replacement. In that case the agent needs to secure adequate surgery time in an operating room, find an orthopedic surgeon that is available at that time, enough nurses to assist, an anesthetist and any specialized equipment and medical supplies that will be needed. The ranking, which reflects the urgency of its case, will be the amount that the agent has to spend to secure all the items on its list. How this ranking, or budget, is determined will be discussed in a later section; for the present we will simply assume that the budget gives a true representation of the urgency of the case.

The agent will bid on each needed item in virtual auctions that will be conducted on an ongoing basis, competing with other agents representing other patients who may seek different procedures and place bids for a somewhat different list of needs. The actual method for determining which agents will obtain the items is quite involved. The agents participating in our large-scale auction will together form an economic game. In designing the game, the objective will be for the equilibrium to be characterized by all items going to the agents that have the highest willingness to pay. A simplified version of the mechanism to be used is the second price or English auction[6]. In this setting, for any particular item, the agent with the highest bid will receive the item, and pay the second highest bid price. Since each agent's valuation for the items on his list depends on the urgency of his own situation, this is called a private values auction.[7]

There is a large literature on second price private values auctions. Essentially it is an economic game; a situation where a number of people are all taking actions and everyone's action affects each person's outcome. Here, the agents are acting in the place of people. The outcome is generally thought to be a Nash equilibrium for the game: a stable set of choices where, if we fix what everyone else is choosing, each agent will not want to change their choice. Another way to state the Nash conditions is that no agent will unilaterally want to change its choice, given the choices of all the other agents.

To understand the Nash equilibrium for second price private values auctions, we initially simplify by supposing that all bidders know each others' valuations. In such a situation, economists have established that although there can be many equilibria, the most compelling one[8] is where the each agent bids his true value. The agent with the highest valuation wins and pays the second highest valuation. In the case of private information, that is, a situation where the agents do not know each others' valuations, the case for truthful bidding by each bidder is even stronger. With unknown valuations, agents will not want to bid a lower price than their own valuation, for fear that there might be another agent with a valuation that is between the amount bid and the agent's valuation, that could outbid it. The agent will not want to bid any higher than what it is worth because of the negative payoff earned it the agent wins the auction. Thus, in the private or unknown values situation, each agent will bid his true value and the highest valuation agent will win.[9]

In the auctions, agents are trying to buy all the components needed for the treatment, and they try to schedule the treatment for the earliest date possible. Consequently, the same procedure at an early date will have a higher price than for a later date. Since all agents are searching at once, only the most urgent cases—where the representing agent can bid higher than anyone else—will succeed in obtaining all the necessary items at an early date.

Just as we have found with markets, it has been shown that private values second price auctions are also always economically efficient. Economic efficiency requires that the object should go to the bidder with the highest valuation. Since in the most compelling Nash equilibrium all agents will bid truthfully, we find that the agents representing the patients with the highest needs (as determined by physicians) are served first, which is the efficient outcome.

Economic literature has established the basic result of the efficiency of private values second price auctions in allocating a single item that is being auctioned by a seller. Things become a little more complicated when there are several items, and multiple units. Further, the literature distinguishes between situations where buyers are interested in purchasing only a single item and where each buyer buys a set of items. Situations where each buyer eventually buys something, are referred to as the assignment problem. A distinction is also made for situations when the value of acquiring one item maybe affected by the entire set of items acquired. This is clearly the case in our setting, since the items are only valuable to the patient if all the necessary ingredients for the required procedure are obtained. Distilling all this literature[10], it seems that an efficiency preserving mechanism that generalizes the second price auction in all these various dimensions can be created. Such a mechanism would constitute our virtual market where the mobile agents would interact, and economic efficiency would be attained.

Ranking by Colleagues

Finding the best way to rank patients is quite a major undertaking. In the Canadian system, a physician maintains his own waiting list by using his/her assessment of his/her patients. Occasionally physicians working in a group may request their colleagues to accommodate early treatment for a particularly serious patient if they will not fit in their own schedules. However, for the most part the waiting lists are not integrated across physicians.

As a result there is no proper ranking across lists to determine the absolute urgency for a patient. This integrated waiting list is a very important aspect of our mechanism. One way to achieve integration is to have a system of multiple ranking. Each physician will periodically be given anonymous information about a list of patients and be asked to rank them impartially. The lists will include not only some of the physician's own patients, but also some patients belonging to other physicians that are also in the system. The list of patients to be ranked by a particular physician will be randomly generated by the computer with the specification that a fraction, such as say at least a three quarters, will be another physicians' patients, and we can also require that every patient is ranked by at least by a certain number of physicians, say a minimum of four.[11] The actual ranking that each patient is assigned will be an average of all the various physicians' rankings, and this will serve as the currency, utilized by the agents representing the patients, in obtaining from the virtual market the various scarce resources required for the needed procedure.

One sentiment raised by the medical profession in our current world of very scarce resources, is that patients also have a role in affecting their health outcomes. In keeping with this line of thinking, patients that have been following prescribed lifestyles and taken all the preventative measures but have nevertheless contracted some illness that needs medical attention should be more deserving of higher rankings[12] than others who may not have been as conscientious. If there was a strong consensus that these factors were to be taken into consideration, such information could also be contained in the anonymous patient profiles.

To the extent that some resources will be common across many procedures, patients from each of these areas would all need to be in a common auction. This will mean that each physician will be ranking patients not only from his own speciality, but also some from other specialities. There may be some apprehension among doctors about having to rank cases outside their respective areas, but if we consider the alternatives, there is no one better qualified to rank than impartial (and unbiased by speciality) physicians themselves; without such a fully universal ranking, we cannot guarantee efficient use of resources that are common to several specialities.

Clearly, the universal ranking that will be produced using this method may initially be somewhat contentious, and perhaps there can be a built in adjustment procedure to allow for over riding corrections of any result that is too anomalous. However, in time we expect that this procedure will provide generally acceptable results. Perhaps over time there will be some adjustment of approaches to ranking as the doctors see how their own choices are connected to the final ranking. If there is a worry that doctors may recognize their own patients from the anonymous profiles that they are asked to rank, and may inadvertently be motivated to rank their own patient higher, the ranking protocol can be adjusted to accommodate such issues by having a lower fraction of the profiles to be ranked be the doctor's own patients, diluting the impact of the own patient ranking. In the end, if this continues to be a serious problem, we can even have that no patients to be ranked will be the doctor's own patients.

Economists have studied incentives in making choices. It is known that there are many incentive compatible mechanisms and they mostly rely on achieving truth telling by not allowing an individual's choices to affect matters that are important to the individual. Thus, a situation where the ranking involves only the patients belonging to other doctors, the outcome will not be biased by any incentive to alter the rankings.

THE DYNAMICS AND PRACTICAL ISSUES OF SCHEDULING

What we have described so far will work for allocating resources at a single moment in time. However, we know that healthcare allocation is an ongoing process. Therefore we need to discuss how the auctions will be held in a dynamic time setting.

It is quite reasonable to think that schedules will be fixed a certain amount of time in advance of the actual date of the procedure; this will be for the convenience of all involved. Such a lead-time may be a couple of weeks or perhaps a month, or it could also be dependent on the specific procedure. All bidding would be finished in advance of this time, and the participants (both patients and medical practitioners) would be informed of the schedule; all people will stick to the schedule unless something completely unexpected happens that forces them to cancel.

If, after the schedule is fixed, an even more urgent patient arrives, they would have to be dealt with as either on an emergency basis or may be able to be accommodated in the regular schedule, if someone has cancelled at the last minute. Until the point at which the schedules are fixed, new agents could be joining the auction. Agents, who could not afford to purchase their treatment requirements at a particular point in time, will automatically start making bids on components for procedures scheduled for a later time. In the meantime, having waited the extra time, their ranking will be higher, and so, all other things being equal, they will have a greater chance of securing the requirements for their procedure. Instead of having to re-rank a continuing patient, perhaps (if the medical profession endorses it) there can be an automatic inflation factor in the ranking of patients that do not secure treatment in a week and must be carried over to another week. The automatic ranking adjustment can be overridden if there is some important change in the patient's health status that requires physicians to revisit the needs ranking of the patient.

The agents can also be given extra information of a non-medical nature such as the patient's scheduling preferences (availability of dates and times, possibility of travelling to nearby locations, and any other relevant aspects for scheduling). An issue that we find in the current system, which can be easily addressed, is that of surgeons and other specialists working and or being on call continuously for extended periods of time, that may be deemed as excessively long. With the agent system, we can easily include system checks that record the duration of work for the various specialists, and we can easily institute regulations such as mandatory breaks after a certain duration of work. This might ensure that specialists performing critical procedures are well rested, and best able to exercise the care and precision needed for good results.

Shadow Prices and Other Incidental Benefits

Besides giving us economically efficient outcomes, there are further advantages associated with our mechanism. The mechanism and the prices therein provide us with some much needed, valuable information.

The prices, at which all the various medical facilities trade, are very significant. They represent the current relative value to the system of each medical component. In situations where there is an opportunity to expand the available facilities these shadow prices will specify which facilities are most in need, as indicated by the highest auction price. Specifically, if more money becomes available and there is a plan to expand the healthcare facilities in the locality, the most efficient use of the funds at the margin is to invest in the particular items that have the highest difference between relative prices and relative real dollar cost. For example if a new hospital bed costs $100 per night and new MRI equipment costs $400 per use[13], say, we compare that to the shadow prices for the same amount of use for each equipment coming from our auction. Suppose the auction prices were 12 and 20, respectively, say, then it would be better to spend on more beds, since the cost ratio of beds to MRI is 1/4, but the ratio of valuations of hospital beds to MRI equipment is 3/5. The beds are valued relatively higher in the auction than their relative dollar cost. Of course, this type of analysis is valid only at the margin. If there is a large infusion of funds, the relative shadow prices will no longer be accurate.

In addition, the whole aspect of being able to computerize all use of the medical system in a constellation of hospitals and medical facilities allows the generation of valuable data about many issues. Of primary importance to the whole business of healthcare provision is that the data from this mechanism will allow us to estimate the lifetime real medical costs of an individual, controlling for any number of characteristics that could be relevant. This would allow for precise and sophisticated forecasting of future healthcare costs for the system as whole, allowing for demographic trends and any other trends that could be relevant.

There will be a huge wealth of other data (of course respecting the understood rules of patient anonymity[14]) that could be useful for medical research; such as in the success rate of various procedures in the treatment of different conditions, the incidence of certain conditions in different populations, better documentation of past treatments of a given patient (instead of relying on the patient's memory) that might be significant for their current ailment. This could lead to a better level of service for the patient, as well as a better understanding of the success of treatments and thus greater progress in development of appropriate treatments.

CONCLUSION

Economists have been pivotal in devising many currently adopted mechanisms for allocation, where the goal is to find the best match, or in other words maximize the economic efficiency of the allocation. An example of such a mechanism is the matching system for medical residents to hospitals.[15] Markets and also auctions are known to maintain economic efficiency, but have the problem that the efficient outcomes are tied to individual wealth, and do not result in an equitable allocation. We have devised a mechanism here to overcome his drawback, by allowing representative agents to be traders in markets for healthcare products and services utilizing a fictitious currency that is equitably distributed according to the medical need of the patient, as determined by physicians. The mechanism further has the potential to provide valuable information about many aspects of healthcare provision, such as trends, estimation of costs, utilization rates of various equipment, and these data can be employed to give precise projections of the future based on demographics, and other relevant information about the population. Also of importance is the feature that the shadow prices arising form the mechanism will point to the areas that have the most benefit from investment and expansion of facilities. Thus, we have the means to develop a mechanism that maintains all the principles underlying a universal publicly funded healthcare system.

REFERENCES

Amoros, P., Corchon, L., & Moreno, B. (2002). The Scholarship Assignment Problem. *Games and Economic Behavior*, *38*, 1–18. doi:10.1006/game.2001.0852

Anderson, M., & Sandholm, T. (1999). Leveled Commitment Contracting among Myopic Individually Rational Agents. [Special Issue on Agent-Based Computational Economics.]. *Journal of Economic Dynamics & Control*, *25*, 615–640. doi:10.1016/S0165-1889(00)00039-7

Bansal, V., & Garg, R. (2001). Efficiency and Price Discovery in Multi-item Auctions. *ACM SIGecom Exchanges*, *2*(1), 26–32. doi:10.1145/844309.844314

Bikhchandani, S., & Haile, P. (2002). Symmetric Separating Equilibria in English Auctions. *Games and Economic Behavior*, *38*, 19–27. doi:10.1006/game.2001.0879

Bikhchandani, S., & Ostroy, J. (2002). The Package Assignment Model. *Journal of Economic Theory*, *107*, 377–406. doi:10.1006/jeth.2001.2957

Clarke, E. H. (1971). Multipart Pricing of Public Goods. *Public Choice*, *11*, 17–33. doi:10.1007/BF01726210

Demange, G., Gale, D., & Sotomayor, M. (1984). Multi-Item Auctions. *The Journal of Political Economy*, *94*(4), 863–872. doi:10.1086/261411

Gilpin, A., & Sandholm, T. (2007). Information-theoretic Approaches to Branching in Search. *Proceedings of the International Joint Conference on Artificial Intelligence (IJCAI)*.

Groves, T. (1973). Incentives in Teams. *Econometrica*, *41*, 617–631. doi:10.2307/1914085

Groves, T., & Ledyard, J. (1977). Optimal Allocation of Public Goods: A Solution to the 'Free Rider' Problem. *Econometrica*, *45*, 783–809. doi:10.2307/1912672

Leonard, M. (1983). Elicitation of Honest Preferences for the Assignment of Individuals to Positions. *The Journal of Political Economy*, *91*(3), 461–479. doi:10.1086/261158

Milgrom, P. (1985). The Economics of Competitive Bidding: a Selective Survey. In L. Hurwicz, D. Schmeidler, & H. Sonnenschein (Eds.), *Social Goals and Social Organization: Essays in Memory of Elisha Panzer*.

Roth, A. (2003). The Origins, History and Design of the Resident Match. *Journal of the American Medical Association*, *289*(7), 909–912. doi:10.1001/jama.289.7.909

Sandholm, T. (1996). Limitations of the Vickrey Auction in Computational MultiagenSystems. *Proceedings of the International Joint Conference on Artificial Intelligence(IJCAI)*.

Sandholm, T., & Lesser, V. (1997). Coalitions among Computationally Bounded Agents. [Special issue on Economic Principles of Multiagent Systems.]. *Artificial Intelligence*, *94*(1), 99–137. doi:10.1016/S0004-3702(97)00030-1

ENDNOTES

[1] This idea of efficiency was first introduced by Pareto, and it is called Pareto efficiency. It includes many components of efficiency, such as allocative efficiency, production efficiency and efficiency of product mix, which are discussed later.

[2] There are several conditions necessary to guarantee efficiency of markets. First all participants must be competitive, and this is typically assured if there are large enough numbers so that the choices of any one agent alone do not affect prices. Next all participants must have full information about the available choices. Now in this auction all that they really need to know is which components they need. Lastly, there are no externalities, which means that one agent's benefit from obtaining a particular item is unaffected by what items other agents have obtained.

[3] This idea was first developed by Adam Smith in 1776 in his famous book, *The Wealth of Nations*.

[4] Markets result in productive efficiency under the same conditions as required for allocative efficiency.

[5] See footnote 2.

[6] The English auction is the one with which we are the most familiar. Bidding begins at a starting or reserve level, set by the seller. Buyers will sequentially offer higher and higher bids until finally no one bids any higher. The winner is the highest bidder, and he pays his winning bid price. As it turns out this formulation can be shown to be identical (in terms of the underlying game and its Nash equilibrium) to the second price (or Vickrey) auction where players simultaneously submit sealed bids; the agent with the highest wins and pays the next highest bid price.

[7] Private values refer to a situation where each agent can have a different valuation for the item being auctioned. This is in contrast to the alternative scenario, termed common values, where all participants have the same value for the item being auctioned. The latter best describes auctions where an asset is being auctioned, all participants value it the

same, since their main purpose in buying it, is for investment; the critical issue in such auctions is whether all participants are fully informed about the what the common value is. In our setting the agents are buying the item for the patient's personal use, and so it is very plausible that different agents have different valuations.

[8] The dominant strategy, as it is called, is to always bid truthfully when playing this game. This is because for each possible choices that the other people make, agent will be no worse off by being truthful, as compared to any other action.

[9] The reader, who may not be familiar with the economics literature, may wonder why we use second price instead of first price auctions. We note that the actual price paid is not important since no real currency is spent; of greater importance is who wins the auction, and whether the allocation was efficient. Since the highest valuation agent wins the second price auction, efficiency is achieved. It turns out that the first price auction can also be efficient, but the argument is more involved.

To provide just a rough idea of the argument, in a Nash equilibrium of the first price auction, there must be an agent that bids just below the winning bid, to prevent the agent with the winning bid to shade his bid lower. Thus, the highest valuation agent can bid anywhere between his own valuation and the next highest valuation and win. In particular, then, he could bid just above the second highest valuation, giving a result which is not too different from the second price auction. Indeed there is a technical result known as the revenue equivalence theorem, which states that the expected social surplus from first and second price auctions is the same.

[10] The early economics literature is on the Clarke-Groves mechanism, where is purpose is to elicit truthful information about individuals' valuation. See Clarke (1971), Groves (1973), Groves and Ledyard (1975), and Leonard (1983). This is not a main concern in this application, since the valuations are known as the rankings are actually assigned by groups of physicians. Instead our focus is on whether the assignment can be implemented by a decentralized process where participants (the agents representing the patients) can arrive at the scene whenever their condition presents itself, and expect to join a process that has already begun with earlier participants. Examples of the literature examining various decentralized mechanisms begin with the simple auctions and branch out to multi item auctions, assignment problems, and package assignment problems. See Milgrom (1985), Demange, Gale and Sotomayor (1986), Bansal and Garg (2001), Amoros, Corcheon and Moreno (2002),Bikhchandani and Ostroy (2002),. Some of the literature is due to computer scientists and is particularly focused on automatic bidding, or agents bidding. See Sandholm (1996) and Sandholm and Lessor (1997), Anderson and Sandholm (1999), and Sandholm and Gilpin (2007). One important idea discussed in some of the recent literature, is the notion that agents may want to renege their contracts with a penalty (cost) if they are not able to obtain all the remaining items needed to complete their list.

[11] The precise values to be used here are not known at this stage. Fine-tuning of the system will be necessary and possible as more experience is gained.

[12] The question of whether a patient's illness is due their own neglect of health or whether it arises through no fault of their own is a very slippery surface. Recently some medical practitioners have advocated that a healthy lifestyle naturally resulting in healthy outcomes should be rewarded, while illness

arising from unhealthy lifestyles should not be as readily treated, particularly for repeat offenders. Of course the worry is that in many instances there cannot be definitive proof that a particular lifestyle choice lead to a particular illness. We suppose that the medical profession is best informed in these matters, and if such consideration is included in rankings all necessary precautions to avoid unfair rankings would be taken.

[13] These numbers are completely hypothetical and do not in any way represent the real costs of any of the medical equipment discussed. Similarly the auction prices are purely fictional and in particular have not been produced from any simulation of the mechanism.

[14] Computer systems are generally very good for maintaining anonymity of data, as it can simply be programmed into the system that all names and other identifying references be dropped when information is being used for purposes other than the patient's own treatment.

[15] The combined work of many economists such as Starr, Ludmerer, Gale and Sahpley, and Roth and Sotomayer has shaped the current system of resident matching programs. See Roth (2003) for a survey of this topic.

This work was previously published in Multi-Agent Systems for Healthcare Simulation and Modeling: Applications for System Improvement, edited byR. Paranjape and A. Sadanand, pp. 13-25, copyright 2010 by Medical Information Science Reference (an imprint of IGI Global).

Chapter 5.22

Information Technology and Data Systems in Disaster Preparedness for Healthcare and the Broader Community

Barbara J. Quiram
Texas A&M Health Science Center, USA

Cara L. Pennel
Texas A&M Health Science Center, USA

S. Kay Carpender
Texas A&M Health Science Center, USA

ABSTRACT

In the healthcare and public health community, information technology and data management tools are indispensable in preventing, preparing for, responding to, and recovering from public health emergencies, both natural and manmade. This chapter is divided into three sections. The first section discusses various uses of health technology and data systems in disaster preparedness and response. The second section expounds on technological applications to train healthcare staff for their roles and responsibilities in delivering critical health services during a disaster, as well as to integrate healthcare organizations and providers into the broader community planning and response processes. The chapter concludes with a model that has been implemented to integrate and train the broader group of community stakeholders, including healthcare organizations and providers, in disaster preparedness and response.

INTRODUCTION

In the healthcare and public health community, information technology and data management tools are indispensable in preventing, preparing for, responding to and recovering from public health emergencies, both natural and man-made. This

DOI: 10.4018/978-1-60566-356-2.ch016

chapter is divided into three sections. The first section discusses various uses of health technology and data systems in disaster preparedness and response. The second section expounds on technological applications to train healthcare staff for their roles and responsibilities in delivering critical health services during a disaster, as well as to integrate healthcare organizations and providers into the broader community planning and response processes. The chapter concludes with a model that has been implemented to integrate and train the broader group of community stakeholders, including healthcare organizations and providers, in disaster preparedness and response.

USING TECHNOLOGY AND DATA TOOLS IN DISASTER PREPAREDNESS

Information technology and data management systems are invaluable in preventing, preparing for, responding to and recovering from emergencies. According to Mathew (2005):

> *preparedness functions, including "prevention strategies, research and epidemiologic studies, education programs, rapid mobility and deployment of resources and services, community preparation, remote area planning, medical incident management, disaster site arrangements, communication network from the disaster site to casualty treatment post, training, disposal of dead, vector control, hygiene and sanitation, and psychological interventions," can be made more effective through the use of technology and data systems. (p. 56)*

A United States federal government report, Bioterrorism Preparedness and Response: Use of Information Technologies and Decision Support Systems, identifies potential technology uses by clinicians and public health officials in the event of a bioterrorist attack (Agency for Healthcare Research and Quality [AHRQ], 2002; Bravata, 2004). To conduct a review of the literature, researchers classified five broad systems categories: detection systems; diagnostic, management, and prevention decision support systems; surveillance systems; reporting and communication systems; and integrated systems. According to another AHRQ report, information technology supports bioterrorism preparedness in the following ways:

- Detection and monitoring systems support disease and threat surveillance and collect national health status indicators.
- Analytical systems facilitate real-time evaluation of live data feeds and turn data into information to identify disease outbreaks.
- Information resources and knowledge management systems provide reference information, distance learning, and decision support.
- Alerting and communications technologies transmit emergency alerts, facilitate routine professional discussions, and support collaborative activities.
- Response systems help manage vaccine distributions, track side effects, and disseminate public health information (Agency for Healthcare Research and Quality [AHRQ], 2005a, p. 3).

This first section describes various existing and emerging uses of information technology and data management systems in the health arena for disaster preparedness and response. The uses addressed here are surveillance, to include disease tracking, detection, diagnosis and reporting; communication; volunteers; electronic health records; modeling and simulation; telehealth; continuity of operations; and education and training.

Surveillance Systems

Surveillance entails the ongoing systematic collection, analysis, and dissemination of data about disease (Teich, Wagner, Mackenzie, & Schafer, 2002). Federal, state and local health departments and private healthcare providers must all work together to effectively detect, manage, communicate, and respond to health threats (Trust for Americas Health, 2007). Information technologies and decision support systems are a vital asset for public health practitioners and healthcare providers during disease outbreaks or in disasters (AHRQ, 2002; Bravata, 2004). Many surveillance systems are integrated systems. This section will briefly discuss disease tracking systems, rapid detection systems, diagnostic systems, and reporting/data sharing systems and provide examples of these integrated systems.

Surveillance systems include surveillance networks of sentinel clinicians, influenza surveillance, laboratory surveillance, foodborne and zoonotic disease surveillance, and sydromic surveillance, such as drug store sales for over-the-counter medications, and hospital-based surveillance, including emergency department data (AHRQ, 2002; Bravata, 2004). Management and prevention systems are designed to make recommendations to clinicians by abstracting clinical information from electronic medical records to make patient-specific recommendations (AHRQ, 2002; Bravata, 2004). Electronic health records will be discussed in greater detail later in this section. According to an AHRQ report (2005a):

> *Disease detection and diagnosis once relied solely on the astute clinician. Now, with advances in information technology, disease monitoring can be done electronically using "real-time" or instantaneous data analysis. While the astute clinician remains critical to early detection, this technology reduces the burden on clinicians to identify an unusual disease occurrence. Automated decision-support systems also offer an important tool to clinicians who are likely to be on the frontlines of detecting a disease outbreak or bioterrorist event. These systems enable the clinician to use computer programs to make a faster diagnosis. (p. 2)*

Disease diagnosis and reporting technology is also used in laboratories. Electronic Laboratory Reporting (ELR) increases the volume of tests reported to surveillance programs and improves the timeliness and completeness of reports (Nguyen, Thorpe, Makki, & Mostashari, 2007). Overall, some ELR system issues and concerns exist such as technology compatibility and interoperability and maintaining security and confidentiality.

Several surveillance systems are effectively being developed and utilized as part of the Public Health Information Network (PHIN). PHIN is a national initiative in the United States to implement a multi-organizational business and technical architecture for public health information systems. It was first funded in 2004 by the U.S. Department of Health and Human Services (DHHS) and the Centers for Disease Control and Prevention (CDC) through Public Health Response and Preparedness Cooperative Agreements. The goal of PHIN is to implement a unified national network of preparedness systems. PHIN's functional requirements include early event detection, outbreak management, laboratory systems linkages, countermeasure and response administration, partner communication and alert, and cross functional components (Loonsk, McGarvey, Conn & Johnson, 2006). PHIN provides national standards that serve as the basis for developing and implementing information technology projects for various CDC-funded programs, including BioSense, the National Electronic Disease Surveillance System (NEDSS), Health Alert Network (HAN), and others, which promote the use of data and information system standards to advance the development of efficient, integrated, and interoperable surveillance and communication systems at federal, state, and local levels (Yale Center for Public Health Preparedness, 2006; Centers for Disease Control and Prevention [CDC], n.d.).

Communication and information sharing, with staff in the healthcare facility, public health officials, emergency responders, and other healthcare institutions, is critical in a disaster. Integrated surveillance systems assist in data reporting and information sharing, as well as performing several other functions. An integrated system in New York, Health Emergency Response Data System (HERDS), has been used in regional and local drills and exercises, in ongoing surveillance and event detection, statewide asset and capacity inventory, and in actual health events. Specifically, this data system has been utilized to:

- Improve usability of the system in drills.
- Test planning and response activities for SNS activation, influenza outbreak, U.S. Postal Service Biohazard Detection System alerts, hypothetical subway bombings, and a SARS outbreak scenario in full-scale exercises.
- Collect and maintain statewide inventories of healthcare staff, assets, and capacities, which are periodically updated and audited.
- Provide advance preparedness for hospital resource planning and event patient management.
- Continually survey bed and equipment availability, blood supply, Emergency Department traffic and symptoms, and hospitalizations, particularly during flu season.

In actual events, this system has enabled detection and response for staff and health resource shortages; response to elevated national threat levels and imminent and actual natural disasters; and identification of, communication with and deployment of medical volunteers. HERDS is a collaboration effort between the healthcare community, local health departments, and response partners resulting from information sharing gaps that emerged during the World Trade Center attacks in September 2001 (Gotham et al, 2007).

Another integrated surveillance and communication system was piloted by the City of Milwaukee Health Department during a time period that coincided with several events expected to attract 1.2 million visitors. The Public Health Dashboard, which linked 13 hospital Emergency Departments (EDs) with local public health agencies, used existing, secure regional Internet infrastructure to gather voluntary and active syndromic cases reported by EDs, clinical laboratory reports of communicable disease, sentinel physicians' offices, hospital emergency room diversions, ambulance runs, medical examiner reports of unusual / suspicious deaths, poison control and nursing hotline call volumes, and pharmacy over-the-counter sales. This information, collected primarily by electronic means, was collated and reviewed by the Milwaukee Health Department's epidemiology unit for unusual trends and then aggregated into the "surveillance dashboard." Baselines were established that would trigger further investigation at a threshold of 2 standard deviations above baseline. Communications regarding potential mass casualty events were piloted during the project period using the Website. E-mail and text pager alerts related to extreme heat conditions and the region's first 2002 occurrence of avian West Nile Virus were sent to and received by all participating EDs. Potential benefits of an early warning surveillance/communication system include both managed healthcare capacity and more effective response in the community. Efficiencies in patient management could result from early alert messaging of a community threat leading to substantial subsequent cost reduction associated with advanced preparation, predetermined therapy, and predefined treatment (Foldy et al, 2004).

Satellites for Epidemiology (SAFE) is an early health warning system that incorporates satellite, radio, wireless networks, Geographic Information Systems (GIS), integrated technology, and data mining to promptly identify and respond to a disease outbreak. The SAFE technology is composed of a pre-hospital mobile coordination center and has the ability to analyze biological samples, monitor resources, and simulate the development of an incident using GIS. SAFE also utilizes electronic health record systems and data mining techniques to provide early health alerts, provide a foundation for evidence-based medical decision-making, support collaboration for second opinions on simulation cases, and utilize video conferencing for coordination of mobile teams (Chronaki et al, 2007).

Communication and Information Sharing

Information technology assists in communication and information sharing prior to, during and after disasters. Communication prior to an emergency may entail using technology systems to raise awareness and provide information to patients and the community. It may also involve communicating with staff and others with emergency response roles, so that they understand their responsibilities and make necessary preparations to ensure readiness. Communication during emergencies includes communication between responders, with appropriate agencies and partners, and with the public. Information sharing might include providing instruction to the public or reporting vital information from the disaster site to healthcare facilities. Post-disaster communication is necessary to assist healthcare organizations, public agencies and other businesses in returning to operations as quickly as possible.

Informatics improves the speed and quality of information shared between partners. It is particularly important to connect field responders to hospitals and healthcare providers (Weiner & Trangenstein, 2007). In a U.S. federal government report identifying existing communication systems, only eight of twenty-six systems were designed for communication among pubic health officials at the local, State and Federal levels. No single system was found that effectively linked members of the public health community at national, State and local levels, although efforts are ongoing to integrate communication of public health information both horizontally and vertically within the U.S. public health system. Five systems were designed for the automated communication of information from hospital-based electronic medical records to clinicians and three systems facilitated communication between emergency departments and first-line emergency response personnel (AHRQ, 2002; Bravata, 2004). Examples of existing communication systems include:

- Maryland's communication network, *Trauma Line*, which enables pre-hospital field care providers to communicate directly with physicians in trauma centers and other referral centers.
- *MobiDoc*, an entirely mobile telecommunication system using wireless technology, which allows teams to perform multiple charting, vital sign monitoring, image collection, and other data acquisition tasks for multiple patients. Data are sent securely to the hospital's intranet and allow for more efficient care and use of limited resources.
- Bar code system technology, developed in St. Louis, to log and track victims of a mass casualty incident and enable family members to locate victims more easily. This system also allows medics to log patients and their belongings using Personal Digital Assistants (PDAs) (Weiner & Trangenstein, 2007).

A RAND report found that communication failures during Hurricane Katrina were due more to "a lack of coordination between the relevant parties…" and not so much to "technical failure on the part of the communications infrastructure" (Ringel et al, 2007, p. v). Technology should be used as a centralized method to share resources, connect local jurisdictions with state and federal officials to request supply needs and inventory, determine if needs were met, by whom and how long it took to deliver (Weiner & Trangenstein, 2007). Information technology also enables secure communication methods with the media by providing interface to the public-at-large and ensuring that information is accurate, timely, and from the designated authority (Weiner & Trangenstein, 2007).

Volunteers

According to testimony given to the United States Congress, U.S. Senate Subcommittee on Bioterrorism and Public Health Preparedness on April 5, 2006, "planning for a medical response to mass casualties remains the most neglected component of public health preparedness and homeland security." Recruiting, training and organizing volunteers to work in their own localities and states should be a top priority (Roundtable on All Hazards Medical Preparedness and Response, 2006). Healthcare volunteers are a necessary component of disaster and emergency response, but they also create challenges. While technology may help solve issues related to registration and credentialing, political and liability issues still exist (Weiner & Trangenstein, 2007).

Technology and databases are being utilized for healthcare volunteer registration and credentialing. The Emergency System for Advance Registration of Volunteer Health Professionals (ESAR-VHP) System is an electronic database of healthcare volunteers that are able to provide assistance in an emergency. "An ESAR-VHP System must 1) register health volunteers, 2) apply emergency credentialing standards to registered volunteers, and 3) allow for the verification of the identity, credentials, and qualifications of registered volunteers in an emergency" (Health Resources and Services Administration [HRSA], 2005, p. 13). This registry aims to discourage and restrict spontaneous volunteers that may not be prepared for a successful response effort (Weiner & Trangenstein, 2007).

Electronic Health Records

According to Brown et al (2007, p. S136), benefits of electronic health records include "improved access, formatting, legibility, and organization of patient data," as well as "timely decision making, improved communication and coordination of care, cost control, public health surveillance, population health planning and clerical task reduction." Electronic health records also aid residents that are forced to evacuate in disasters that leave important documents, such as health records, behind and are unable to locate or reach their primary care provider. Electronic health record systems grant public health and healthcare providers access to patient medical, prescription and immunization records. In the case of Hurricane Katrina, paper medical records faired poorly against the water and mold, and few healthcare providers remained in or returned to the area to retrieve records (Choi, 2006).

In New Orleans alone, tens of thousands of evacuees required immediate medical care and over 200,000 had chronic conditions that required ongoing management (Brown et al, 2007). While problems, such as ownership of records and interoperability of systems, exist, these systems have been used post-disaster with some success. After Hurricane Katrina, an online service for authorized health professionals, www.Katrinahealth.org, was created to provide access to evacuees' medical history and medication information in order to renew prescriptions, prescribe new medication, and coordinate care. The database was a compilation of government and commercial sources including community pharmacies, government health insurance programs, such as Medicaid, private insurers, and pharmacy benefits managers in affected states (Weiner & Trangenstein, 2007).

Due to the Department of Veterans Affairs ongoing efforts to "maintain appropriate and un-interrupted care" through nationally accessible, standardized, comprehensive electronic health records, the experience of VA patients and providers was entirely different than other evacuees (Brown et al, 2007, p. S137). Existing health records, which included patient demographic data, inpatient and outpatient medications, visits and diagnoses, laboratory results and vital signs, were made available through a national call center, a web-based interface, and by rehosting the New Orleans data systems to a physical computer system in Houston, Texas. After Hurricane Katrina, records were accessed for thirty-eight percent of New Orleans VA patients or a total of 14,941 (Brown et al, 2007).

Information systems were also utilized for immunizations after Hurricane Katrina to make these records available to healthcare providers for hurricane evacuees. Use of immunization records provided benefits to patients, parents, and immunization providers and saved money and the inconvenience of revaccinating displaced children. According to estimates, electronic records were located for 18,900 to 21,000 children and provided an estimated cost savings of $3.04 million to $4.6 million in revaccination expenses (Boom, Dragsbaek & Nelson, 2007; Urquhart, Williams, Tobias & Welch, 2007).

After Hurricane Katrina, the Markle Foundation, an information and communication technologies firm, convened experts to improve the use of electronic health records in disasters. They identified the following needs:

- Foster immediate discussions regionally and nationally among government health leaders, insurers, healthcare providers, and information technology companies to determine what, how, and when patient medical information can be shared securely and quickly in the event of a disaster.
- Create electronic health information systems that are based on simple, open web standards, so that data can be provided in different formats from different users and still be accessible to all.
- Agree upon a method to authenticate the identities of doctors, pharmacists, other health professionals, and patients using the web site, so that they can quickly and securely access private health information needed for their ongoing treatment.
- Make electronic health information records accessible to nurse practitioners, physician assistants, and nurses who will likely be working with physicians and clinics in a disaster's aftermath, rather than just by physicians.
- Examine federal and state public policies governing privacy and medical records-such as the Health Insurance Portability and Accountability Act of 1996 and existing state privacy laws-to be sure they do not hinder the delivery of medical care for displaced persons post-disaster (Weiner & Trangenstein, 2007).

Modeling and Simulation Programs

When a disaster occurs, local jurisdictions may go unaided for up to 72 hours. Modeling programs, using existing technology, databases, and software, help decision-makers forecast and plan local response efforts, make informed decisions, and utilize training tools. Modeling programs provide information through situational analysis, spatial modeling, and disaster mapping, and simulate disasters by evaluating the history of disasters, risks and vulnerabilities in communities, and associated health effects (Mathew, 2005). Modeling programs aid community leaders in making decisions regarding priorities, resources, and next steps, developing and implementing policy, and making more efficient decisions to decrease time and save lives (Weiner & Trangenstein, 2007).

Similar to modeling programs, companies and institutions like Sandia National Laboratories, Noblis, and the University of Illinois School of

Public Health Center for the Advancement of Distance Education are creating video games to simulate health-related emergencies and biological, chemical, radiological and natural disasters. According to Breslin, McGowan, Pecheux, and Sudol (2007):

> *Although healthcare delivery is often divided into organizational silos–ambulatory care, acute care hospitals, emergency rooms, critical care, post-acute care, public health services, etc.–the need to plan, train and prepare for new situations that require the coordinated interactions of many healthcare organizations grows every day. These needs are even greater when looking outside the modes of delivery to include other areas of the healthcare continuum such as prevention and disaster response. (para. 4)*

These video games are designed to cross-train healthcare workers, public health and emergency response personnel, decision-makers, volunteers, and others in multiple responder tasks and roles, as well as assist in collaborative preparedness planning and asses the effectiveness of alternate response strategies (Sandia National Laboratories, 2007; Christopher, 2005; Breslin, McGowan, Pecheux, & Sudol, 2007).

Telehealth Applications

As technology has improved, opportunities for telehealth application have increased and expanded. In the event of a disaster, telehealth technology provides disaster-site expertise and support; remote management of trauma patients for remote guidance of procedures; specialty consults and information services to remote areas in a more effective and timely manner; and distance learning and continuing education for community health providers and other responders who are located away from urban training centers or not able to leave their community due to staffing shortages (Weiner & Trangenstein, 2007; Mathew, 2005). Telehealth applications depend on having an existing infrastructure that may be unreliable or even destroyed in a disaster (Weiner & Trangenstein, 2007).

Continuity of Operations

A special report in the Journal of Homeland Defense addresses the importance of technology for continuing workplace operations in the event of a pandemic or other major disaster. “Access to communications, applications, data and even other people” will allow employees to work from home or designated government centers and provide means to coordinate and communicate with a mobile or remote workforce. Utilizing technology to continue operations supports sustainable programs and processes if the workplace closes down due to fires, hurricanes, and power outages or when employees cannot or should not come into the office because of a flu pandemic, transit strike, or blizzard (Philpott, 2007, p. 2).

Telecommuting, or teleworking, is vital to the continuity of operations because the ability to communicate and exchange information in a disaster is critical. According to Philpott (2007), “a telework program creates an emergency communications system during a crisis and a resource to keep key employees engaged and in touch during an emergency. It also enables employees to remain close to their family during a crisis, reduces reliance on transportation and other infrastructure which may be seriously overstretched during an emergency, and it provides the basis for a speedier path to resumption of normal operations (p. 2).” However, systems have to be in place to allow staff to train and exercise before they have to respond to an actual crisis. Further, many of the critical resources necessary to provide continuous patient care, such as MRI, telecommunications, electrical systems, databases, data encryption, server virtualization and disk-to-disk backup, are technology dependent (Rozek & Groth, 2008).

Education and Training

Internet technology develops knowledge bases, decision support systems, and expert systems to provide necessary information and data to responders and decision-makers, who can then evaluate and analyze options and rapidly make appropriate decisions for disaster management (Mathew, 2005). Technology prepares healthcare provider and other responders through competency-based education, training and exercises. In 2001, the Agency for Healthcare Research and Quality released the report, *Training of Clinicians for Public Health Events Relevant to Bioterrorism Preparedness*. This report found that satellite conferences improved knowledge, enhanced print-based materials and appeared to be as effective as classroom training (Agency for Healthcare Research and Quality [AHRQ], 2001). In the past years, U.S. Centers for Disease Control and Prevention (CDC) -funded Centers for Public Health Preparedness (CPHP) have taken a lead in training multiple disciplines in an all-hazards response. Primarily located at Schools of Public Health, CPHPs "are a national network of academic institutions working in collaboration with state and local public health departments and other community partners to provide life-long learning opportunities to the public health workforce, in order to handle the next public health crisis" (ASPH, n.d.).

The New York eClinician Project provided Personal Digital Assistants (PDAs) and wireless internet to clinicians working in Community Health Centers to:

> *1) Increase awareness and encourage adoption of information technology among providers in Community Health Center by providing PDAs as first line strategy towards achieving this goal, 2) enhance access to information on emergency preparedness, 3) improve patient outcomes by providing PDA-based clinical decision-support tool, 4) encourage chronic care management and health promotion/disease prevention activities, and 5) increase productivity and efficiency. (Adusumilli et al, 2006, p. 839)*

Other IT systems, such as one developed and implemented at the Marburg University Medical Center in Germany, have been used to improve clinician compliance and performance through computer-based decision support, reminder systems, guidelines to reduce undesirable practice variability, and patient-specific advice at the time and place of consultation (Blaser et al, 2005; Lenz et al, 2006; Blaser et al, 2007). These systems, which improve quality of care and reduce costs, could also provide guidance and assess and improve capabilities, compliance, and performance by clinicians and other responders in disasters.

USING TECHNOLOGY TO TRAIN AND INTEGRATE HEALTHCARE STAFF INTO THE BROADER COMMUNITY PLANNING AND RESPONSE

One technology application for the healthcare population previously mentioned is education and training. It is essential to train and prepare healthcare staff for their roles and responsibilities in delivering critical services during a disaster. As technology has improved and expanded, it has increasingly been used to educate clinicians and improve clinical performance, efficiency and decision-making (AHRQ, 2001; Mathew, 2005; Adusumilli et al, 2006; Blaser et al, 2005; Lenzet et al, 2006; Blaser et al, 2007).

Training healthcare staff increases their capacity to respond to an emergency within the hospital walls, but it does not facilitate an integrated, community-wide response. Existing technological infrastructure can incorporate multiple disciplines into emergency preparedness planning and response through integrated systems and collectively increase knowledge, skills and abilities to prevent disasters from occurring, protect the public, and respond to and recover from disasters. Multidisciplinary collaboration provides an opportunity for healthcare organizations and other partners to share resources, learn from one another, leverage best practices, and combine forces to achieve together what they could not do alone (PricewaterhouseCooper's Health Research Institute, 2007). To announce the 2007 report, *Improving Health System Preparedness for Terrorism and Mass Casualty Events*, published jointly by the American Medical Association (AMA) and the American Public Health Association (APHA), Georges Benjamin, MD, FACP, FACEP(E), Executive Director of the APHA, said:

> *For too long public health and medicine have responded to emergencies in separate silos. Today's report represents our attempt to bridge the gap so that our health care and public health systems are fully integrated and interoperable in ways that allow for a rapid and efficient disaster response. (American Medical Association [AMA], 2007, para. 3)*

The Health Center Emergency Preparedness Guide, *Working With Your Community: Preparing for Emergency Response,* emphasizes the necessity for healthcare organizations to convene community stakeholder, establish good working relationships, be aware of available resources, develop and practice a comprehensive community-wide emergency response plan in advance of an emergency, and effectively mobilize resources when a disaster takes place (Community Health Care Association of New York State, n.d.).

Local healthcare providers are essential in detecting the first signs of an outbreak and are key resources for responding to a potential outbreak event. These providers need better linkages to the public health infrastructure, including local health departments, State laboratories, and emergency departments. Strengthening these ties to public health is important as well as enhancing and reinforcing information technology connectivity between the health care system and the public health infrastructure (Agency for Healthcare Research and Quality [AHRQ], 2005b). Coordinated and integrated planning efforts involve both vertical and horizontal coordination and integration, with private healthcare practitioners, local clinics and hospitals, larger health systems, and regional, state and federal agencies and associations working together, as well as local healthcare providers and organizations working with the multiple stakeholders at the local level, including government, emergency management, public health, law enforcement, other first responders, and mental health personnel. Thus, in addition to training, technology can be used to incorporate healthcare organizations and providers into the broader, integrated community planning and response processes to assist local community stakeholders in all phases of emergency management.

AN APPLIED TRAINING AND INTEGRATION MODEL

Recognizing the need to prepare the broader workforce of responders to plan and respond to the consequences of public health emergencies, the Texas A&M Health Science Center School of Rural Public Health (SRPH) launched a self-supporting, continuing education initiative in March 2003, designed to offer training to individuals throughout Texas with responsibility for emergency planning, preparedness, and response. The Texas Training Initiative for Emergency Response (T-TIER), developed using the U.S. Centers for Disease Control and Prevention-identified competencies by focus area, is a three-module training initiative that builds upon the knowledge, skills, and abilities that participants acquire in each preceding module. To address the need to change the traditional emergency response model, T-TIER assembles a broader audience of public health, healthcare, emergency management, and other professionals responsible for emergency planning and response. Within this collaborative environment, participants exercise and roleplay their own job roles, as well as the roles of other key stakeholders within their local jurisdictions, thus ensuring a more effective multidisciplinary response. Due to national attention and the need for this type of training initiative beyond Texas, T-TIER was expanded nationally into USA-TIER and offered in other primarily rural states and rural sections of the country. USA-TIER fosters the integration and collaboration of key disciplines and organizations, including healthcare institutions, and enhances the multiple roles and skills needed to increase the capacity and effectiveness of local planning and response to bioterrorism, emerging health threats, or other public health emergencies (Quiram, Carpender, & Pennel, 2005).

To increase efficacy, USA-TIER uses multiple training methodologies and modalities, including live presentations, hands-on practical activities, tabletop exercises, satellite broadcasts and archived video streaming, CD-ROM tool-kits, and a combination of interactive video-conferencing, connecting multiple sites with on-site professional support. This unique, multidisciplinary approach enhances respect and collaboration among the various disciplines, limiting unilateral emergency preparedness planning and response at the national, state, and local levels. The final section of the chapter describes the four elements of this initiative: Rural Preparedness Roundtables, Module I (Didactic Training), Module II (Tabletop Exercise), and Module III (Technical Assistance Team Visits). It will further examine USA-TIER as a model for clinician training and integration and explain the uses of technology in its application to healthcare and the broader community.

Rural Preparedness Roundtables

The mission of the SRPH is to improve the health of communities, with emphasis on rural and underserved populations, through education, research, service, outreach and creative partnerships. Although applicable to urban, rural and suburban areas, USA-TIER, in practice, has a particular emphasis on primarily rural states and rural sections of the country. According to Dobalian, Tsao, Putzer, and Menendez (2007), there is a need to assess resources and response mechanisms in rural and neighboring urban communities to meet anticipated post-event health needs. Rural Preparedness Roundtables (RPR) are a strategy that have proven effective in engaging a target audience in a rural community or communities; identifying local strengths and resources, existing relationships and gaps within the current system; distinguishing the broader, non-traditional rural public health system and additional stakeholders; identifying and educating local decision makers; and working together to address a specific rural health issue. This strategy has been used successfully in a number of venues to elicit a wide variety of outcomes including improving local emergency preparedness and bioterrorism planning; developing networks of interested health professionals working in the HIV/AIDS arena; initiating local infrastructure building processes; facilitating dialog to identify local resources and access issues; and identifying coalition building, obesity prevention and rural disaster planning best practices and success stories (Pennel, Carpender, & Quiram, 2008).

The purpose of the RPR is to engage local stakeholders in a face-to-face discussion about a particular public health issue. This informal, facilitated discussion endeavors to create a local network between the participants, facilitate a broader and more inclusive dialogue, enhance communications to evolve the local network that will continue once the facilitating organization leaves and empower local groups to take ownership, plan and problem solve with existing assets. The Roundtable focuses upon relationship building and serves as a catalyst for rural communities to work together to initiate and make changes based on the issues discussed and the assets available (Pennel, Carpender, & Quiram, 2008).

With a concentration on rural communities, which frequently lack the strong technology infrastructure found in urban areas, fostering these linkages during the planning process is integral. A tool that has provided personal connections between stakeholders, when face-to-face discussions are not feasible, is an internet-based message board. When using Distance Education (DE) modalities, the message board serves as a means for participants to ask questions, obtain information, resources, or technical assistance, communicate with experts, communicate with one another, and share issues and proposed solutions.

Module I: Didactic Training

The objectives for Module I address competencies that parallel the Critical Capacities and Critical Benchmarks for Focus Areas in the CDC Continuation Guidance for Cooperative Agreement on Public Health Preparedness and Response for Bioterrorism. While there is flexibility depending on the needs of the audience, Module I is typically a 4 ½ -day training module. The curriculum for this module consists of didactic classroom activities and interactive training components. Guest speakers with real-world expertise conduct presentations in core areas of emergency planning and response. These presentations typically include Historical Preparedness Perspective; The Threat Factor and a Viable Response; Biological Agents; Infectious Disease Control Practices; Chemical Agents; Agroterrorism; Communication and Information Technology; Disaster Preparedness in Hospitals and Clinics; Strategic National Stockpile; Syndromic Surveillance; Epidemiology/Outbreak Investigation; National and International Perspectives on Preparedness; Risk Communication and Information Dissemination; Law Enforcement and Public Health: Federal Bureau of Investigation Perspective; Department of Emergency Management Structure; and Incident Command System/National Incident Management System.

Module I participants actively take part in lectures, discussions, team projects, and role-playing scenarios. Participants benefit from practicing their work-related roles, as well as having the opportunity to assume the roles of other key stakeholders with responsibility at the local, regional, or state level. In addition, they profit from shared experiences and lessons learned from colleagues in jurisdictions from across the state. A culminating tabletop experience, led in partnership with the National Emergency Response and Rescue Training Center, allows demonstration of knowledge, skills, and abilities through participation in a simulated emergency response situation that considers multidisciplinary approaches to planning and preparedness. Certificates of USA-TIER completion are awarded, in addition to 36 contact hours or 3.6 hours of Continuing Education Units, upon successful completion of this module. Much of the didactic classroom work for this program has been converted to a significantly web-based training to support broader participation throughout the United States.

Module II: Tabletop Exercise

Module II consists of components that address those competencies related to education and training (Focus Area G in the CDC Continuation Guidance): the design, implementation, and evaluation of disaster training activities and an integrated, 1-day functional exercise in a training center facility that requires participants to apply and demonstrate the knowledge and skills acquired within a structured, role-playing scenario. While there is flexibility depending on the needs of the audience, Module II is typically presented over a 2 ½-day period. Participation in Module I, or a training equivalent, is required prior to undertaking this module. Certificates of completion are awarded, in addition to 20 contact hours or 2.0 hours of Continuing Education Units, upon successful completion of this module. Module II exercises are frequently provided through a combination of interactive technologies, such as video-conferencing, telephone, and fax machine, connecting multiple sites with on-site professional support.

Module III: Technical Assistance Team

Module III are designed to make available Technical Assistance Team visits to geographically dispersed sites to observe and provide specific assistance to local officials who have attended Modules I and II of USA-TIER. This module consists of a 2-day, on-site visit, staffed by professionals with expertise in areas specified by the jurisdiction. The teams travel to regional and community public health headquarters or other locations within a jurisdiction to meet in groups with USA-TIER participants, as well as other local stakeholders. At these meetings, the Technical Assistance Team is prepared to review and provide technical advice on plans for (and possibly observe) local/regional response exercises. If requested, these site visits can also be conducted via teleconference technology. Whether by site visit or by teleconference, the Technical Assistance Team provides participants with a wide range of technical assistance related to emergency preparedness planning and response to public health emergencies.

CONCLUSION

Information technology and data systems are vital components to disaster preparedness and response. As technology advances, its utilization in disasters will expand exponentially. Current uses include disease tracking, detection, diagnosis and reporting; communication and information sharing; volunteers; electronic health records; modeling; telehealth; continuity of operations; and education and training. Technology also helps integrate the many stakeholders and disciplines at the local, regional, state and national levels required to prepare for and respond to disasters. The Texas A&M Health Science Center School of Rural Public Health has implemented such a training and exercise initiative in several states through the Texas Training Initiative for Emergency Response (T-TIER) and USA-TIER to assemble and train the broader audience of public health, healthcare, emergency management, and other professionals and to ensure a more effective multidisciplinary response. This initiative has been adapted to various technology applications and continues to expand and investigate new, innovative methods to reach, train and fully integrate multiple disciplines into coordinated emergency planning and response efforts.

REFERENCES

Adusumilli, S. R., Tobin, J. N., Younge, R. G., Kendall, M., Kukafka, R., Khan, S., et al. (2006). The New York City e-clinician project: Using personal digital assistants and wireless Internet access to support emergency preparedness and enhance clinical care in community health centers. *American Medical Informatics Association Annual Symposium Proceedings*, 839.

Agency for Healthcare Research and Quality, U.S. Department of Health and Human Services. (2001). *Training of clinicians for public health events relevant to bioterrorism preparedness (AHRQ Publication No. 02-E007)*. Rockville, MD. Retrieved on October 25, 2007, from http://www.ahrq.gov/clinic/epcsums/biotrsum.htm

Agency for Healthcare Research and Quality, U.S. Department of Health and Human Services. (2002). *Bioterrorism preparedness and response: Use of information technologies and decision support systems (AHRQ Publication Number 02-E061)*. Rockville, MD. Retrieved on October 25, 2007, from http://www.ahrq.gov/clinic/epcsums/bioitsum.htm

Agency for Healthcare Research and Quality, U.S. Department of Health and Human Services. (2005a). *The role of information technology and surveillance systems in bioterrorism readiness, bioterrorism, and health system preparedness* (Issue Brief 5). Rockville, MD. Retrieved on October 25, 2007, from http://www.ahrq.gov/news/ulp/btbriefs/btbrief5.pdf

Agency for Healthcare Research and Quality, U.S. Department of Health and Human Services. (2005b). *Bioterrorism and other public health emergencies: Linkages with community providers. Bioterrorism and health system preparedness* (Issue Brief 6). Rockville, MD. Retrieved on October 25, 2007, from http://www.ahrq.gov/news/ulp/btbriefs/btbrief6.pdf

American Medical Association. (2007). *Coalition of 18 health organizations releases recommendations for improved disaster response*. Retrieved onNovember 15, 2007, from http://www.ama-assn.org/ama/pub/category/17836.html

Association of School of Public Health. *Centers for public health preparedness*. Retrieved on January 9, 2008, from http://preparedness.asph.org/home.cfm

Blaser, R., Schnabel, M., Biber, C., Bäumlein, M., Heger, O., & Beyer, M. (2007). Improving pathway compliance and clinician performance by using information technology. *International Journal of Medical Informatics*, *76*(2-3), 151–156. doi:10.1016/j.ijmedinf.2006.07.006

Blaser, R., Schnabel, M., Heger, O., Opitz, E., Lenz, R., & Kuhn, K. A. (2005). Improving pathway compliance and clinician performance by using information technology. *Studies in Health Technology and Informatics*, *116*, 199–204.

Boom, J. A., Dragsbaek, A. C., & Nelson, C. S. (2007). The success of an immunization information system in the wake of Hurricane Katrina. *Pediatrics*, *199*(6), 1213–1217. doi:10.1542/peds.2006-3251

Bravata, D. M., McDonald, K. M., Smith, W. M., Rydzak, C., Szeto, H., & Buckeridge, D. L. (2004). Systematic review: Surveillance systems for early detection of bioterrorism-related diseases. *Annals of Internal Medicine*, *140*(11), 910–922.

Breslin, P., McGowan, C., Pecheux, B., & Sudol, R. (2007, October). Serious gaming. *Health Management Technology*. Retrieved on June 6, 2008, from http://www.healthmgttech.com/features/2007_october/1007disaster_gaming.aspx

Brown, S. H., Fischetti, L. F., Graham, G., Bates, J., Lancaster, A. E., McDaniel, D., et al. (2007). Use of electronic health records in disaster response: The experience of Department of Veterans Affairs after Hurricane Katrina. *American Journal of Public Health, 97*(Suppl. 1), S136-S141. Centers for Disease Control and Prevention, U.S. Department of Health and Human Services. *Emergency preparedness and response: Surveillance*. Retrieved on January 7, 2008, from http://www.bt.cdc.gov/episurv/

Choi, E. (2006). Disaster relief informatics: Access to KatrinaHealth.org prescription data via OQO ultra mobile PC and cellular wireless connectivity. *American Medical Informatics Association Symposium Proceedings*, 888.

Christopher, A. (2005, December 12). Games tackle disaster training. *Wired.* Retrieved on June 6, 2008, from http://www.wired.com/science/discoveries/news/2005/12/69580

Chronaki, C. E., Berthier, A., Lleo, M. M., Esterle, L., Lenglet, A., & Simon, F. (2007). A satellite infrastructure for health early warning in post-disaster health management. *Medinfo*, *12*, 87–91.

Community Health Care Association of New York State. *Working with your community: Preparing for emergency response.* Retrieved on July 15, 2007, from http://www.chcanys.org/clientuploads/downloads/ep_misc/CHCANY-SEP_WorkingWithYourCommunity.pdf?PHPSESSID=75d7342be8cc5203509057bd4b0de6fd

Dobalian, A., Tsao, J. C. I., Putzer, G. J., & Menendez, S. M. (2007). Improving rural community preparedness for the chronic health consequences of bioterrorism and other public health emergencies. *Journal of Public Health Management and Practice*, *13*(5), 476–480.

Foldy, S. L., Biedrzycki, P. A., Baker, B. K., Swain, G. R., Howe, D. S., & Gieryn, D. (2004). The public health dashboard: A surveillance model for bioterrorism preparedness. *Journal of Public Health Management and Practice*, *10*(3), 234–241.

Gotham, I. J., Sottolano, D. L., Hennessy, M. E., Napoli, J. P., Dobkins, G., & Le, L. H. (2007). An integrated information system for all-hazards health preparedness and response: New York State Health Emergency Response Data System. *Journal of Public Health Management and Practice*, *13*(5), 486–496.

Health Resources and Services Administration, U.S. Department of Health and Human Services. (2005). *Emergency system for advance registration of volunteer health professionals (ESAR-VHP): Interim technical and policy guidelines, standards, and definitions, version 2.* Retrieved on December 14, 2007, from ftp://ftp.hrsa.gov/bioterror/ESAR-VHP_intermGuidelinesL20050614_final.pdf

Lenz, R., Blaser, R., Beyer, M., Heger, O., Biber, C., Baumlein, M., & Schnabel, M. (2006). IT support for clinical pathways–lessons learned. *Studies in Health Technology and Informatics*, *124*, 645–650.

Loonsk, J. W., McGarvey, S. R., Conn, L. A., & Johnson, J. (2006). The public health information network (PHIN) preparedness initiative. *Journal of the American Medical Informatics Association*, *13*(1), 1–4. doi:10.1197/jamia.M1815

Mathew, D. (2005). Information technology and public health management of disasters–a model for south Asian countries. *Prehospital and Disaster Medicine*, *20*(1), 54–60.

Nguyen, T. Q., Thorpe, L., Makki, H. A., & Mostashari, F. (2007). Benefits and barriers to electronic laboratory results reporting for notifiable diseases: The New York City Department of Health and Mental Hygiene experience. *American Journal of Public Health*, *97*(Suppl. 1), 142–145. doi:10.2105/AJPH.2006.098996

Pennel, C. L., Carpender, S. K., & Quiram, B. J. (2008). Rural health roundtables: A strategy for collaborative engagement in and between rural communities [Electronic version]. *Rural and Remote Health*, *8*(4), 1054.

Philpott, D. (2007). Telework and continuity of operations. *Homeland Defense Journal*. Retrieved on January 12, 2008, from http://www.homeland-defensejournal.com/hdl/SpecialReportArchive.asp

PricewaterhouseCooper's Health Research Institute. (2007). *Closing the seams: Developing an integrated approach to health system disaster preparedness.* Retrieved on January 10, 2008, from www.pwc.com/extweb/pwcpublications.nsf/docid/9CEC1E9BD3BCAC478525737F005C80A9

Quiram, B. J., Carpender, K., & Pennel, C. (2005). The Texas training initiative for emergency response (T-TIER): An effective learning strategy to prepare the broader audience of health professionals. *Journal of Public Health Management and Practice*, *11*(Suppl. 6), S83–S89.

Ringel, J. S., Chandra, A., Leuschner, K. J., Lim, Y., Lurie, N., Ricci, K. A., et al. (2007, February). *Lessons learned from the state and local public health response to Hurricane Katrina working paper.* Prepared for the U.S. Department of Health and Human Services Office of the Assistant Secretary for Preparedness and Response. WR-473-DHHS. http://www.rand.org/pubs/working_papers/2007/RAND_WR473.pdf

Roundtable on All Hazards Medical Preparedness and Response. 109th Cong., S. Hrg. 109-612, April 5, 2006. Congress of the United States, *U.S. Senate Subcommittee on Bioterrorism and Public Health Preparedness.* (Thomas Inglesby, MD, Deputy Director and COO, Center for Biosecurity of University of Pittsburgh Medical Center). Retrieved on November 15, 2007, from http://www.upmc-biosecurity.org/website/resources/hearings/content/Hearings_2006/20060405allhazardsmedprep.html

Rozek, P., & Groth, D. (2008, March). Business continuity planning. *Health Management Technology.* Retrieved on June 6, 2008, from http://www.healthmgttech.com/features/2008_march/0308_business_continuity.aspx

Sandia National Laboratories. (2007, August 28). Video games as disaster-training tools. *ScienceDaily*. Retrieved on June 6, 2008, from http://www.sciencedaily.com/releases/2007/08/070823175729.htm

Teich, J. M., Wagner, M. M., Mackenzie, C. F., & Schafer, K. O. (2002). The informatics response in disaster, terrorism, and war. *Journal of the American Medical Informatics Association*, *9*(2), 97–104. doi:10.1197/jamia.M1055

Trust for America's Health. (2007). *Ready or not? Protecting the public's health from disease, disasters, and bioterrorism*. Retrieved on January 13, 2008, from http://healthyamericans.org/reports/bioterror07/BioTerrorReport2007.pdf

Urquhart, G. A., Williams, W., Tobias, J., & Welch, F. J. (2007). Immunization information systems use during a public health emergency in the United States. *Journal of Public Health Management and Practice*, *13*(5), 481–485.

Weiner, E. E., & Trangenstein, P. A. (2007). Informatics solutions for emergency planning and response. *Medinfo*, *12*, 1164–1168.

Yale Center for Public Health Preparedness. (2006). *Preparedness glossary.* Retrieved on July 20, 2007, from http://publichealth.yale.edu/ycphp/Glossary.html#P

KEY TERMS AND DEFINITIONS

Continuity of Operations: Business planning that accounts for how quickly workplaces can recover from a disaster to quickly resume or restore operations or to continue or maintain work operations away from traditional worksites before, during or after a disaster.

Disaster Communication: Using multiple methods of sharing information with, as well as receiving information from hospital and healthcare staff, first responders, appropriate agencies and partners, media, public, and patients and their families before, during, and after a disaster.

Disaster Education and Training: Increasing knowledge, skills, and abilities to prepare healthcare, public health and first responder personnel to plan and respond to public health emergencies and other disasters.

Electronic Health Records: Documentation of patient health data in shared systems that can be utilized by healthcare and public health providers in disasters when paper records are lost, destroyed or otherwise unavailable.

Healthcare Volunteers: A necessary component of disaster response that will be needed to supplement the healthcare workforce.

Integration: Interdisciplinary training, planning, and exercising in preparation for and responding to disasters, both horizontally and vertically, within and outside of the healthcare system and at the local, state and national level.

Modeling: Electronic programs and tools that can aid decision-makers and other stakeholders in disaster forecasting, simulation, training and education, and planning.

Surveillance: The ongoing systematic collection, analysis, and dissemination of data about disease.

Telehealth: Utilizing an existing technological infrastructure to provide on-site disaster expertise and support; remote management of trauma patients; specialty consults and information services to remote areas; and distance learning and continuing education for community health providers and other responders who are located away from urban training centers or not able to leave their community due to staffing shortages.

This work was previously published in Handbook of Research on Information Technology Management and Clinical Data Administration in Healthcare, edited byA. Dwivedi, pp. 247-263, copyright 2009 by Medical Information Science Reference (an imprint of IGI Global).

Section VI
Managerial Impact

This section presents contemporary coverage of the managerial implications of health information systems. Particular contributions address the implantation of an enterprise system in a healthcare network and applications of a case management software system in non-profit organization. The managerial research provided in this section allows executives, practitioners, and researchers to gain a better sense of how health information systems can inform their practices and behavior.

Chapter 6.1

A Process Architecture Approach to Manage Health Process Reforms

Christine Stephenson
Emirates Airlines, Dubai, UAE

Wasana Bandara
Queensland University of Technology, Brisbane, Australia

ABSTRACT

Business Process Management (BPM) is often perceived as a top priority concern in organisations; both in public and private sectors. This has been clearly noticed in the Australian health care sector, evidenced by the Australian Government's commitment to pursuing a reform agenda that reflects a new approach to improving health and aged care services. The adoption of a business process management approach can be a key tool to facilitate health reform in the public and private sectors. This approach provides a structured and hence rigorous approach to ensure that health processes are reviewed, improved and implemented consistently throughout the organisation, especially where public health services are provided from multiple service points. Process modeling is an embedded component of most BPM initiatives, yet a resource intensive task. How process models can be derived efficiently (i.e. with less resources and time) and effectively (at a high quality to meet the specific needs) is an integral element of interest to most organisations, however, this area of research is still in its infancy. This paper aims to address this gap by proposing a 'process-pattern' based approach to process modeling where models are created and managed within a 'process architecture'. The process pattern approach is explained with evidence from a large state based health organisation using an integrated risk management process for health care service management as an example. The study employed an action research approach and the chapter unfolds its findings around the main phases of the research method. The contributions from this work are two-fold. From the perspective of practice, it offers a validated high level example of a process pattern for an Integrated Risk Management Program for health. From an academic perspective: it presents a validated Risk Management process pattern for

DOI: 10.4018/978-1-60566-030-1.ch018

delivering health services which can be used as or a benchmark in further research.

INTRODUCTION

Australia's growing health demands are creating new challenges for governments at the national, state, territory and local levels (Minister of Ageing, 2008). The Australian Federal Health Department intends to spend $51.8 Billion dollars on National Health initiatives in 2008-2009 through the National Health and Hospitals Reform Plan. The aim is to improve the capacity of the states and territories to deliver health services when and where the citizens (in particular, working families) need them. The current Australian Health Care Agreements will be extended for 12 months with an extra $1 billion in provided funding. New agreements will be finalised by the end of 2007, with opportunities for major reform (Department of Health and Ageing, 2007). One of the major challenges to implement the intended reforms relates to how Hospitals are currently organized using logical groupings (functions) of clinical specialties instead of being grouped according to process groupings. Taking a process-oriented approach to improving processes can be challenging as these processes need to cross the traditional functional boundaries in order to realize process efficiencies (Vera, A. & Kuntz, L. 2007).

The adoption of a Business Process Management (BPM) approach can be a key tool to facilitate health reform in the public and private sectors. Business Process Management (BPM) provides a structured and consequently a rigorous approach to ensure that health processes are reviewed, improved and implemented consistently throughout the organisation, especially where public health services are provided from multiple service points.

BPM in general, includes methods, techniques, and tools to support the design, enactment, management and analysis of business processes (van der Aalst et al., 2003). One of the key concerns and challenges when applying BPM is the lack of accepted methodologies, and resources to guide these initiatives (Larsen and Myers, 1998; Murphy and Staples 1998; Amoroso, 1998; Indulska et al., 2006). A common BPM methodology that can be utilised and catered for all specific contexts is yet to be derived; and may not be feasible due to the complexities that each individual context brings in. However, a common aspect of all BPM approaches is the orientation towards understanding the current-processes and aim towards an improved better-process. Business process articulation in the form of high-level and detailed process models is a common component of most process improvement projects (Indulska et al., 2006; Bandara 2005). Process Modeling provides a structured and consequently a rigorous approach to ensure that all required aspects of processes are reviewed, improved and implemented consistently. However, detailed process modeling can be an expensive exercise (Becker et al, 2003), and also complex in terms of managing all the different types and levels of processes (and their models), their relationships and interdependencies. While Process Architectures are highly recommended for this (Davis and Bradander, 2007), there is a dearth of examples and information on how to implement such an approach. Addressing this gap is the main aim of this chapter.

In this chapter, we propose a Process Architecture approach where Process Patterns are used at different levels to capture and deploy s for health processes. A risk management process in the health arena is selected to demonstrate the design and application of the proposed Process Architecture concept. This research combines diverse concepts in the area of risk management, business process analysis and health treatments services. The remainder of the chapter commences by first briefly introducing these concepts. The chapter then introduces the Organisation in which this research was designed and implemented at. The paper then proceeds to provide a detailed example which demonstrates how a Process Architecture is designed and implemented (by using process patterns). The details are presented in the form of empirical evidence gathered through an action research approach Finally, the chapter concludes with a discussion of the limitations, of this work as well as a preview of future activities.

INTRODUCING KEY CONCEPTS

This section is dedicated to describing the many terms and concepts used later in the chapter during the overall research process and findings discussions that are followed.

The term 'best practice' is used to describe the process of developing and following a standard way of doing things that can be used (i.e. for management, policy, and especially software systems development) multiple times. Even though the term 'best practice' has now become a buzz word within organizations, it is not a new notion. For example, Frederick Taylor (1911) stated that *"Among the various methods and implements used in each element of each trade there is always one method and one implement which is quicker and better than any of the rest*" (Taylor, 1911). Best practice is ideally, defining ways that can be used to get things done based on past experience. Organizations benefit by adapting these, as they assure quality results and consistency when the process is followed. Today, 'best practices' are documented in various forms, such as in reference models and information libraries (i.e. SCOR, ITIL, PMBOK, ETOM etc) and are accepted more as 'better-practice' that can assist organizations to define, design, implement and monitor business process improvement initiatives. These documented s often use graphical models to illustrate the methods to follow.

Process Modeling

Process modeling is an approach for visually depicting how businesses conduct their operations by defining the entities, activities, enablers and further relationships along control flows (Curtis et al., 1988; Gill, 1999). It is widely used to increase awareness and knowledge of business processes, and to deconstruct organizational complexity (Davenport, 1993; Hammer and Champy 1993; Smith and Fingar 2003). The visualization of business processes in the form of process models has increased in popularity and importance (Bandara et al., 2005). Process modeling is an embedded component of most BPM initiatives, yet a resource intensive task (Becker et al., 2003). "*The importance of business processes has been amplified by being in the centre of late technological inputs in the form of ERP and workflow systems that aim at increasing productivity and functional interconnectivity by automating internal and external transactions*" (Adamides and Karacapilidis, 2006). Thus, how process models can be derived efficiently (i.e. with less resources and time) and effectively (at a high quality to meet the specific needs) is an integral element of interest to most organisations. This area of research is still in its infancy, with only a few studies conducted on critical success factors of process modeling (e.g. Bandara et al, 2005). Even these, (while they depict what the critical success factors are with empirical evidence) do not provide procedural guidelines on how to achieve these success factors, to improve the efficiency and effectiveness of process modeling initiatives.

Process Pattern

A pattern in general is "*an abstraction from a concrete form which keeps recurring in specific non-arbitary contexts*" (Riehle and Zullighoven, 1995). Patterns have been usefully applied across different disciplines in the past. Alexander et al., (1977) describes how patterns can be used for building architectural designs. Patterns have been widely applied in the Software development arena since the "Gang of Four" (GoF) patterns were introduced by Gamma et al., (1995), they have also been widely applied in the workflow management arena[1]. Recent research (i.e. Van der Aalst et al, 2003) has proposed the use of patterns for the description and evaluation of workflow management technologies. Forster (2006) describes potential business process improvement options across different layers of an organisation using a pattern approach. Literature predicts the high proliferation of patterns within the BPM arena (Harmon, 2003).

The basic benefit of a pattern is that the fundamental elements can be reused and hence better knowledge management, efficiency and effectiveness reached, when they are applied within projects. Patterns can be seen as *building blocks*, which when put together form a meaningful entity with minimal effort. However, the knowledge (held by the person applying the patterns) of how to, and when to bring them together, plays a critical role for its success. Patterns can also be perceived as *standard recipes*, where the basic fundamental concepts can be adapted and catered for to meet specific needs.

Within a BPM context, a pattern is "*an idea that has been useful in one practical context and will probably be useful in others*" (adopted from Fowler, 1997, p.8). Hence patterns are not invented, rather discovered by observing its success over a number of applications. In other words, a process-pattern is a common approach to solve problems that are proven to work in practice (adapted from Ambler, 2000). Process patterns are different to reference models (such as SCOR, ITIL, PMBOK etc) – which have been applied widely for process improvement projects. "*A reference model is an abstracted depiction of reality that serves as a standardised or suggestive conceptual basis for the design of enterprise specific models, usually within a like domain*" (Taylor, 2003, p. ii). A pattern has a much smaller focus, and can be a part of a reference model. While process patterns may inherent some features of reference models, they do not provide 'enterprise' solutions, rather provide process specific solutions, which are much smaller in scope. Process patterns can be usefully applied across the various phases of a BPM project.

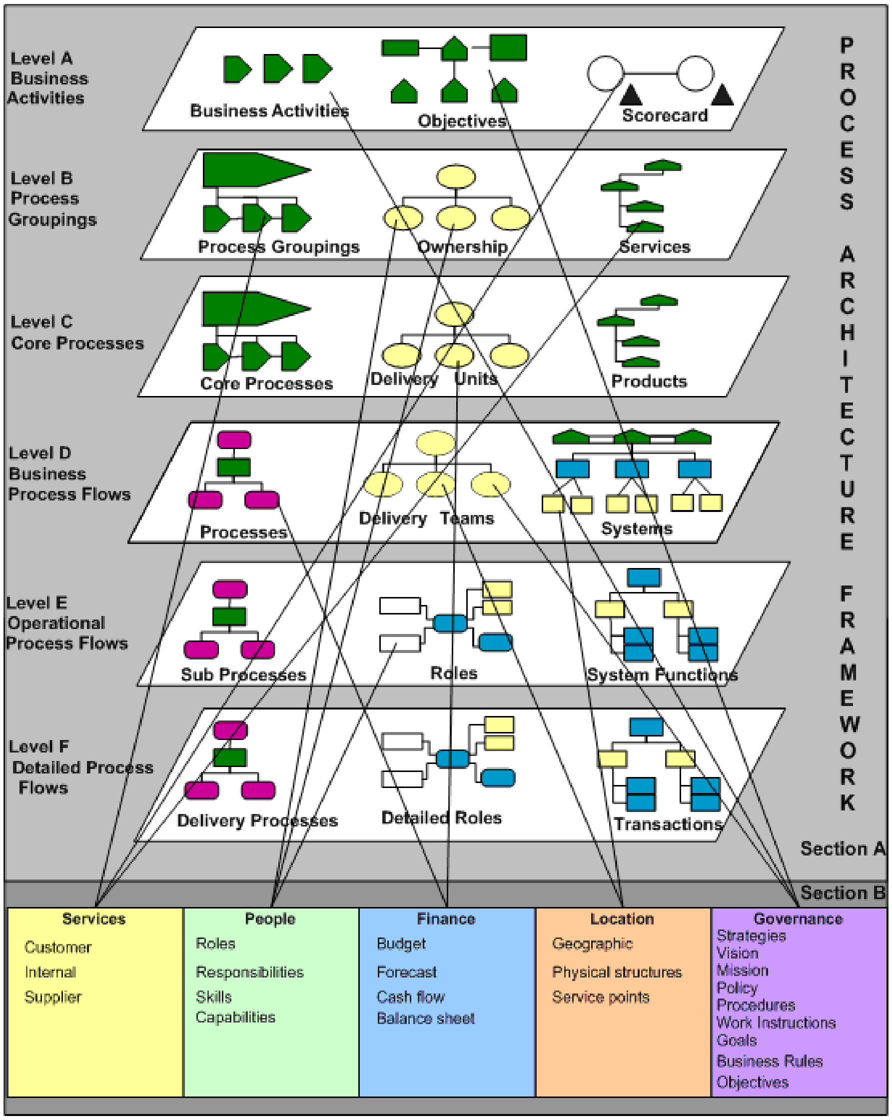
Enterprise Business Architecture and Process Architecture

An Architecture illustrates the relationships between parts that create a whole; however, they do not illustrate flow, sequence or timing of events (Whittle and Myrick, 2005). Therefore, an Enterprise Business Architecture provides the guiding framework that describes the relationship between all the parts of the organisation from the strategy to implementation[2]. The Enterprise Business Architecture is made of a number of facets of the organisation as shown in Figure 1.

The Zachman framework for Enterprise Architecture developed by John Zachman, provides a guide for how information about an Enterprise should be organised. The purpose of Zachman's framework was to provide a simple structure that supports the enterprise to access, interpret, develop, manage and change descriptions of the organisation (The Open Group, 2007). The framework proposed above in Figure 1 aligns well with the Zachman approach by providing multiple perspectives of the organization from the contextual, conceptual, logical and physical layers of the enterprise (Figure 1- section A) which also describes the what, how, where, who, when and why in the Zachman model (Figure 1- section B) for each perspective outlined in the figure below.

The process architecture is one of the facets of the Enterprise Business Architecture, where it provides the framework by which the organisation's processes can be structured. The process architecture more importantly provides the relationship between the processes to the other facets

Figure 1. Facets of enterprise business architecture



of the Enterprise Business architecture such as the People, Finance, Location, Governance etc. In general terms, process architecture is the structural design of general process systems.

“A business process architecture is a hierarchical structure of process description levels and directly related views covering the whole organisation from a business process point of view. It starts with high-level process maps representing a conceptual business view down to the detailed process flow descriptions describing specific tasks and their relation to roles, organisation, data and IT systems.” (Davis and Brabander, 2007, p.50). This process architecture defines a framework for organising, deriving, managing and maintaining the process pattern.

A process architecture organises the processes so that staff can easily adopt a pattern based approach to their work as this provides them with a structure to manage their business analysis and improvement projects. The process architecture model adopted in this study is shown in Figure 1 Section A. This is the architectural process modeling approach proposed by Davis (2006) which is also applied across British Telecom. This model provides a top down approach using six layers from A to F (see Figure 1 section A and Table 1 for details on each layer) where the level of detail represented by the process models increases from top to bottom. Process patterns can be identified at each level of the model which is actually the 'design' of the organisation and how it is meant to operate.

THE CASE ORGANIZATION

A major Australian Health organization[3] provides public health treatment services to a geographically dispersed population of nearly 4 million people. These services are provided through a number of tertiary hospitals, clinics, aged care facilities and community health centers in metropolitan, rural and remote regions. Table 2 provides a brief overview of the case organization under investigation.

This large state-wide Health Services organization has introduced a major program of improvement and transformation which is supported by funding provided under the Australian Health Care Agreement 2003 – 2008 (Department of Health

Table 1. Process architecture hierarchy descriptions (adapted from Davis and Brabander, 2007)

Process Architecture Framework Levels	Definitions
Level A: Enterprise Map	This may be represented as three fundamental activities that are carried out to run the organisation's business: • Direct the Business; • Manage the Business; and • Operate the Business. It distinguishes operational customer oriented processes from management and strategic processes.
Level B: Process Groupings	The level defines different views of how the processes are structured to deliver the three business activities at Level A, which are to Direct, Manage and Operate the Business. These Processes may be structured from: • A process execution perspective showing standard end-to-end processes (e.g. Service Fulfilment); or • A functional perspective (e.g. Value Domains such as Emergency Services, Health Services).
Level C: Core processes	These are recognisable sub-processes of end-to-end Processes. They can generally be carried out by a Business Unit or a Line of Business functional area. These types of models define those activities that deliver services that are unique to an organisation and that no other organisation delivers, as distinct from supporting processes. Level C Process Models are normally modelled as Value Chains and are comprised of tasks that are defined in detail in the Business Process Flows at Level D.
Level D: Business Process Flows	This level defines the process flows of the core processes defined at Level C and are comprised of tasks. They are normally defined generically (i.e. not specific to a particular product, service, customer, geographical operation, etc). It often will only show the 'Happy Case' (the most common) scenario and exclude the detail of alternative actions, failures and error recovery. Tasks can be decomposed into more detail if required in Level E Operational Process Flows.
Level E: Operational Process Flows	These process models define in more detail the Business Process Flows defined at Level D. It is comprised of steps, normally specific to an operational environment and will be characterised by the Application Systems and Organisational Units or Positions that support and execute them. These types of models typically will include the 'Sad Case' scenario showing the detail of alternative actions, failures and error recovery. The 'Happy Case' and 'Sad Case' scenarios comprise the Business Rules of the organisation. These steps can be decomposed into more detail if required in Level F; Detailed Process Flows.
Level F: Detailed Process Flows	This level defines in more detail the Operational Process Flows defined at Level E. It is comprised of operations and may be used to generate workflows or be used as detailed requirements for systems development. An example of an operation is to describe program logic using pseudo code which can then be coded in the specific programming language. This is embedding the operation logic into the software.

Table 2. Brief overview of the of the case organization

Population Serviced	**3.9 Million[4]**
Annual Budget (as of 2007)	Approximately $8.3 Billion
Hospitals	38
Number of Public Health Service Centers including hospitals	Approximately 160
Number of Beds	Approximately 10,000
Key Stakeholders	• Members of the Public – Health Service Consumers • Primary Health Care Providers • Specialists • Non-Government Organizations • Health Service Industry Partners such as Diagnostic Service Providers
Number of employees (including full-time, part-time and contractors)	• Approximately 75, 000
Types of services provided	• Public Health Services • In-Patient and Outpatient Clinical and Non-Clinical Health Services • Aged Care • Community Health
Number of IT Systems	Approximately 45 Statewide systems with over 25, 000 localized systems
Number of IT Staff, full-time, part-time and contractors	Approximately 900

and Ageing, 2008). As a result of this initiative, a business unit was established – its focus being on innovation and reform in the workplace. The objective of the new business unit was to develop a culture of safety and standardize systems and clinical practice to ensure . These goals align well with the concept of using a pattern-based approach to achieve . The Integrated Risk Management (IRM) program was identified as a key strategic initiative that would ensure that a approach was taken to ensure patient safety and support a culture of risk management where staff are encouraged to report clinical incidents and ensure that risk management strategies are implemented to minimize risk. The overarching goal of the Integrated Risk Management program was to document a set of Business Requirements to review the current business processes and define a set of Functional Requirements for an ICT solution to facilitate the capture and management of risk information.

A number of projects commenced as a result of this IRM program which was to define an enterprise-wide Risk Management policy, standards, guidelines and the implementation of an IT system within all Health Service Centers from hospitals to clinics and other health facilities. The IRM Program consisted of three major projects; (i) to define an IRM Framework for the enterprise, (ii) define business requirements for a Complaints Management system, and (iii) define business requirements for a Clinical Incident Management system. Each of the three projects required a detailed review of the current (As-Is) business processes where workshops were conducted with key stakeholders.

The Clinical Incident Management project commenced first due to critical strategic and political pressure resulting from negative press reports in the local paper reporting stories of negligence by clinical staff. The objective of the project was to improve the management of clinical incident reporting at health service centers and restore confidence in the public. The Complaints Management project commenced shortly after, followed by the Integrated Risk Management framework which was meant to integrate the risk areas across the Enterprise.

Table 3. Brief descriptions of the three risk management projects

Projects	Description
Clinical Incident Management	The proactive identification and treatment of hazards before they can lead to patient harm. This also includes the minimization of harm when it does occur and corrective action to minimise the risk of the incident occurring again.
Complaints Management	The management of complaints made by members of the public. This process identifies the incident(s) which lead to the complaint and ensures that an investigation is conducted ending in feedback being provided to the complainant on the corrective action taken.
Integrated Risk Management	The integration of risk management at each level of management into all business activities including strategic planning and decision-making processes

These three projects, in the Integrated Risk Management Program, were implemented sequentially where the intention was to incrementally build on the lessons learnt from each implementation phase. At the time of commencement, similarities between each project were not clear and the objective was to leverage any synergies identified between them.

PROJECT DESIGN AND FINDINGS

An action research method was chosen for this project, which was conducted as a combined consulting and research project, with the goal of producing immediate practical and academic outcomes. Action research is proposed as a useful methodology when the goal is the inquiry into a particular situation and the development of a solution to a problem. It is a form of research that is not a separate, specialised technical activity but one which is closely linked to practice and which can be comfortably undertaken by practitioners. This is particularly valid for the nature of research conducted in the health services sector (Winter and Munn-Giddings, 2001).

The principal researcher led the proposed Process Architecture design and pattern design and played an integral role within the project settings. "*Action research aims to contribute both to the practical concerns of people in an immediate problematic situation and to the goals of social science by joint collaboration within a mutually acceptable ethical framework*" (Rapoport, 1970, p.499). It also assists to "*develop self-help competencies of people facing problems*" (Susman, and Evered, 1978, p.588). It is a scientific research method that has its roots and methods well established since Kurt Lewin (1946) first introduced the term 'action research' as the pioneering approach towards social research (cited in Susman, and Evered, 1978, p. 586).

While different studies classify action research in various ways, most action research follows the traditional 'plan-do-check' approach (Chein et al., 1948). We have adapted the Susman, and Evered (1978) five phased action research model, following an 'experimental action research' approach (Chein et al, 1948; Susman, and Evered, 1978). The five core phases are; (i) diagnosing, (ii) action planning, (iii) action taking, (iv) evaluating, and (v) specifying learning. The next sections will describe each of these phases in detail.

Diagnosing

This phase primarily identifies and defines and problem. Health administrations are increasingly experiencing the need for disclosing their processes and proving the efficiency of their occupation. Process modeling methods have proven to be an adequate mechanism in order to achieve transparency, but process modeling projects can be very expensive and time consuming, often with many external consultants involved (Becker et al, 2003). Thus, a high level framework (pattern) to depict the major process tasks and flows is proposed as a useful way to get started (Davis and Bradander, 2007).

Aligning organisation strategy and the implementation of the strategy is a challenge faced by all organisations (Smith, 2007). The public sector in Australia is faced with an increase in demand for health services, combined with an ageing population and an acute skills shortage[5]. Overseas trained specialist skills are being sourced to fill this gap, but with such a strategy come complications in terms of culture, language etc[6]. It is critical that processes are put in place to ensure that health services are delivered safely and patient care is optimal. In order to implement an Integrated Risk Management strategy, it is therefore important to ensure the implementation of the strategy is structured and closely aligned to achieving the right outcome.

Many organisations in Australia and New Zealand adopt the ASNZS4360:2004 standard as the framework to manage risk which can be applied to a wide variety and wide range of activities from the public, private or community organisations and by groups and individuals (ASNZS4360:2004). The risk management framework consists of a number of steps which is shown in summary through Figure 2. Appendix 1 provides an overview of the standard and its core steps. This framework has been adopted by the case study organisation as the standard approach to managing risk in clinical and non-clinical areas. Subsequent policies, procedures and governance processes have been implemented by hospitals, clinics and other health treatment service centres to ensure compliance.

It is expected that the implementation of the Risk Management Framework would provide a systematic process to ensure that all internal systems promote evidence-based strategies to minimizing risk across the entire organization increasing patient safety and reducing the risk of harm.

Action Planning

Alternative courses of action for solving a problem are considered in this phase. The Program Manager provided the Program Management Steering Committee, as the Governance Authority, with two alternative approaches to implement the Integrated Risk Management Program. The alternatives endorsed by the Steering Committee were two fold:

Approach 1: Establish a Risk Management Policy and Allow Each Business Unit to Implement the Policy Independently

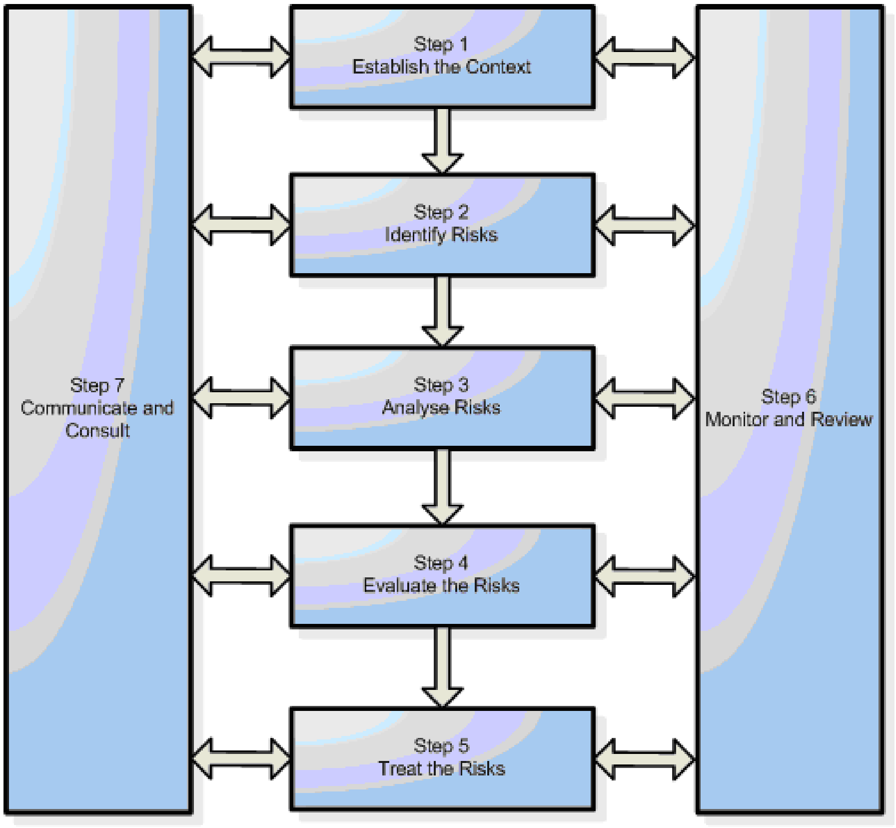
This would be a typical approach adopted in a large federated organisation where the head of each federated unit is accountable for implementing the policy. Such an approach would require each jurisdiction to report their alignment with the policy but manage risk independently within their area. The problem with such an approach is that it becomes difficult to manage risk consistently across the organisation with varying levels of maturity, budget pressures, skills etc. The policy is open to interpretation and hence implementation becomes inconsistent.

This approach has been used in the past in the Case Study organisation and was the current approach before the IRM Program was proposed. During the development of the Business Case for the IRM Program a significant issue observed was the inconsistent interpretation of the current State-wide policy across the Health Service Centres.

Approach 2: Implement a Process Architecture Approach

A process architecture approach will provide the structure required to ensure that there is clear alignment between the policy, procedures, work instructions, business and system requirements definition. This approach will use process pat-

Figure 2. Risk management framework (Adopted from the Australian and New Zealand Standard on Risk Management ASNZS 4360:2004)



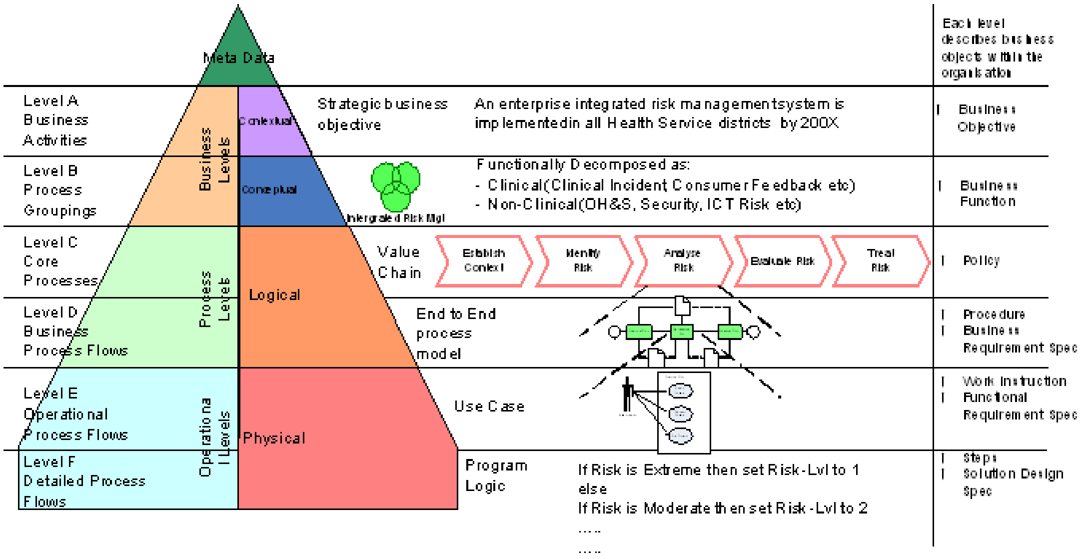
terns to facilitate the implementation of the IRM framework independent of business context areas of Clinical Incidents, Complaints Management and Risk Management.

The contexts for each of the three projects was observed by the business to be very different processes and not related to each other. Clinical Incident staff such as Nurses and Doctors believed that they were responsible for ensuring that clinical incidents did not occur while treating patients. Patient Liaison staff responsible for managing complaints made by members of the public (including patients), felt their objective was to investigate complaints and provide feedback in a timely manner. The only similarities observed by these staff were when it came to assessing the risk of each clinical incident or customer complaint, the investigator identified process patterns for each business context area to demonstrate that by using a process pattern approach, it was possible to identify other areas of process synergy and view all three contexts from the same process pattern. These demonstrations lead to an increased understanding of all the stakeholders of how the overarching Risk Management Policy applied equally to Clinical Incident, Complaints and Risk Management.

Action Taking

This phase deals with the selection of some form of action and the actual implementation of it. Reforming and aligning the organisation's services, processes, people, budgets, location to

Figure 3. Applied six level process hierarchy (adopted from Davis and Bradander, 2007)



the new Integrated Risk Management Policy required a Process Architecture approach to ensure alignment from the Conceptual to the Physical Implementation level in the organisation.

Given that it is challenging to align policy and outcomes, the process pattern approach taken will allow for the effective implementation of strategic policy and operational outcomes. This approach involved a detailed review of the different business context areas within the organisation and a top-down approach was designed for this purpose. Figure 3 (accompanied with Table 4) depicts the overall approach taken in graphical form.

The researcher reviewed the Health organisation's strategic information to firstly understand how the organisation currently implemented Risk Management Policy. Standards, procedures, work instructions, information system solutions relevant to risk management were examined to get an understanding of how the staff within the organisation enacted the processes which manage risk within the organisation constraints (business rules). It soon became apparent that managing risk was a high level corporate goal to provide safe and quality health services to the public. Each federated health service centre was responsible for interpreting the enterprise risk management policy to define internal risk management standards, policies, procedures and work instruction. Federated information systems were also built within each area to support the capture of incident data for analysis and reporting. Appendix 2 depicts in detail the business objects that were looked at each main level of the Process Architecture, demonstrating the artefacts that were reviewed and the model types that were use to depict these (within the Process Architecture). Appendices 3 to 8[8] contain example models used to document each of the Process Architecture levels.

The levels depicted above in the Process Architecture hierarchy in Figure 3, provides levels of abstraction (the ability to decompose a concept, in a structured way to manage the complexity more effectively) in this case within the Risk Management pattern. Enterprise Architects frequently use these levels of abstraction to develop and use models of the organization (Aitken, 2007). In this case study, business process models have been used to provide these levels of abstraction within the Clinical Incident, Complaints and Integrated

Table 4. Levels of abstraction of the process architecture (Aitken, 2007)

Model type7	Purpose	Alignment attribute type	Description
Contextual	Provides a description of the goal or purpose of the process	Goal Requirements	Consists of the Business Vision, Mission, Goals, Objectives etc. that describe the motivation of the organisation
Conceptual	Describes what the process must achieve in order to satisfy the high level goal	Objectives Constructs	The way the organisation is structured to support the strategic objectives
Logical	Describes the implementation criteria for the process - the logic for implementing the processes in a particular manner	Design principles and assertions Logical components and implementation criteria	The Policies and Procedures provide the guiding logic for who is responsible for enacting a process and how it should be enacted.
Physical	An exact description of what is to be implemented	Measures Physical components	The instantiation of the processes which are guided by the work instructions. Detailed business rules provide guidance on what should be done to complete a process.

Risk Management business context areas. Each of these levels of abstraction are described in the Table 4.

The Risk Management process pattern is embedded from the strategy, policy and procedure levels right down through to the lowest program logic level to transparently align the organization from the top to the bottom. The statewide IRM policy (Level C in Figure 3) and procedures (Level D in Figure 3) are issued as corporate governance documents to every Health Service Centre. Alignment with the policy is monitored through planned audits of each Health Service Centre's implementation of the corporate policy. The IRM policy is also used to articulate a set of business requirements for ICT solutions to support Clinical and Non-Clinical Risk Management areas. The business processes are embedded in these business requirement specifications to communicate how the Risk Management policy and procedures are to be implemented by other business solutions providers such as trainers, change managers etc.

Based on the preliminary research conducted at the early stages of this phase (refer to Appendix 2 for details), a process pattern was documented, that described the 'Integrated Risk Management Framework' that describes the essential steps involved in managing risk in the organisation (see Appendix 5) . Although the research was a time consuming exercise, the development of the pattern was relatively quick as a Risk Management expert was approached to support the documentation and validation of the pattern. As mentioned earlier, Appendix 2 provides a list of documents that were provided by the Risk Management expert and reviewed through out the exercise. The pattern was then tested during the phased implementation of the Clinical Incident and Complaints Management projects assigned to the researcher with the various stakeholder groups identified in the process pattern, who came from an a variety of service areas within the business.

It was important to ensure that this process architecture and pattern approach could be applied independent of the context of the risk being managed. The areas reviewed as part of the exercise were from within hospital administration, clinical service, occupational health and safety, fire safety and building management.

Instead of drawing separate process models for each of the three areas reviewed, the risk management process pattern was used to validate the process within each risk context area. Typically such projects take life between three to six months (as evidence from archived past project documentation), however, the process pattern approach enabled the researcher complete the project in one month. Adopting a pattern-based approach allowed one model (pattern) to be used to validate the process at each area with the analysis focusing on the similarities and differences between them.

Evaluating

This phase is dedicated to studying the consequences of the action(s) taken. As discussed earlier, the pattern based approach was very effective to meet with accelerated time frames and provide quality process models.

Figure 4 (together with Table 5) below describes the high level approach taken to implement and evaluate the three projects. Things were implemented in 6 core role-out phases, each phase having an evaluation and feedback loop (as described in column 3 of Table 5).

However, this is not to say that the approach is without its limitations. Some of the limitations identified through reflection and observation were as follows:

- **Low level of process architecture maturity:** The non existence of a process architecture meant that the researcher had to develop the process architecture as the project evolved. The process of discovering and developing patterns would have been more efficient if an architecture and hence, a structure, defined for discovering and developing patterns was already in place.
- **Organizational cultural hindrances:** Typically in large organisations, stakeholders believe that their process is 'different' or unique and thus, do not lend itself to things that may seem 'generic'. Patterns on the other hand are generic forms of information (derived through the extraction on what keeps on recurring within certain contexts). A process pattern is a successful tool to initially focus on the similarities in the process (and not the differences). When the pattern based approach was applied with each risk context areas stakeholders, the idea of being too unique hindered its acceptability and created resistance. However, once it was shown that only the terms used to describe incidents and risk were different, but the process was essentially the same, the pattern based approach was accepted and adapted. In addition to self reflection and observations, evaluative data were gathered through formal feedback through a series of interviews. Clients were asked to provide feedback on the approach taken during the project and post-project. Clinical and non-clinical staff positively commented on the reduction in time taken to complete workshops without

Figure 4. Project implementation steps

Table 5. The project implementation approach

Step	Description of each step	Evaluation Technique(s) used
Project Scope	Project scope was defined with key stakeholders such as the Project Sponsor, Steering Committee and Subject Matter Experts. Three health service centres were identified as representative sites from which to gather data.	Face-to-face meetings Scoping Workshops Review of Strategic Documents, standards, external legislation
Define Business Baseline	The As-Is business processes were defined and issues identified based on input from subject matter experts at each of the three sites. Process Pattern for Risk Management Documented.	Workshops Interviews with frontline staff On the Job observations Review of Policies, Procedures and Work Instructions Review of current Information Systems used
Analyse Process Synergies	The As-Is processes at each site were compared against the Process Pattern to identify process synergies.	Workshops with Subject Matter Experts.
Document Target Business Processes	Target business processes were defined for each business context area highlighting the processes that were in common – Risk Identification, Risk Analysis, Risk Evaluation, Risk Treatment and Monitoring and Review	Workshops with Subject Matter Experts
Design New Business Solution	The Target business processes provided the functional business requirements which were described using Use Cases and the Solution Requirement Specification which used UML models to describe the interactions of the user with the software system	Workshops and documentation of the functional requirements by the business analyst Joint Application Development workshops with the Super User, Business Analyst and Systems Analyst Development and User Acceptance testing of the software system
Implement the New Business Solution	The new system was rolled out across the organisation and is current in use today. Change management techniques were used to train staff to use the new system.	State wide Training sessions Communication of the updated policy, procedures and work instructions through the Intranet website Link to the web-enabled software system with a User Manual

the need to consume significant amounts of Subject Matter Expert time. Remarks were made on the quality of the business analysis artefacts, mainly due to the fact that the researcher could spend more time on reviewing the process models, conducting detailed analysis and providing recommendations for improving the business. A range of specific organisational benefits of using a pattern approach were stated during these interviews. They are briefly summarised below.

- ***Better control on how things are done:*** An organisation can reduce overhead costs by analysing the most efficient and effective way to implement a business process to ensure alignment of the business with the strategic objectives. This process pattern can then be implemented right across the organisation to conduct business in a consistent way.
- ***Clearer requirements definitions for Enterprise solutions:*** An organisation should first document the current business process for the ideal scenario (in a pattern) and use this model (the pattern) to examine the differences between business areas to the pattern/ideal scenario. Significant differences can then be analysed and decisions made to standardise the processes (to-be pattern) and define requirements for the Enterprise solution.

-***Audit for Compliance*:** Quality management systems typically use policy, procedures and work instructions to conduct audits. Audits consist of checks to see if a process has been implemented the way it is supposed to. A pattern repository can enable the organisation to assign benchmarks to the pattern and assist audit the business area based on the benchmark.

- ***Communication and transparency on how things are done*:** Training staff consistently to do the same thing the same way can be challenging, especially in large organisations. A pattern based approach can be adopted where the process pattern is used to develop training material.

Specifying Learning

The goal of this phase is to use a process architecture to implement process patterns so that these patterns may be used as a solution to realise an organisation's strategic objectives using a structured top-down approach. Eight main issues were identified as major areas to be addressed when applying a pattern based approach. They were classified as Process Architecture requirements and high and low level project requirements. *Process Architecture requirements* related to (i) Defining a process architecture framework, (ii) establishing standard terms and definitions. *High level project requirements* related to the elements that were important at a project level when implementing a pattern based approach and included (iii) the creation of a pattern repository, and (iv) the documentation of pattern governance and ownership. The *low level project requirements* were those elements that related to the individual patterns and consisted of; (v) having different levels of abstraction, (vi) fragmentation, (vii) embedded flexibility and (viii) context specification.

Process Architecture Requirements

- ***Defining a process architecture framework:*** In the absence of literature or empirical evidence, there is very little guidance on what a good process architecture framework looks like, leave alone what a process architecture framework should be. It is critical however to define such a framework in order to represent the different levels of abstraction in the organization and the relationships between the variety of process perspectives.
- ***Establishing standard terms and definitions:*** There is a significant amount of ambiguity in the Business Process Management domain where terms and definitions are confusing. It is important therefore, for an organization to establish a standard set of terms and definitions to reduce ambiguity and establish a common language prior to proceeding with projects as these.

High Level Project Requirements

- **The creation of a pattern repository:** The processes and the frameworks have to be stored somewhere in order for people to access them. These repositories should store the pattern models, the meta models and the processes on how to use the meta models.
- **Pattern governance and ownership:** Governance processes should dictate who the pattern owners are and ensure that the patterns are reviewed regularly, so that they don't end up becoming shelfware. Changes in the business environments are inevitable, the impact of these changes on the process patterns should be evaluated periodically to ensure the pattens continue to be ".

Low Level Project Requirements

- **Maintain different levels of abstractions:** Every process pattern has to fit with the process architecture, otherwise its applicability within the organisation becomes vague. Thus, each pattern must be within the layers of the process architecture, with clear meta-data on which perspectives it captures and the degree of detail it entails.
- **Maintain fragmentation (for reuse):** Large scale process modeling projects are often conducted in a piece mental manner (Green and Ould, 2004). End to end processes can be broken down to fragments, where each fragment can be depicted by a process pattern, which can be adapted separately. While fragmentation, and structured layering of process patterns is important, an overarching structure (a high level pattern) to depict how these fragments fit together is very important.
- **Allow flexibility and context specification:** Flexibility has to be maintained within the patterns to allow minor changes to fit the process/ context . Issues related to flexibility has to be integrated into the guidelines on how to use the patterns (i.e. *'how can one expand and edit the models*?' has to be described within the pattern deployment guidelines). What is a detailed pattern within a certain context can be extracted at a higher level, which can be then used as a pattern at a higher level across any context (e.g. delivering a treatment in health vs a generic delivery of service). The higher the pattern sits in the Process Architecture (refer to figure 2, Level (i.e. A, B C) compared to lower levels (i.e. D, E, F), the more context free it is and hence the more flexible it should be.

FUTURE TRENDS

There are numerous opportunities for organizations to adopt a business process management approach that includes process architecture to enable the successful implementation of organization strategy that is aligned from the top level to the implementation level. Organizations using a process architecture approach to link the various facets of the business to processes will provide the linkage required to align strategy with outcomes. This approach can also be used to provide a common platform to lead valuable discussions between various functional areas of the organisation and to identify how each functional area relates and their contribution to the common goals and objectives.

Further research could be conducted to populate process repositories consisting of process models at each level in the organization where these patterns could then become 'free ware' and re-usable in the truest sense of a pattern in any organization. The identification of these process patterns is worthy of research as business context patterns such as health, manufacturing, research etc could be shared amongst organizations especially in areas where there is a high degree of commonality in business processes (e.g. Governance, HR, Finance, Quality Management etc).

CONCLUSION

This chapter proposed a pattern based modeling approach for health services to enhance related business processes. It depicted an example of deploying an Integrated Risk Management Program within a large health organisation. The study followed an action research approach within a reputed public heath organisation, in Australia. It first presented an introduction to the research context, with an overview on the key concepts applied and a brief introduction to the case organization. The research design and findings within each phase were then presented unfolding the story of how the research conclusions were obtained.

The study's findings are of benefit to both the research and practicing communities. In particular, the paper depicted how process patterns can be implemented using Process Architecture framework to (i) align organisations strategies to the actual implementation of these strategies, and (ii) derive a 'standard' to the services across federated organizational units.

The study is not without its limitations. Process patterns are presented here as '' (or 'better practice'); as a possible 'standard' that can be followed within a particular setting or context. Past evidence has shown that the adoption of such standards is hindered by lack of stakeholder awareness and lack of perceived usefulness. Furthermore, process patterns are relevant only to document a certain limited high-level process flow, and there is a fair amount of skill that is required by the adoptee of the patterns to usefully apply it in a given context. Process patterns can have embedded constraints based on organisational policies, legislations, culture and varying structures. The notion of 's' does not commit people or companies to one inflexible, unchanging practice, instead, s is a philosophical approach based around continuous learning and continual improvement, hence the process patterns need to be continuously reviewed and updated.

The results reported in this paper are the first steps towards depicting the value of a pattern based approach for better process management and reform within the health context, and further improvements to the reported findings are underway. Means of increasing the awareness of the benefits and buy-in for process patterns (to increase their adoption and proliferation) has to be conducted. More empirical data can to be collected for triangulation purposes in the evaluation phase of the study design. 'Usability' testing (in the form of extended empirical tests) to identify what further details can be provided to support the adoption of these patterns within specific contexts needs to be addressed. In particular, the integration of context specific information within the process patterns (Rosemann, 2006) will be useful to support the adoption of these high-level process patterns within the specific, detailed processes of an organization. While the process patterns provide a useful body of knowledge, this should be owned and managed by a process-pattern-owner in order to sustain its currency and usefulness in this ever - changing environment.

For Health Reform Managers, there is an opportunity to take a holistic approach to reform by identifying process patterns before embarking on a reform project. Process patterns can help manage behavior and enforce compliance by demonstrating similarities between seemingly disparate groups to encourage the organisation and staff adopt the process pattern as a tried and tested method to achieve an objective. Managers can sell their business case for reform more effectively by being able to identify areas of synergy through the use of the pattern and demonstrating the cost effectiveness of using a uniform approach to manage the reform. The added advantage, of course, is being able to demonstrate the linkage between reform in practice to the overall organisation goals and objectives.

REFERENCES

Adamides, E. D., & Karacapilidis, N. (2006). A knowledge centred framework for collaborative business process modeling. *Business Process Management Journal*, *12*(5), 557–575.doi:doi:10.1108/14637150610690993

Aitken, C. J. (2007). Design integrity and EA governance. In P. Saha (Ed.) *Advances in Government Enterprise Architecture.* Hershey, PA: Idea Group

Alexander, C., Ishikawa, S., & Silverstein, M. (1977). *A Pattern Language: Towns, Buildings, Construction.* New York: Oxford University Press.

Ambler, S. (2000). Reuse patterns and antipatterns. *Software development*.

Amoroso, D. L. (1998). *Developing a model to understand Reengineering project success*. Washington, DC: IEEE.

Bandara, W., Gable, G. G., & Rosemann, M. (2005). Factors and measures of business process modeling: Model building through a multiple case study. *European Journal of Information Systems*, *14*, 347–360. doi:10.1057/palgrave.ejis.3000546

Becker, J., Kugeler, M., & Rosemann, M. (2003). Process Managament - a guide for the design of business processes. Berlin, Germany: Springer.

Chein, I., Cook, S. W., & Harding, J. (1948). The field of action research. *The American Psychologist*, *3*, 43–50.doi:doi:10.1037/h0053515

Curtis, B., Krasner, H., & Iscoe, N. (1988). A field study of the software design process for large systems. *Communications of the ACM*, *31*(11). doi:10.1145/50087.50089

Davenport, T. (1993). *Process innovation: Reengineering work through information technology*. Cambridge, MA: Harvard Business School press.

Davis, R. (2006). British Telecom - Six-Level Process Hierarchy. In *Proceedings of the Process days conference*, Sydney Australia, August 22-24.

Davis, R., & Bradander, E. (2007). *Aris Design Platform: Getting Started with BPM*. Berlin, Germany: Springer-Verlag.

Department of Health and Ageing. (2007). *Budget statements for 2008-09*. Retrieved July 7th 2008, from http://www.health.gov.au/internet/budget/publishing.nsf/Content/2008-2009_Health_PBS/$File/Department_Overview.pdf

Department of Health and Ageing. (2007). *2003-08 Australian Health Care Agreements- Information sheet number 1 - April 2007*. Retrieved July, 2008, from http://www.health.gov.au/internet/main/publishing.nsf/Content/ahca0308-infosheet1.htm

Forster, F. (2006). The idea Behind Business Process Improvement: Towards a Business Process Improvement Pattern Framework. *Business Process Trend Advisor,* 04-06.

Fowler, M. (1997). *Analysis Patterns: Reusable Object Models*, (Vol. Reading). Reading MA: Addison- Wesley.

Gamma, E., Helm, R., Johnson, R., & Vlissides, J. (1995). *Design Patterns: Elements of Re-usable Object- Oriented Software.* Reading, MA: Addison – Wesley.

Gill, P. J. (1999). Application Development: Business Snapshot -Business Modeling Tools Help Companies Align Their Business and Technology Goals. *Information Week*.

Green, S., & Ould, M. (2006). *The primacy of process architecture*. Retrieved Nov 22nd from http://www.csm.uwe.ac.uk/~sjgreen/paper2.pdf

Hammer, M., & Champy, J. M. (1993). *Reengineering the corporation: a manifesto for business revolution.* London: Nicholas Brealey Publishing, Allen and Urwin.

Harmon, P. (2003). "Business Process Change: A Manager's guide to improving redesigning, and automating processes". Amsterdam, Boston: Morgan Kaufmann.

Indulska, M., Chong, S., Bandara, W., & Sadiq, S. (2006). *Major Issues in Business Process Management: An Australian Perspective*. Paper presented at the Australian Conference on Information Systems (ACIS 2006).

Larsen, M. A., & Myers, M. D. (1998). BPR Success or failure? A business Process reengineering project in the financial services industry. *Communications of the ACM*, 367–381.

Minister of Ageing. (2008, June 12th). *Historic meeting of ministers for ageing/seniors – responding to Australia's changing demographics*. Retrieved July 7th 2008, from http://www.health.gov.au/internet/ministers/publishing.nsf/Content/A58A5B08571D0BDDCA2574650024A4C1/$File/JE082.pdf

Murphy, F., & Staples, S. (1998). Reengineering in Australia: Factors affecting success. In *Proceedings of the Australasian Conference of Information systems*, Sydney, Australia.

Rapoport, R. N. (1970). Three dilemas of action research. *Human Relations*, *23*, 499–513. doi:10.1177/001872677002300601

Reihle, D., & Zullighoven, H. (1995). A pattern Language for tool construction and integration based on the tools and materials metaphor. In J.O Coplian & D.C Schmindt (Eds.), *Pattern Languages of Program Design.* Reading, MA: Addison Wesley Professional.

Rosemann, M. (2006). *Understanding Context-awareness in buisness process design*. Paper presented at the Australasian Conference on Information Systems, Dec 6-8, Adelaide.

Smith, H., & Fingar, P. (2003). Business Process Management. *The Third Wave.* Tampa, FL: Meghan-Kiffer Press.

Smith, R. (2007). *Business Process Management and the Balanced Scorecard: Using Processes as Strategic Drivers*. Hoboken, NJ: John-Wiley and Sons.

Susman, G., & Evered, R. (1978). *An assessment of scientific merits of action research* (Vol. 25, pp. 582-603).

Taylor, C. (2003). *Reference Models for IT service Provision*. Masters dissertation, Queensland University of Technology, Brisbane, Australia.

Taylor, W. F. (1911). *Modern History Sourcebook: The Principles of Scientific Management.* Retrieved November 22nd, 2006 from http://www.fordham.edu/halsall/mod/1911taylor.html

The Open Group. (2007). The Open Group Architecture Framework (TOGAF 8.1.1). Retrieved July 14th 2008 from http://www.opengroup.org/bookstore/catalog/g063v.htm

Van der Aalst, W. M. P., ter Hofstede, A. H. M., & Weske, M. (2003). Business Process Management: A Survey. In *Proceedings of the International conference of Business Process Management*, Eidhoven, The Netherlands, June 26-27.

Vera, A., & Kuntz, L. (2007).Process-based organization design and hospital efficiency . *Health Care Management Review*, *32*(1), 55–65.

Whittle, R., & Myrick, C. (2005). Enterprise Business Architecture: The formal results between strategy and results. Boca Raton, FL: Auerbach Publications.

Winter, R., & Munn-Giddings, C. (2001). *A handbook for action research in health and social care*. New York: Routledge.

KEY TERMS AND DEFINITIONS

'Best Practice': The term 'best practice' is used to describe the process of developing and following a standard way of doing things that can be used (i.e. for management, policy, and especially software systems development) by multiple times.

Business Process: A business process is a collection of tasks that produce something of value to the organisation, its stakeholders or its customers.

Business process architecture: A business process architecture is a hierarchical structure of process descriptions levels and directly related views covering the whole organization from a business process point of view. It starts with high-level process maps representing a conceptual business view down to the detailed process flow descriptions describing specific tasks and their relation to roles, organization, data and IT systems. (Davis and Brabander, 2007).

Business Process Management: Refers to aligning processes with the organization's strategic goals, designing and implementing process architectures, establishing process measurement systems that align with organizational goals, and educating and organizing managers so that they will manage processes effectively. (http://www.bptrends.com/resources_glossary) last accessed 9/7/2008

Business Process Modeling: Business process modeling includes techniques and activities used as part of the larger business process management discipline. Business process modeling is an activity performed by business analysts within an organisation. Analysts use modeling tools to depict both the current state of the business and the desired future state.

Business Requirement: A method of describing in business terms of what an organisation does and how it does it in order to achieve a business objective.

Enterprise Business Architecture: Enterprise Business Architecture provides the guiding framework that describes the relationship between all the parts of the organisation from the strategy to implementation[9].

Pattern: A pattern in general is "an abstraction from a concrete form which keeps recurring in specific non-arbitrary contexts" (Riehle and Zullighoven, 1995).

Policy: A policy is a deliberate plan of action to guide decisions in order to achieve an organisation's objective.

Process Architecture: The process architecture is one of the facets of the Enterprise Business Architecture, where it provides the framework by which the organisation's processes are structured. The process architecture more importantly provides the relationship between the processes to the other facets of the Enterprise Business architecture such as the People, Finance, Location, Governance etc.

Process Modeling: Process modeling is an approach for visually depicting how businesses conduct their operations by defining the entities, activities, enablers and further relationships along control flows (Curtis et al., 1988; Gill, 1999).

Risk Management: Is the culture, processes and structures that are directed towards realizing potential opportunities whilst managing adverse effects.

Work Instruction: The detailed description of the steps person, robot or a computer system must complete in order to fulfill a task.

Value Chain: A value chain is a sequence of activities that is initiated by a firm's customer and ends when that customer receives an outcome (service or product).

Task: A task is an atomic activity that is included within a process.

Business Rules: Business rules describe how an organisation operates and the constraints under which the operations are performed.

Operations: Operations are ongoing recurring activity that a business is involved in. Business operations deliver direct or indirect value to the organisations customers.

ENDNOTES

[1] See http://workflowpatterns.com for further details. Last accessed, 14th of July, 2008.

[2] See The Business Analysis Body of Knowledge www.theiiba.org. Last accessed on 14th of July, 2008.

[3] Please note that the organisation is kept anonymous in this paper for confidentiality purposes.

[4] Office of Economic and Statistical Research Information Brief, released 24 March 2005. Australian Demographic Statistics September Quarter 2004

[5] See http://www.anu.edu.au/aphcri/Domain/Workforce/Thistlethwaite_3_FINAL.pdf, for further details on the Health related skills shortage in Australia. Last accessed July 14th, 2008.

[6] See http://www.humanresourcesmagazine.com.au/articles/59/0c028f59.asp for further details on issues with filling the gap with overseas employees. Last accessed July 14th, 2008.

[7] This also relates to the levels of abstraction of the Process Architecture.

[8] **Appendix C:** ***Level A***: Sample Contextual Model of the Integrated Risk Management function **Appendix D:** ***Level B*****:** Sample Conceptual Model of the Complaints Management function **Appendix E:** ***Level C:*** Sample Process Models (related to Integrated Risk Management) which shows the application of the ASNZS4360:2004 Risk Management framework in the case study organization. **Appendix F:** ***Level D*****:** Sample Business Process Flow Model which shows how risks are treated **Appendix G:** ***Level E***: Sample UML Use Case description that was used to document how Risks are assessed. **Appendix H:** ***Level F***: Sample Operational Process Flow Model (in BPMN) that depicts the recording of potential and actual incident and intervention information These clearly demonstrate the funnel like decomposition of complex concepts within each level of abstraction.

[9] See The Business Analysis Body of Knowledge www.theiiba.org. Last accessed on 28 Jan 2008

APPENDIX A: EXTRACT FROM THE ASNZS:4360:2004 RISK MANAGEMENT STANDARD

Risk management involves managing to achieve an appropriate balance between realizing opportunities for gains while minimizing losses. It is an integral part of good management practice and an essential element of good corporate governance. It is an iterative process consisting of steps that, when undertaken in sequence, enable continuous improvement in decision-making and facilitate continuous improvement in performance.

Risk management involves establishing an appropriate infrastructure and culture and applying a logical and systematic method of establishing the context, identifying, analysing, evaluating, treating, monitoring and communicating risks associated with any activity, function or process in a way that will enable organizations to minimize losses and maximize gains.

To be most effective, risk management should become part of an organization's culture. It should be embedded into the organization's philosophy, practices and business processes rather than be viewed or practiced as separate activity. When this is achieved, everyone in the organization becomes involved in the management of risk.

Although the concept of risk is often interpreted in terms of hazards or negative impacts, this Standard is concerned with risk as exposure to the consequences of uncertainty, or potential deviations from what is planned or expected. The process described here applies to the management of both potential gains and potential losses.

Organizations that manage risk effectively and efficiently are more likely to achieve their objectives and do so at lower overall cost.

The Main Elements of Risk Management are as follows:

- **Establish the context:** Establish the external, internal and risk management context in which the rest of the process will take place. Criteria against which risk will be evaluated should be established and the structure of the analysis defined.
- **Identify Risks:** Identify where, when, why and how events could prevent, degrade, delay or enhance the achievement of the objectives.
- **Analyse Risks:** Identify and evaluate existing controls. Determine consequences and likelihood and hence the level of risk. This analysis should consider the range of potential consequences and how these could occur.
- **Evaluate Risks:** Compare estimated levels of risk against the pre-established criteria and consider the balance between potential benefits and adverse outcomes. This enables decisions to be made about the extent and nature of treatments required and about priorities.
- **Treat Risks:** Develop and implement specific cost-effective strategies and action plans for increasing potential benefits and reducing potential costs.
- **Monitor and Review:** It is necessary to monitor the effectiveness of all steps of the risk management process. This is important for continuous improvement. Risks and the effectiveness of treatment

measures need to be monitored to ensure changing circumstances do not alter priorities.

- **Communicate and Consult:** Communicate and consult with internal and external stakeholders as appropriate at each stage of the risk management process and concerning the process as a whole.

The Risk Management Standard provides a generic guide for managing risk in any organisation context whether it is public, private, community, enterprise or individual. It is thus a scalable framework that can be applied quite successfully independent of industry or economic sector.

APPENDIX B: CASE STUDY SAMPLE DOCUMENTS

The table below catalogs the documents that were reviewed as part of the research project. When conducting a document review, each document was categorized into the relevant Process Architecture Levels to identify what type of business object needed to be identified and reviewed. The principal researcher then selected the appropriate model type to be used to capture the relevant information about the business object. Adopting this approach provided a structured method for gathering and analysing information that is relevant to the exercise and supports the implementation of a Process Architecture approach.

Process Architecture Levels	Business Objects	Artifact Reviews – Content Extracted	Model Type
A	Business Objective	Strategic Plan - Provide safe and sustainable services	• Contextual Model drawn using blocks, arrows, triangles • Organisation function chart
B	Business Functions	Function Groupings from Organisation Charts: Clinical Incident Management Complaints Management Integrated Risk Management	• Service groupings • Functional perspective • Conceptual models
C	Policy	Review of Policy Document to extract Value Chains and IDEF0 models: Clinical Governance Policy Consumer Complaints Management Policy Integrated Risk Management Policy	• Value Chains • End-to-end processes using BPMN or IDEF0 • Logical models
D	Procedure Business Requirement Specifications	For each Business Context Area IDEF0 models were drawn: - Implementation Standards and Procedures e.g. Management of Clinical Adverse Events Procedure, Consumer Feedback Management Procedure - Business Requirements Specification consisting of AS-IS process models	BPMN Process Model, IDEF0 or IDEF3, UML Workflow
E	Work Instructions	For each Business Context Area at each Health Service Centre an example of the Work Instruction artifacts observed to define Use Cases: - Incident Reporting using the Central Information System Database - Receiving a Complaint Work Instruction - Pressure Area Care Work Instruction As part of the Business Analysis activities, Functional Requirements Specifications were created for each of the three Business Context Areas.	BPMN Activity Model, Use Cases

Process Architecture Levels	Business Objects	Artifact Reviews – Content Extracted	Model Type
F	Steps	UML Workflow models were used to depict workflow: The Corporate Integrated Risk Management Solution was built based on detailed Solution Requirement Specifications defined for each of the three Business Context Areas.	Flowcharts, System Flow Chart, Data Flow Diagram

APPENDIX C: LEVEL A CONTEXTUAL MODEL: INTEGRATED RISK MANAGEMENT

The Model shown in Figure 5 was used to show conceptually how the Integrated Risk Management function collectively supports the achievement of the case study organisation's strategic objective. The model also shows how the Integrated Risk Management function is structured within the organisation.

APPENDIX D: LEVEL B CONCEPTUAL MODEL: COMPLAINTS MANAGEMENT

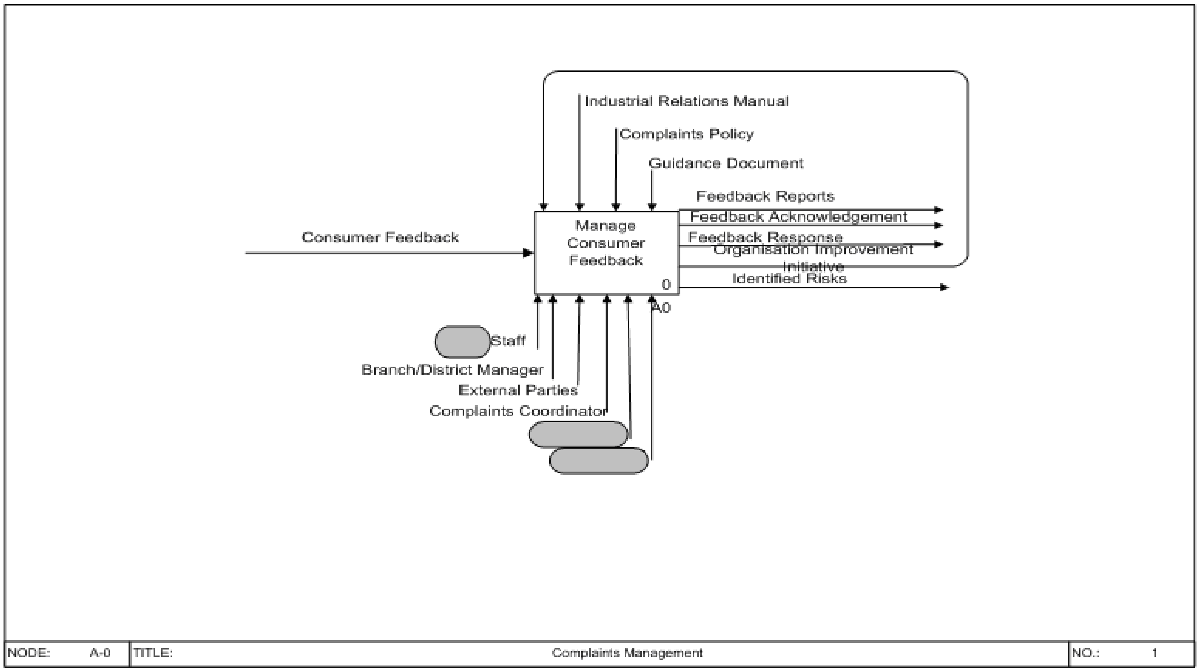
The IDEF0 High-Level A0 model (see Figure 6) was used to define the scope of the Complaints Management function. The same approach was taken to identify the scope of the Clinical Incident and Integrated Risk Management functions.

APPENDIX E: LEVEL C PROCESS MODELS – INTEGRATED RISK MANAGEMENT

IDEF0 was used as the notation to document the end-to-end process (value chain) for all three projects. Figure 7 is an example of the IDEF0 model which shows the application of the ASNZS4360:2004 Risk Management framework as it is implemented in the case study organisation. The same pattern was used to document the Clinical Incident and Complaint Management Processes.

Figure 5.

Figure 6.



APPENDIX F: LEVEL D BUSINESS PROCESS FLOW MODEL – TREAT RISKS

The IDEF0 business process flow model shown in Figure 8 was used to document how Risk is treated within the case study organisation. This pattern was used to validate that risk is treated the same way in Clinical Incident, Complaints and Risk Management.

APPENDIX G: LEVEL E USE CASE – COMPLAINTS MANAGEMENT – ASSESSING RISK

Figure 9 is an example of the UML Use Case that was used to document how Risks are assessed. This Use Case is meant to show how business rules are applied and cause branches in logical flow. Use Case provided the Solution Requirement specifications to the IT software development group on how a solution is required to interact with the User/Actor.

APPENDIX H: LEVEL F OPERATIONAL PROCESS FLOW MODEL

Figure 10 is an example of a detailed Operational Process Flow Model. Typically, Systems Analysts use these types of model to document how a software developer will convert the business logic and business rule into software syntax. The human-computer interaction is also depicted in these models to clearly demonstrate when the user is required to interact with the software system.

Figure 7.

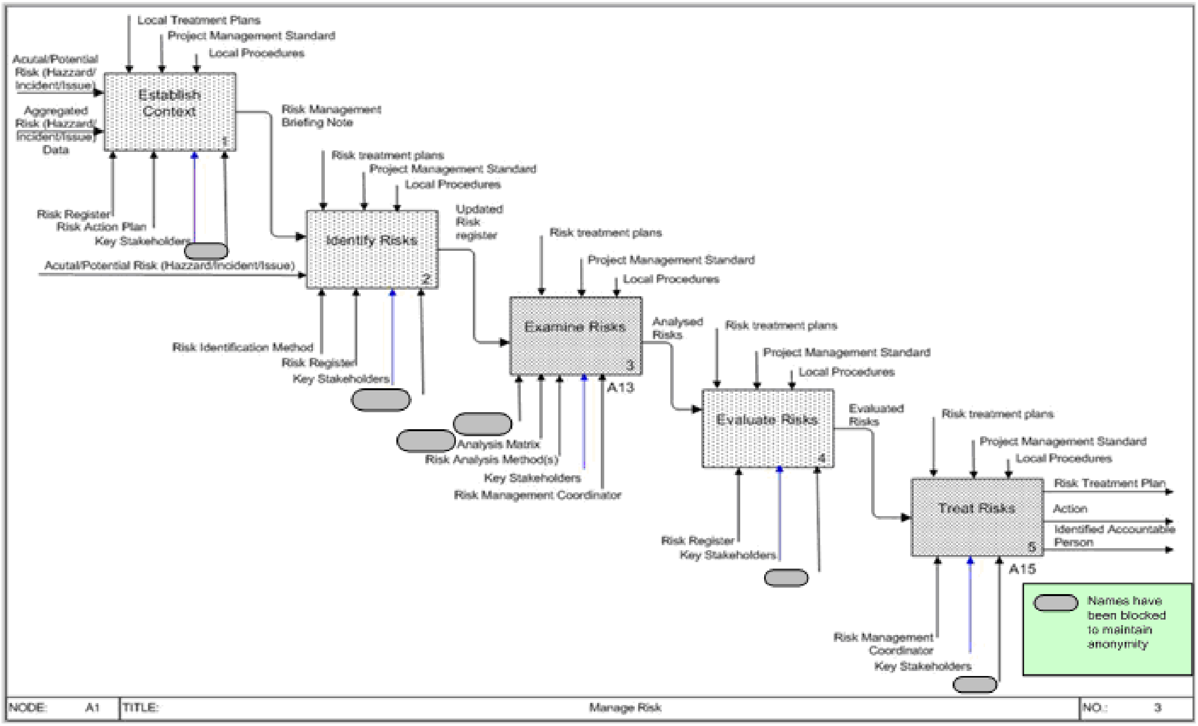


Figure 8.

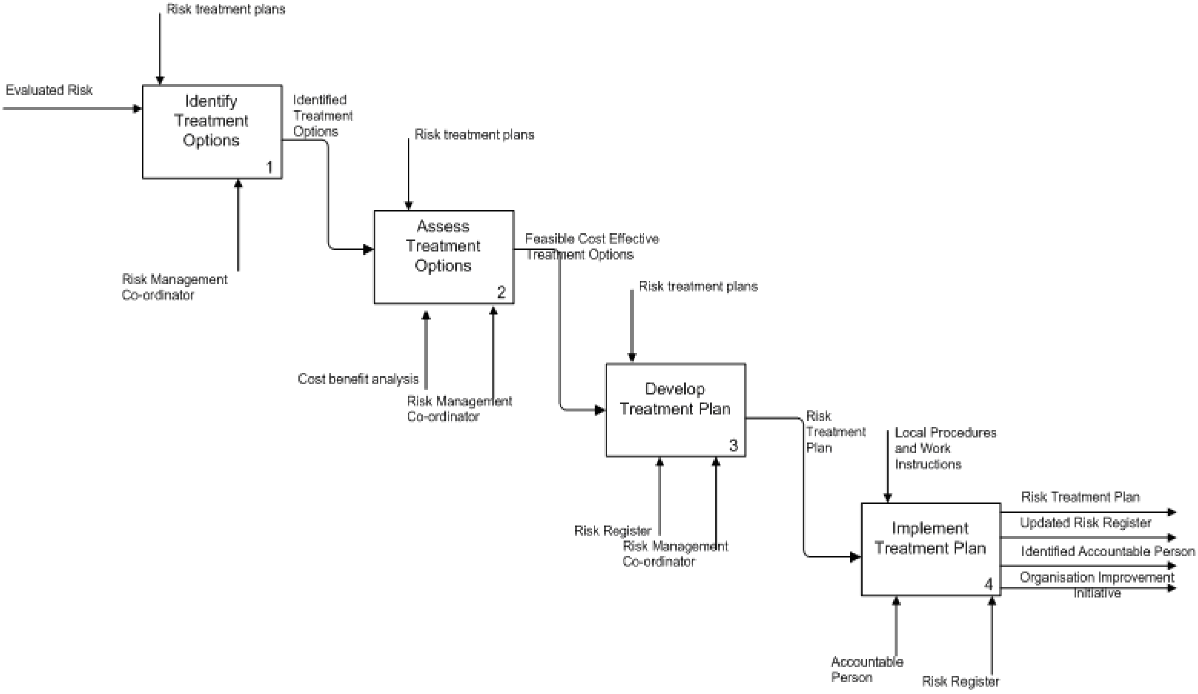
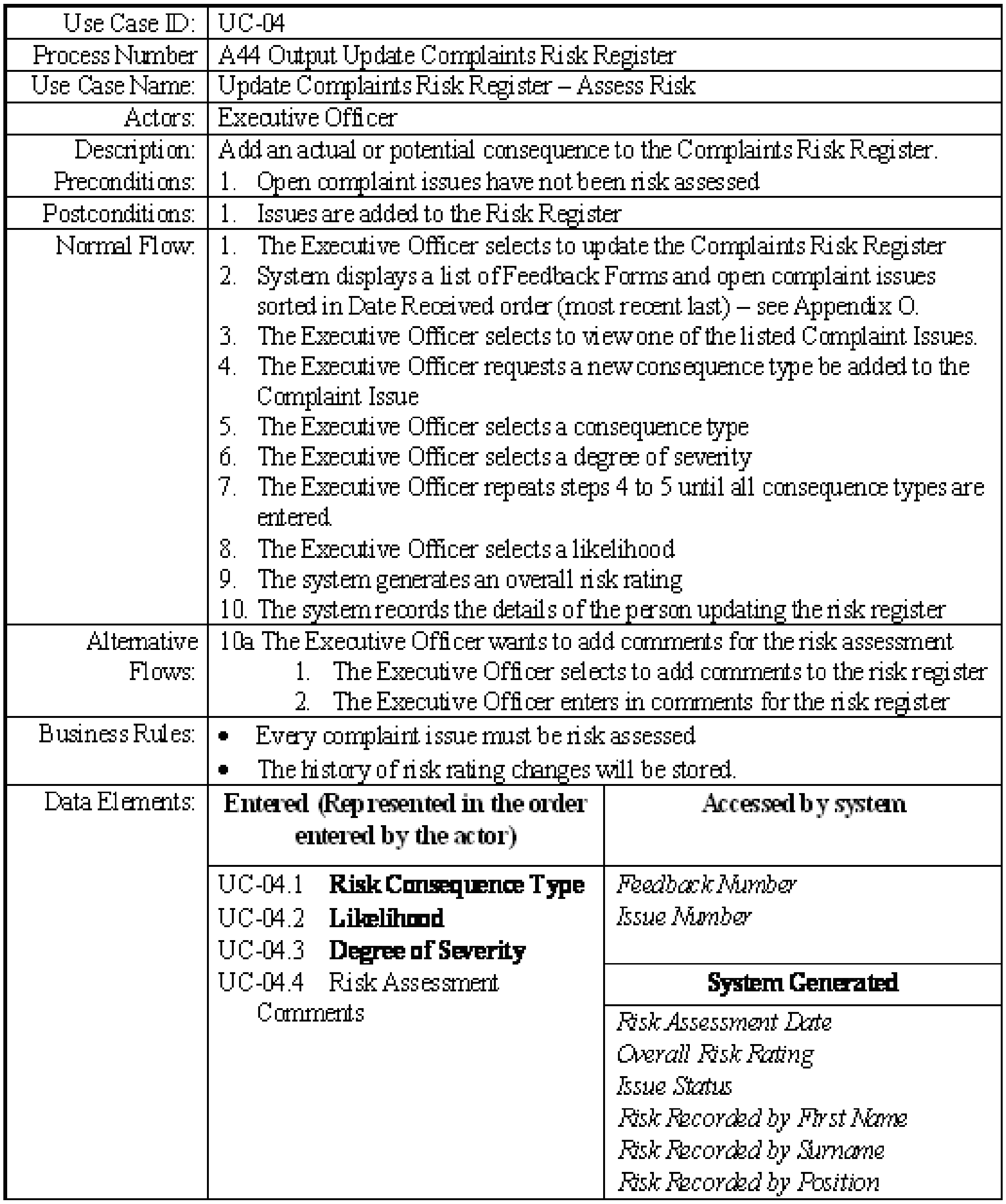
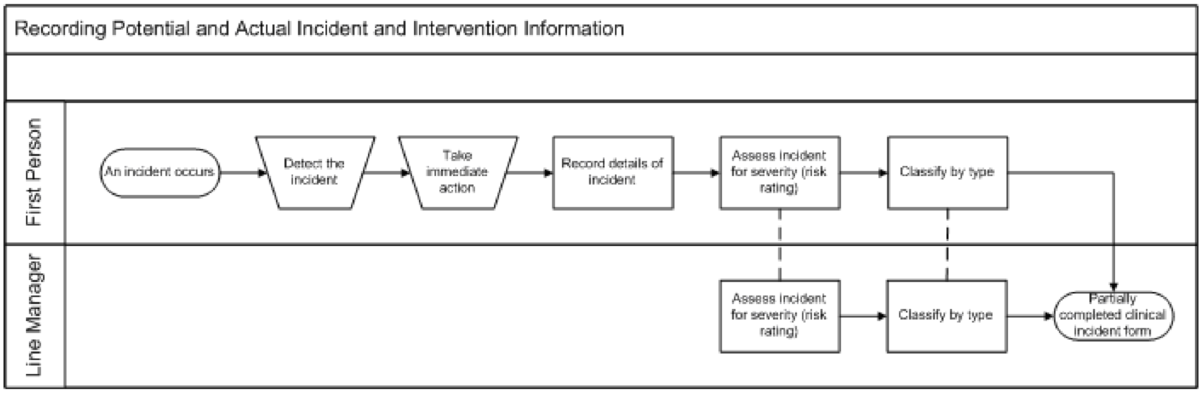


Figure 9.



Use Case ID:	UC-04	
Process Number	A44 Output Update Complaints Risk Register	
Use Case Name:	Update Complaints Risk Register – Assess Risk	
Actors:	Executive Officer	
Description: Preconditions:	Add an actual or potential consequence to the Complaints Risk Register. 1. Open complaint issues have not been risk assessed	
Postconditions:	1. Issues are added to the Risk Register	
Normal Flow:	1. The Executive Officer selects to update the Complaints Risk Register 2. System displays a list of Feedback Forms and open complaint issues sorted in Date Received order (most recent last) – see Appendix O. 3. The Executive Officer selects to view one of the listed Complaint Issues. 4. The Executive Officer requests a new consequence type be added to the Complaint Issue 5. The Executive Officer selects a consequence type 6. The Executive Officer selects a degree of severity 7. The Executive Officer repeats steps 4 to 5 until all consequence types are entered. 8. The Executive Officer selects a likelihood 9. The system generates an overall risk rating 10. The system records the details of the person updating the risk register	
Alternative Flows:	10a The Executive Officer wants to add comments for the risk assessment 1. The Executive Officer selects to add comments to the risk register 2. The Executive Officer enters in comments for the risk register	
Business Rules:	• Every complaint issue must be risk assessed • The history of risk rating changes will be stored.	
Data Elements:	**Entered (Represented in the order entered by the actor)**	**Accessed by system**
	UC-04.1 **Risk Consequence Type** UC-04.2 **Likelihood** UC-04.3 **Degree of Severity** UC-04.4 Risk Assessment Comments	*Feedback Number* *Issue Number*
		System Generated
		Risk Assessment Date *Overall Risk Rating* *Issue Status* *Risk Recorded by First Name* *Risk Recorded by Surname* *Risk Recorded by Position*

Figure 10.



This work was previously published in Handbook of Research on Advances in Health Informatics and Electronic Healthcare Applications: Global Adoption and Impact of Information Communication Technologies, edited byK. Khoumbati; Y.K. Dwivedi; A. Srivastava; B. Lal, pp. 289-318, copyright 2010 by Medical Information Science Reference (an imprint of IGI Global).

Chapter 6.2

Difficulties in Accepting Telemedicine

María José Crisóstomo-Acevedo
Jerez Hospital, Spain

José Aurelio Medina-Garrido
University of Cadiz, Spain

ABSTRACT

Telemedicine requires a new type of worker: the health care teleworker. Nevertheless, physicians remain wary of adopting telemedicine. This work examines the sources of the resistance to incorporating telemedicine. We adopt a focus centering on the difficulties that human factors have in accepting the practice of telemedicine. Employees' resistance to change comes mainly from the inertia that perpetuates traditional routines and methods of working. The success of telemedicine projects will be determined by these human factors as well as by an adequate use of information technology and an appropriate organizational management. This work also offers some practical implications in human resource management for managers of telemedicine projects to consider.

INTRODUCTION

Information technology (IT) can improve aspects of both medical care and of the underlying administrative infrastructure. Thus, as in any other industry, we are seeing a proliferation of specialist applications and systems such as hospital information systems (HIS), medical decision support systems, interpretation of biomedical signals and medical images, integration of knowledge-based systems with HIS, and telemedicine.

Telemedicine enables the provision of health care services or the exchange of health care information across geographic, temporal, social, and cultural barriers (Chau & Hu, 2004). Telemedicine makes use of a wide range of technologies to overcome distances, such as radio, analog landlines, e-mail, the Internet, ISDN, satellites, telesensors, and so forth, for the transmission of medical information (data, voice, and video) and provision of medical services from a distance.

Thanks to telemedicine, health care centers can offer diverse specialty services to other centers, to other physicians, or directly to the patient, such as, for example, telecardiology, teledermatology, teleendoscopy, telemedicine, telemonitoring, telenursing, telepathology, teleradiology, and telesurgery (Tachakra, 2003).

The concept of telemedicine does not actually require the use of information technologies. Indeed, it was common in the past to exchange medical opinions and prescribe treatments using mail, the radio, or even visual signals. People living in remote areas of Australia at the beginning of the 20th Century used radio to communicate with the Royal Flying Doctor Service of Australia. At this time, physicians on dry land also used the radio to communicate with ships suffering from medical emergencies (Wootton, 2001). Some African villages used smoke signals to warn outsiders not to approach the village during an epidemic. Similarly, ships used flags to warn that they were in quarantine (Darkins & Cary, 2000). Nevertheless, modern IT has given new meaning to the practice of telemedicine (Bladwin, Clarke, & Jones, 2002).

Telemedicine requires a new type of worker: the health care teleworker. Indeed, telemedicine can be seen as a pioneering activity in the field of teleworking. But unlike in other types of telework, the human factor is much more important for the success of projects in telemedicine. Nevertheless, physicians remain wary of adopting telemedicine. Most experts agree that the major barriers to implementing telemedicine are known but that the solutions are complex and require cooperative efforts.

This chapter examines the sources of the resistance to incorporate telemedicine. We adopt a focus centering on the difficulties that human factors have in accepting the practice of telemedicine. Employees' resistance to change comes mainly from the inertia that perpetuates traditional routines and methods of working (Pardo & Martinez, 2003; Rumelt, 1995). The success of telemedicine projects will be determined by these human factors, as well as by an adequate use of IT and an appropriate organizational management (Bruque-Cámara, Vargas-Sánchez, & Hernández-Ortiz, 2004; Khatri, 2006; Melville, Kraemer & Gurbaxani, 2004; Powell & Dent-Micallef, 1997).

The rest of this chapter is organized as follows. The second section discusses the relationship between telemedicine and human resource management. The third section tries to identify the obstacles in the way of an adequate acceptance and development of telemedicine. This section also offers some practical implications in human resource management for managers of telemedicine projects to consider. Section four suggests some future research opportunities within the domain of the telemedicine and human resource management topics.

BACKGROUND

There has been a considerable amount of work on telemedicine in the scientific literature (Demiris & Tao, 2005; Roine, Ohinmaa, & Hailey, 2001), but academics have focused mainly on technical questions—to do with what technologies are available for the practice of telemedicine (Rao, 2001)—or on health care issues: to what medical fields telemedicine can be applied (Fishman, 1997; Tachakra, 2003).

Researchers have shown rather less interest, however, in questions concerning the organization and management in the adoption and implementation of telemedicine projects. In particular, few studies analyze the impact of telemedicine projects on the management of the human resources participating in such projects (Croteau & Vieru, 2002; Hu & Chau, 1999; Hu, Chau, Sheng, & Tam, 1999).

Health care staff's reluctance to accept the new technology or collaborate on it is one of the main causes of the failure of such projects, these professionals being the proposed end-users of the system (Gagnon, Lamothe, Fortin, & Cloutier, 2005). The rejection of telemedicine by the health care workers involved is often a result of the resistance to change generated by inertias in the existing organizational routines (Pardo & Martinez, 2003; Rumelt, 1995). These routines are threatened by the need to redefine traditional professional roles and by the professionals' loss of status, since IT blurs the functional and hierarchical boundaries in health care organizations (Aas, 2001; May, Gask, Atkinson, Ellis, Mair, & Esmail, 2001).

Apart from the problem of acceptance, there are problems due to the fact that the staff involved are not only teleworkers—their work is also based on the possession, application, and exchange of knowledge. In this sense, telemedicine collaborations can be mutually beneficial exchanges of knowledge to develop partner absorptive capacity and access to unique learning experiences and data (Robinson, Savage, & Campbell, 2003).

There is a common misconception that investing in IT leads to a reduction in costs and enhanced efficiency in the production or services delivered. This belief led to what some have called the productivity paradox, or technology paradox, whereby productivity is negatively associated with investment in IT. As in other sectors, investment in telemedicine and its advantages have been exaggerated. Clearly, not all investments in telemedicine projects satisfy initial expectations, and some even fail. Explanations for the productivity paradox include (Bruque & Medina, 2002): organizations need to learn how to use new technologies efficiently, which takes time; the strategic necessity hypothesis, whereby organizations invest in IT to match other companies competitively rather than to achieve advantages over them; savings in production and transaction costs are achieved, but they are outweighed by the investment made in IT; and when the social and technical systems do not have the same interests, format, or structure. With regard to the latter, a mere change in the information systems is not enough to change the culture of the organization. Technology cannot transform a company by its mere presence. The necessary transformation requires a fundamental change in habits, attitudes, values, expectations, and incentives relating to information management.

DIFFICULTIES IN ACCEPTING TELEMEDICINE

There is no doubt that telemedicine offers considerable advantages. Physicians can gain by accessing digital information that can help them in their diagnoses and treatments, as well as use the technology to exchange opinions with expert colleagues. Nevertheless, the use of telemedicine is advancing only slowly, and health care professionals have shown some reluctance to embrace it (Audet, Doty, Peugh, Shamasdin, Zpaert, & Schoenbaum, 2004; Parente, 2000; Sands, 2004; Wilson, 2005).

This section analyzes the main factors that may explain practitioners' resistance to accept telemedicine. The most important obstacles to the development of telemedicine are as follows: inertias in the existing organizational routines, problems inherent to telework, lack of time, opposition from professional organizations, limitations of the technologies, difficulty in using the technologies and understanding their utility, lack of training, and lack of trust.

The most common inertias, or obstacles to change, in the specific case of telemedicine projects, are those that arise either from the management of the telemedicine project or from organization members' resistance to change (Arjonilla-Domínguez & Medina-Garrido, 2002). Project managers may fail due to lack of leadership, lack of top management support, lack of adequate training, the failure to adapt the project to the organization's strategy or to the available organizational resources, or the failure to adapt the structure of the organization to the proposed changes.

Employees' resistance to change may be a result of their lack of participation in the project, the failure to consider their interests or needs, the fear that their jobs or status are under threat, lack of training and information, fear of uncertainty of what will happen when the new system is launched, the perception that change is unnecessary, the tendency to concentrate on short-run problems, the refusal to believe that past successes may end unless things change, group pressure on the individual to continue with what has been normal up to now, the risk of failure, the effort required when adopting something new, a lack of strategic vision throwing doubt on whether the right path has been taken, a lack of consensus with regard to the decisions taken, the difficulty in breaking with the established routines, and waiting for others to act so as not to run the risk of changing unilaterally.

The essence of telemedicine is to move the medical knowledge and experience rather than move the patient physically. For this, telemedicine involves rather more than just taking medical services to where they did not exist before. It has also become a practice of transmitting and handling knowledge. It enables medical practitioners to exchange their knowledge (Robinson et al., 2003) so that others can apply it in specific situations.

Health care professionals who practice telemedicine can therefore be said to be knowledge teleworkers. Nevertheless, the nature of the work of a knowledge worker is inconsistent with the flexibility associated with telework (Bentley & Yoong, 2000). In this respect, there are various problems with the development of telemedicine with regard to its consideration as telework (Arjonilla-Domínguez & Medina-Garrido, 2002):

- Telework is mainly an after-hours' activity, and thereby extends the normal working day (Bentley & Yoong, 2000). But this activity tends to be measured by results rather than by the time dedicated, so it frequently leads to overworking.
- The figure of teleworker is not as legislated in most countries as other contractual labor figures. This can generate some labor and economic insecurity, as well as fewer social security benefits.
- Teleworkers, depending on where they are located, can feel isolated from their firm or from their profession and may perceive a lack of status. Their location may often provide an inadequate working environment.
- Often, not of the technical resources necessary to do the work are available due to insufficient planning. A telemedicine project is often validated by implementing a small-scale pilot project, only for the full-scale project to be denied the equivalent resources when it is launched.
- Telemedicine teleworkers, being knowledge workers, can easily feel isolated, making it difficult for them to work in a team and resolve operational problems.

Some possible solutions to the above problems include:

- Establish areas and timetables requiring teleworkers' presence. Mix telework with presential work. Create telework centers and networks of teleworkers. Develop contact mechanisms (meetings, discussion forums, etc.).
- Offer clear contractual conditions, and conditions for promotion and training. Offer competitive economic incentives (Ahern, Kreslake, & Phalen, 2006).
- Offer continuing support from the firm, and provide the necessary resources.
- Communicate a feeling of being in a team,

and develop group training.

In addition, these problems of health care teleworkers make it necessary to develop the right human resource policies to retain valuable personnel in the telemedicine projects. Such policies include notably: offer telemedicine as a flexible working environment, that is, as a chance to reconcile working life with family life; retain valuable personnel who wish to retire or work part time; offer recognition and status visible to others; and since the work processes are not always observable in telemedicine, it is useful to link incentives with the measurable results obtained (Ahern et al., 2006; Arjonilla-Domínguez & Medina-Garrido, 2002; Bentley & Yoong, 2000).

Physicians often argue that they do not have time to attend to patients remotely, as they are too busy with the consultations and medical services they provide to the patients who see them in person. This is a shortsighted view from the strategic perspective, since they would be able to attend to more patients if they saved time on traveling and if they automated medical services wherever possible. By using technology to automate existing routine tasks, performance can be optimized (Kirsch, 2002). Better efficiency is driven by better use of information, and this is where telemedicine can be utilized. In this respect, many of the services provided to patients are routine and repetitive, and by definition, are capable of being automated. For example, it is possible to automate the process of dispensing prescriptions to patients, if the physicians establish the treatment requiring them in the computer system, or if they have diagnosed a chronic illness. But automating this process would lead to a loss of power on the part of these professionals.

The power that professional colleges hold over health care professionals is well known. This is particularly true in the case of the medical colleges. Telemedicine projects need broad institutional support to gain legitimacy. This institutional environment is made up of the public authorities, legislators, labor unions, the population, and the above-mentioned professional colleges. Nevertheless, some medical colleges are drawing up ethical codes of conduct that make it difficult to do telemedicine properly. Such colleges have even criticized the practice of medicine realized exclusively by mail, telephone, radio, press, or the Internet (Ferrer-Roca, 2001).

One of the arguments used by the organizations of health care professionals to reject telemedicine concerns privacy. Although this is a legitimate concern, patient data can be more vulnerable in physical files in a medical filing room than in electronic records in a well-designed information system. Despite this, many interest groups resist change in the name of the right to privacy (Kirsch, 2002).

One of the most reasonable concerns of telemedicine professionals is the doubt about whether telemedicine can really substitute properly for face-to-face care. For example, in a videoconference-based telemedicine project involving Hope Hospital, in Salford (UK), and the University of Salford, nurses tried to monitor the neonatal intensive care unit from a distance. Many participants complained that the image quality made it impossible to detect the subtle color changes in the infants' pallor, and that the sound quality made it impossible to correctly hear their breathing (Qavi, Corley, & Kay, 2001). On the other hand, physicians' acceptance of telemedicine is strongly influenced by psychological and perceptual factors. Thus, physicians' acceptance of telemedicine depends on: their attitude towards the use of technologies in general, their previous experience in using technologies (Qavi et al., 2001), and their perception that the technologies are easy to use, and that they will prove useful in their work (Hu et al., 1999).

These psychological factors suggest some useful conclusions for the management of human resources in telemedicine projects. Managers need to cultivate a favorable attitude towards the general use of technologies among health care staff (Hu et al., 1999). To achieve this objective, the health care organization that is promoting the telemedicine project should communicate clearly and to all concerned the utility of the technologies in medical work. Technical and informational sessions need to be organized to communicate their utility for medical practice. It will not always be possible to reduce the perception that some technologies are difficult to use, but this problem can be alleviated through intensive training courses. To encourage acceptance of change, these courses should focus on how the new technologies can make patient care and the services provided to patients more efficient, rather than on how they should support the already existing organizational routines.

The need for training and preparation in the use of the technologies supporting telemedicine is not reflected in the syllabuses of university medical departments (Ferrer-Roca, 2001). This is why many health care professionals fail to see the connection between their work and the technical issues (use of applications and databases, electronic interchange of data and image files, standards to use, etc.) or legal issues (IT security, data protection and privacy, international practice of telemedicine, etc.) that concern telemedicine.

Trust plays a key role in all collaboration relationships (Gefen, 2000), and this is particularly true in virtual relationships. Telemedicine projects that do not inspire trust among the physicians do not tend to encourage team working (Paul & McDaniel, 2004). Nevertheless, telemedicine brings its own additional problems in creating and maintaining trust. This is because telemedicine involves the participation of multidisciplinary teams, and in virtual processes that are different from the ones health care professionals are used to. Launching a telemedicine project can also be seen as a threat—as the first step in the replacement of the health care professionals by other professionals delocated geographically, even in other countries.

From the practical perspective, managers need to foster confidence in the telemedicine projects they are implementing if they wish the professionals to work together successfully in teams (Paul & McDaniel, 2004). For this, they should be aware that telemedicine depends on a social context in which the professionals may be reluctant to work together and may distrust the management's intentions. The most practical way of improving this confidence is by training, information sessions and meetings involving the participating professionals. At the same time, the management of the health care institution needs to make it clear that the intention is not to substitute the staff participating in the project, and offer incentives (salary, social, status, professional, quality of working life, etc.) to the participants (Ahern et al., 2006). Managers also need to emphasize the professional advantages possible from using telemedicine, and the improved service quality it can provide.

The most significant advantages of telemedicine for health care professionals are (Robinson et al., 2003; Wilson, 2005): quick access to information anytime, anywhere; real-time access to specialty consultations; access to continuing training; platform for learning specific medical techniques; fast diffusion of information, knowledge, and skills; generation of professional contact networks, useful for collaboration in work and in research; better communication and coordination between physicians; specialist support for primary care physicians treating patients; less traveling and loss of time spent reaching remote areas, working in teams, receiving training or learning specific techniques, and so forth.

Health care professionals also need to be informed about the benefits telemedicine can bring to their patients. These benefits include: fast access to health care services; specialty care under the supervision, or not, of the family physician; freedom to choose or switch hospitals and physicians; staying close to home and to relatives whenever possible; convenience for the patient; continuous improvement in the health care services; more information about the illness suffered and the prescribed treatment; less traveling and concomitant time wasted; prescription of over-the-counter (OTC) medicines, and so forth.

Some authors ask why some companies encounter difficulties and yet others prosper when using the same IT, and why IT-based advantages dissipate so quickly. Their response is that integration should be produced between the IT, complementary human resources, and business capabilities (Bruque-Cámara et al., 2004; Khatri, 2006; Melville et al., 2004; Powell & Dent-Micallef, 1997). The integrated management of IT and complementary resources and capabilities can be regarded as the most feasible path towards attaining IT advantages. A list of these complementary resources and capabilities is shown in Table 1.

The benefits of IT lie in its capacity to free up information throughout the organization. An artificial culture or structural constraints devalue the technologies. The philosophy of having an open organization and an open communication permits access to operational information and promotes informal and frequent communication across functional and project boundaries.

Consensus is not necessarily always positive for performance in a technological project—a low level of conflict enriches and enables innovation—but a high level of conflict is dysfunctional. Consensus reinforces the capacity of IT to expand communications and disseminate information. Conflicts rooted in territorial disputes or between health care professionals frustrate this consensus and inhibit the functionality of the technologies.

Management commitment increases the success of telemedicine projects, making resources available for their implementation, integrating IT into the organization's strategies and processes, and ensuring that the investment in IT will continue over time.

Another requirement for the adequate implementation of a telemedicine project is organizational flexibility. Implementing a telemedicine project provokes significant changes in the organization's structure, communication models, and power relationships. But individuals tend to show resistance to change (Pardo & Martinez, 2003; Rumelt, 1995). This resistance is even stronger if the changes imply the need to acquire new knowledge or to modify work routines.

The management capabilities listed in Table 1 include the need to take investment decisions regarding the technologies for telemedicine that are consistent with the organization's strategic planning. The technologies used in telemedicine cannot be chosen to meet operational health care needs in an improvised way; they must be adequately planned. At the same time, managers need to integrate the choice of the most appropriate technologies for the telemedicine projects being implemented into the strategic planning of the entire organization.

The technologies used to connect with the health care service providers and suppliers, although not regarded as telemedicine, are contained within the concept of e-health. As in other industries, specific standards of electronic data

Table 1. Complementary human resources and business capabilities (Source: Adapted from Powell and Dent-Micallef (1997))

Human resources	Business capabilities
• Open organization • Open Communication • Consensus • Commitment of managers • Flexibility	• Strategic planning and IT • Relationship with suppliers • Connect IT with suppliers • IT training • Redesigning processes • Orientation towards teamwork • Benchmarking

interchange (EDI) systems are put in place to facilitate electronic interaction with the providers. But such a system is of little use unless there is a relationship of open communication and trust with the provider. Thus, connecting electronically with the providers should be preceded by the establishment of mutual trust that creates a favorable environment for making investments in specialist technologies. This trust is essential because these specialist investments cannot always be used for interchanges with other providers. All this, of course, does not preclude the necessary contractual guarantees.

Implementing any technology is sure to fail if the individuals that are to use it do not have sufficient technical training. But the majority of university courses in the health care area do not include this training in their syllabuses. Although extrapolating traditional health care practice to the electronic universe may seemingly be immediate, in fact this is generally not the case. Some authors estimate that it takes about 2 years for health care staff to be trained to use telemedicine properly in medical practice (Ferrer-Roca, 2001). They need to relearn how to manipulate and interpret patient information (for example, from their electronic medical records), images (such as radiographs, high-resolution medical images, computer tomography scans, magnetic resonance imaging pictures, ultrasound images, electrocardiograms or echocardiograms, video images of endoscopic cameras, etc.), or sounds (for example, from electronic stethoscopes) (Rao, 2001).

Supporters of process reengineering argue that the traditional functional structure of organizations can mask the best way of conducting some processes at work. The organization's management should not invest in IT that immortalizes its current processes, but should instead find a new, more rational design for the processes. Indeed, the access to information and the support IT provides to communication dissolve traditional hierarchical and departmental boundaries, and enable work processes crossing these boundaries to be designed. In the case of telemedicine, it is essential to design new processes that meet the technical and health care needs of each telemedicine service (telenursing, teleradiology, telepathology, teledermatology, telecardiology, telesurgery, etc.), eliminating or automating many of the bureaucratic and administrative activities that clog up the process without adding any value to the traditional health care services.

One of the most important uses of IT lies in the support it offers for working in teams. Technologies such as e-mail, voice mail, conference by computer and videoconference make it possible to coordinate the asynchronous and geographically-separated tasks that normally hinder team working. Telemedicine frequently implies that there is an exchange of health information, without personal contact, between two physicians. Thanks to telecommunications technologies, telemedicine enables the exchange of health care information across geographic, temporal, social, and cultural barriers (Chau & Hu, 2004).

In telemedicine, as in other innovative applications of IT, benchmarking the best practices of other health care organizations is a fundamental tool. This procedure allows managers to precisely evaluate the characteristics, functionalities, benefits, applications, and costs of the technology. All telemedicine projects should avoid the mistake of "reinventing the wheel." Thus, when planning the telemedicine project the strategic analysis stage should carry out an in-depth study of the characteristics of other, similar telemedicine projects carried out in other organizations and countries.

FUTURE TRENDS

Implementing and managing IT cannot be undertaken independently of the management of other elements in the organization. The human resources and business capabilities of the managers are two vital factors for the success of any technological project, and, by extension, of any telemedicine project. In this respect, managers of telemedicine projects would be recommended to develop human resource management practices centering on: (1) the existence of a fluid communication between technical staff and the management; (2) the absence of any organizational conflict; (3) flexibility in the procedures and decision-making; (4) the use of inter-departmental working groups; (5) the explicit leadership of the top management in the process of technological renovation; (6) the dedication of efforts in training for the new technologies; (7) an inclination towards change of the organization members; and (8) the fit between the technology used and the socio-economic system of the organization (Bruque-Cámara et al., 2004).

Future research should examine whether these human resource practices have the same positive impact on the performance of IT-based projects in the health care sector as in other industries. In this respect, some particular characteristics of health care professionals should be considered, such as their feeling of professional autonomy, perception of a high social and professional status, and strong professional corporatism, the existence of protocols and organizational work routines that are difficult to change, the fact that the results of the work are not always easily observable, and the possession of knowledge that is difficult to structure and automate.

CONCLUSION

Now in its early years, telemedicine will have to overcome the same legal, financial, personal, and cultural obstacles that have confronted every other technological change in the history of medicine (Jarudi, 2000).

In this chapter we have analyzed various factors leading health care staff to reject telemedicine. Chief among these have been the obstacles to change generated by inertias in the current organizational routines, problems inherent to their nature as teleworkers, the irrational excuse of lack of time, the influence of the professional organizations' opposition, the impossibility of these technologies substituting for personal contact with the patient, the perception of the ease of use and utility of the technologies to be applied, the lack of training and preparation in the use of the technologies, and problems of trust for working in virtual teams.

Analysis of these obstacles to acceptance allows us to offer some practical implications for managers of the human resources involved in telemedicine projects. They would be advised to promote the trust of the participants, inform professionals about the benefits of telemedicine both for the professional and for the patient, and correctly manage the complementary human resources and business capabilities of the managers.

Many authors have forecast the rapid diffusion of telemedicine for supporting health care services provision, but in fact the new markets being created by these technologies are growing very slowly, rather like the acceptance of such technologies by health care professionals. The first thing that really needs to be done to ensure that a telemedicine project will work—and be accepted by the health care staff—is to combine the real and current needs with user-friendly technologies, so that current processes can work better, more quickly, and more cheaply (Kirsch, 2002).

REFERENCES

Aas, I. H. M. (2001). A qualitative study of the organisational consequences of telemedicine. *Journal of Telemedicine and Telecare*, *7*(1), 18–26. doi:10.1258/1357633011936093

Ahern, D. K., Kreslake, J. M., & Phalen, J. M. (2006). What is e-health: Perspectives on the evolution of e-health research. *Journal of Medical Internet Research*, *8*(1), e4. doi:10.2196/jmir.8.1.e4

Arjonilla-Domínguez, S. J., & Medina-Garrido, J. A. (2002). *La gestión de los sistemas de información en la empresa*. Madrid, Spain: Pirámide.

Audet, A. M., Doty, M. M., Peugh, J., Shamasdin, J., Zapert, K., & Schoenbaum, S. (2004). Information technologies: When will they make it into physicians' black bags? *Medscape General Medicine*, *6*(4), 2.

Bentley, K., & Yoong, P. (2000). Knowledge work and telework: An exploratory study. *Internet Research*, *10*(4), 346. doi:10.1108/10662240010342658

Bladwin, L. P., Clarke, M., & Jones, R. (2002). Clinical ICT systems: Augmenting case management. *Journal of Management in Medicine*, *16*(2/3), 188–198. doi:10.1108/02689230210434925

Bruque, S., & Medina, J. A. (2002). The technology paradox: Characteristics, causes and implications for information technology management. *International Journal of Information Technology*, *8*(1), 75–94.

Bruque-Cámara, S., Vargas-Sánchez, A., & Hernández-Ortiz, M. J. (2004). Organizational determinants of IT adoption in the pharmaceutical distribution sector. *European Journal of Information Systems*, *13*(2), 133. doi:10.1057/palgrave.ejis.3000490

Chau, P. Y. K., & Hu, P. J. (2004). Technology implementation for telemedicine programs. *Communications of the ACM*, *47*(2), 87–92. doi:10.1145/966389.966396

Croteau, A. M., & Vieru, D. (2002, January 7-10). Telemedicine adoption by different groups of physicians. In *Proceedings of the 35th Hawaii International Conference on System Sciences*, IEEE, Big Island, HI.

Darkins, A. W., & Cary, M. A. (2000). *Telemedicine and telehealth: Principles, policies, performance, and pitfalls*. New York: Springer Publishing.

Demiris, G., & Tao, D. (2005). An analysis of the specialized literature in the field of telemedicine. *Journal of Telemedicine and Telecare*, *11*(6), 316–319. doi:10.1258/1357633054893328

Ferrer-Roca, O. (2001). *La Telemedicina: Situación Actual y Perspectivas*. Madrid, Spain: Fundación Retevisión.

Fishman, D. J. (1997). Telemedicine: Bringing the specialist to the patient. *Nursing Management*, *28*(7), 30–32. doi:10.1097/00006247-199707010-00007

Gagnon, M. P., Lamothe, L., Fortin, J. P., & Cloutier, A. (2005). Telehealth adoption in hospitals: An organisational perspective. *Journal of Health Organization and Management*, *19*(1), 32–56. doi:10.1108/14777260510592121

Gefen, D. (2000). E-commerce: The role of familiarity and trust. *Omega*, *28*(6), 725–737. doi:10.1016/S0305-0483(00)00021-9

Hu, P. J., & Chau, P. Y. (1999). Physician acceptance of telemedicine technology: An empirical investigation. *Topics in Health Information Management*, *19*(2), 20–35.

Hu, P. J., Chau, P. Y., Sheng, O. L., & Tam, K. Y. (1999). Examining the technology acceptance model using physician acceptance of telemedicine technology. *Journal of Management Information Systems*, *16*(2), 91–112.

Jarudi, L. (2000). Doctors without borders. *Harvard International Review*, *22*(1), 36–39.

Khatri, N. (2006). Building IT capability in health care organizations. *Health Services Management Research*, *19*(2), 73–79. doi:10.1258/095148406776829095

Kirsch, G. (2002). The business of e-health. *International Journal of Medical Marketing*, *2*(2), 106–110. doi:10.1057/palgrave.jmm.5040062

May, C., Gask, L., Atkinson, T., Ellis, N., Mair, F., & Esmail, A. (2001). Resisting and promoting new technologies in clinical practice: The case study of telepsychiatry. *Social Science & Medicine*, *52*(1), 1889–1901. doi:10.1016/S0277-9536(00)00305-1

Melville, N., Kraemer, K., & Gurbaxani, V. (2004). Review: Information technology and organizational performance: An integrative model of it business value. *MIS Quarterly*, *28*(2), 283–322.

Pardo del Val, M., & Martinez Fuentes, C. (2003). Resistance to change: A literature review and empirical study. *Management Decision*, *41*(1/2), 148–155.

Parente, S. T. (2000). Beyond the hype: A taxonomy of e-health business models. *Health Affairs . Chevy Chase*, *19*(6), 89–102.

Paul, D. L., & McDaniel, R. R. Jr. (2004). A field study of the effect of interpersonal trust on virtual collaborative relationship performance. *MIS Quarterly*, *28*(2), 183–227.

Powell, T. C., & Dent-Micallef, A. (1997). Information technology as competitive advantage: The role of human, business, and technology resources. *Strategic Management Journal*, *18*(5), 375–405. doi:10.1002/(SICI)1097-0266(199705)18:5<375::AID-SMJ876>3.0.CO;2-7

Qavi, T., Corley, L., & Kay, S. (2001). Nursing staff requirements for telemedicine in the neonatal intensive care unit. *Journal of End User Computing*, *13*(3), 5–12.

Rao, S. S. (2001). Integrated health care and telemedicine. *Work Study*, *50*(6/7), 222–228. doi:10.1108/EUM0000000006034

Robinson, D. F., Savage, G. T., & Campbell, K. S. (2003). Organizational learning, diffusion of innovation, and international collaboration in telemedicine. *Health Care Management Review*, *28*(1), 68–92.

Roine, R., Ohinmaa, A., & Hailey, D. (2001). Assessing telemedicine: A systematic review of the literature. *Canadian Medical Association*, *165*(6), 765–771.

Rumelt, R. P. (1995). Inertia and transformation. In C.A. Montgomery (Ed.), *Resource-based and evolutionary theories of the firm: Towards a synthesis* (pp. 101-132). Kluwer Academic Publishers.

Sands, D. Z. (2004). Help for physicians contemplating use of e-mail with patients. *Journal of the American Medical Informatics Association*, *11*(4), 268–269. doi:10.1197/jamia.M1576

Tachakra, S. (2003): Telemedicine and e-health. In *Business briefing: Global health care 2003*. World Medical Association.

Wilson, P. (2005, September). *My health/my e-health. Meeting the challenges of making e-health personal.* Paper pesented at ICLM9, Brazil

Wootton, R. (2001). Telemedicine. *British Medical Journal*, *323*, 557–616. doi:10.1136/bmj.323.7312.557

KEY TERMS

E-Health: The provision of any health care service that is supported by electronic processes and communications.

Electronic Medical Records: Computer-based patient medical records. Patient medical records are a systematic documentation of a patient's medical history and care.

Over-the-Counter (OTC) Medicine: A medicine that can be bought without a doctor's prescription, such as some analgesics.

Telecardiology: The digital transmission between health care professionals of information relating to electrocardiograms, echocardiograms, angioplasty, and cardiac pacemaker monitoring.

Teledermatology: The digital transmission between health care professionals of images of the skin using a dermascope.

Teleendoscopy: The digital transmission between health care professionals of the results of endoscopic examinations.

Telemedicine: The use of information and communications technologies to exchange information between practitioners, or to deliver medical services to a patient remotely.

Telemonitoring: The remote monitoring of patients' state of health. It is fundamentally used to control and treat chronic patients.

Telenursing: Health care services provided by nurses remotely, such as monitoring patients in their homes or referring patients to the appropriate medical services through the processing of patient data.

Telepathology: The digital transmission between health care professionals of high-resolution images of, for example, microscope slides, photographs of injuries or smears, and so forth.

Teleradiology: The digital transmission between health care professionals of electronic radiology images such as X-rays, computerized axial tomography scans, or magnetic resonance images.

Telesurgery: Remote surgery using robotics and audio/video devices.

Virtual Health Care Teams: Teams made up of health care professionals that share information about patients electronically in order to improve their knowledge and decision-making.

This work was previously published in Handbook of Research on Virtual Workplaces and the New Nature of Business Practices, edited by P. Zemliansky and K. St.Amant, pp. 681-691, copyright 2008 by Information Science Reference (an imprint of IGI Global).

Chapter 6.3

Investigating Trust Relationships in a Healthcare Network[1]

Stefanie Kethers
Monash University, Australia

Günter Gans
RWTH Aachen University, Germany

Dominik Schmitz
Fraunhofer FIT, Germany

David Sier
CSIRO Mathematical and Information Sciences, Australia

ABSTRACT

Public hospitals currently face an ever increasing demand on their resources, and there are many attempts at streamlining processes and patient flows. However, in many cases, optimizing processes is not enough, as 'soft' factors such as the relationships between hospital wards influence how efficiently the resources needed to treat patients are utilized. These factors are often ignored when attempting to improve patient flows. In this chapter, the authors describe a case study investigating the relationships between an acute stroke ward and a specialist stroke rehabilitation ward of a large metropolitan health service. The motivation for this study was the hospital management's interest in improving communication and collaboration across wards as a means to optimize hospital processes, and thus, patient care. To assess the relationships between the two wards, the authors examined the patient handover process that links the wards' activities and applied the Trust-Confidence-Distrust (TCD) framework of Gans et al. (2003), which was developed to model trust relationships in social networks, to examine the trust relationships between the wards.

INTRODUCTION

Public hospitals are under a lot of pressure to improve both their efficiency and service quality, and many hospitals have therefore been spending time and effort to optimize their processes. For example, Ramakrishnan et al. (2005) note that attempts to reduce the lengths of waiting lists for elective procedures and long stays in emergency departments often focus on policy setting, clinical process mapping, or capacity models of patient flows. However, perfectly well-designed processes can run less than smoothly if they fail to address the human side of patient movement through a hospital. In many cases 'soft' factors such as the relationships between hospital staff in different wards along a clinical pathway will determine how efficiently the resources needed to treat patients are utilized. In many situations these factors are ignored when attempting to improve patient flows.

In this paper, we describe the application of the Trust-Confidence-Distrust (TCD) framework defined by Gans et al. (2003) to the investigation of trust relationships between two hospital wards engaged in a patient handover process. This case study represents one of the first applications of the TCD framework to a real-life situation with real-life data. Given that the two wards were part of a large metropolitan health service which is more similar to an organization than to the social network described by Gans et al. (2003), we were particularly interested to see which aspects of the framework were still applicable, and which ones were not.

This paper is structured as follows: In the subsequent section, we outline the background of our study. Then, we briefly describe the TCD framework for analyzing trust relationships. Afterwards we give an overview of the case study we performed, including the setting. Having introduced the research methodology, especially the data capture process, we describe our analysis of the trust relationships using the TCD framework. Eventually, we evaluate the applicability of the TCD framework to the context of our case study and briefly sketch future trends.

BACKGROUND

In health informatics, clinical, organizational processes are mainly investigated in regard to how they can be supported or improved by information technology. Even though this is not the focus of our contribution, such analyses presuppose means to describe and model these processes. Due to the focus on information systems, typical process modelling notations such as event-driven process chains (Scheer, 1994), Petri net based workflow notations (van der Aalst and van Hee, 1996), or languages like the business process modelling notation BPMN (www.bpmn.org) are commonly used. In (Framinan et al., 2005) some have been investigated in the context of business process reengineering of clinical processes. They allow capturing the timely relation of activities and the assignment of resources and responsibilities of involved actors. Also Saboor et al. (2007) propose a method, named MedFlow, to support the systematic assessment of clinical processes focusing on the quality of information logistics. They derived relevant quality criteria from literature, developed an extended process modelling notation based on UML activity diagrams, and evaluated the method in a preliminary case study. Their analysis distinguishes four different process aspects, i.e. control flow, data flow, tool usage, and organizational information. For each of them, a rule-set that represents a "pattern of critical cross-points" was used, to detect weak points within these views. A shortcoming of these modelling means is that the human side of the process, the social interaction of the people that carry out these processes and for example, trust issues that are involved, are neglected. When trust is investigated in the context of health informatics, mostly three fields are considered: how to build up trust in online communities or health information on the web (Luo and Najdawi, 2004; Song and Zahedi, 2007), trust issues in the context of electronic health records (Smit et al., 2005), or regarding the physician-patient relationship.

Networked organizations in health care have already been explored by Peterson et al. (2000). They focused on the foundational constitution and enabling conditions. From their observations they derived that networks "develop through different phases of maturity and network-ability". While the study concerned IT as the enabler, they emphasized that IT is a facilitator but not the major driver for the direction and development of the network. "[It] is the organisation, its professionals and management that ultimately drive networking." Similarly when Avison and Young (2007) investigated the failures of ICT projects in the field of health care, they identified two main reasons: For one, health care should not be treated at an enterprise level but on a national scale. For another, they emphasized that "better person-to-person models are needed to understand how the collegiate and interpersonal elements of care delivery could be embodied better in the systems used for care delivery." Thus, while focussing IT support they again also emphasize the need to consider social interactions.

We thus agree with the views expressed by Avison and Young, and Peterson et al. and others, e.g. (Coiera, 2004): "Since health systems are sociotechnical systems, where outcomes emerge from the interaction of people and technologies, we cannot design organisational or technical systems independently of each other". Therefore, we have employed the Trust-Confidence-Distrust (TCD) framework, as described in the next section, to investigate the social interactions in the transfer of stroke patients from an acute ward to a rehabilitation ward. We have paid special attention to the perceptions that the people involved have of this process; in particular, how staff members of the two wards see the other ward's goals and priorities. As Wachter and Shojania (2004) state, "Psychologically, human beings simply communicate better and more often with people they know than with strangers—particularly if they feel those others are on the same team, have the same interests, and share the same goals".

The next section describes the Trust-Confidence-Distrust (TCD) framework in more detail.

THE TCD FRAMEWORK

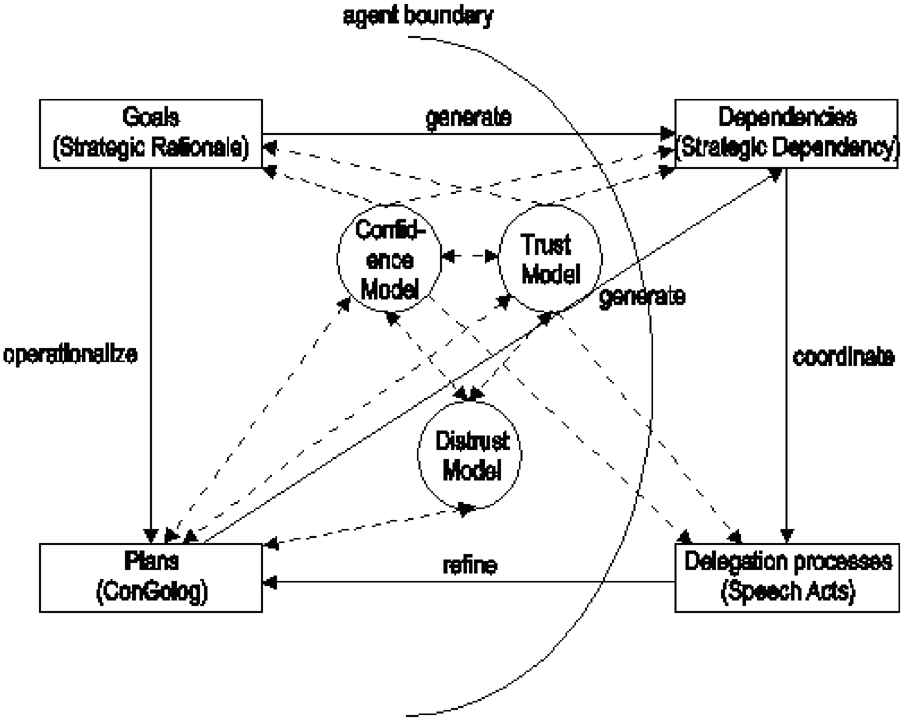
The TCD framework was developed for application in a social network, which Gulati (1998) defines as "a set of nodes (e.g., persons, organizations) linked by a set of social relationships (e.g., friendship, transfer of funds, overlapping membership) of a specified type". Weyer (2000) expands on this idea by defining a social network as an autonomous form of coordination of interactions whose essence is the trusting cooperation of autonomous, but interdependent agents who cooperate for a limited time, considering their partners' interests, because they can thus fulfil their individual goals better than through non-coordinated activities. The "agents" in this definition can be organizations or people, or people representing, or working for organizations. According to Powell (1990), networks rely on reciprocal patterns of communication and exchange, and reciprocity and complementarity are essential for the success of a network: "In essence, the parties to a network agree to forego the right to pursue their own interest at the expense of others". As Powell (1990) states, networks are well suited for situations where there is "a need for efficient, reliable information."

In contrast to those of a network, Powell (1990) lists stability, reliability, and accountability as the main strengths of an organization (also called a hierarchy). In an organization, management defines work roles and administrative procedures. Work is often highly specialized and therefore interdependent. As Powell (1990) states, "relationships matter and previous interactions shape current ones, but the patterns and context of intra-organizational exchange are most strongly shaped by one's position within the formal hierarchical structure of authority". In an organization, there is less freedom of choice for the individual agents, as they are constrained by organizational rules and policies. Given that our case study took place in an organizational, rather than a network, environment (cf. next section), we were particularly interested to see whether the TCD framework was applicable to our setting.

In our investigation of trust, confidence, and distrust, we stay in accordance with the definitions given by Gans et al. (2003): We follow the definition of Mayer et al. (1995) of trust as "the willingness of a party to be vulnerable to the actions of another party based on the expectation that the other will perform a particular action important to the trustor, irrespective of the ability to monitor or control that other party". Trust thus occurs between two agents, the trustor and the trustee, and has an element of risk, since the trustor cannot ensure that the trustee will perform the action. In social networks, trust needs to be distinguished from what Gans et al. (2003) call confidence, and Luhmann (1988) calls system trust, in the network as a whole. This is because a network's mesh of dependencies is not completely visible to, let alone manageable by, the trustor. Thus, participation in a social network results in a double vulnerability: to identifiable opportunists, and to the generally incomprehensible mesh of dependencies between all the network partners. Participation in such a network therefore requires confidence in the network (e.g. its rules and stability) as a whole. The third relevant concept described by Gans et al. (2003) is distrust, which the authors distinguish from lack of trust; cf. also Lewicki et al. (1998). For example, a dissatisfied network member can cultivate, but hide her distrust while still exhibiting trustful behaviour. This means that the agent continues as a network member, postponing her decision for voicing dissatisfaction or exiting the network, but starts to collect information (which can be costly and time-consuming), by, for example, monitoring other network members' actions. The agent then typically interprets this information in a subjective way that is strongly influenced by her distrust. According to Luhmann (1988), distrust therefore has an inherent tendency to become stronger.

Gans et al. (2003) call the model describing the interplay of trust, confidence, and distrust, and its effects on the relationships within the network the TCD framework. Figure 1 shows how the TCD framework can be formalized as a multi-perspective framework based on formalisms taken from requirements engineering and computer science at large. By managing the static and dynamic interrelationships through reasoning and/or simulation, the possibly conflicting perspectives and viewpoints can be dealt with. The left side of Figure 1 depicts the intra-agent modelling aspects of the framework, that is, an agent's goals, which are represented by i* strategic rationale models described by Yu (1995), and plans. Plans are based on the strategic rationale diagrams together with pre- and post-conditions using the ConGolog formalism. ConGolog, described in De Giacomo et al. (2000), is a logic-based high-level planning language used in artificial intelligence approaches which is suitable for describing and representing processes. The right hand side of Figure 1 shows the inter-agent aspects, namely, the strategic dependencies between agents, represented as Yu's (1995) i* strategic dependency diagrams, and the implementation of these dependencies in delegation processes formalized as Speech Act diagrams (see Schäl (1996)). We prefer the i* formalism (strategic rationale (SR) and strategic dependency (SD) models) to other languages like UML, ER diagrams, or Petri nets, because it is explicitly designed to cope with strategic goals and agents' intentions, and furthermore is equipped with formal semantics. Thus, as a main feature, it allows not only to reason about the "how" but also about the "why" of different alternatives. The solid lines in Figure 1 indicate the nature of the interrelationships between these different perspectives. For example, strategic dependencies shape and lead to delegation patterns, and the latter are evaluated partially with respect to the former. Conversely, strategic goals lead to operational plans, which

Figure 1. Interplay between modelling perspectives



then potentially generate strategic dependencies on other agents. Trust, confidence, and distrust, depicted in the middle part of the figure, influence the four main components of the framework, as well as each other (represented as broken lines). For example, the level of trust between agents will influence one agent's propensity to become dependent on the other, say for specific tasks or resources, and the level of distrust can lead to the addition of monitoring tasks to the operational plans. These monitoring tasks may increase or decrease the level of distrust felt by the agent.

While trust has been studied in the social sciences for many years, its formalization from a computational point of view has not been studied for very long. Some approaches like us, view trust as a subjective probability or provide logical approaches to modelling trust. None of the approaches in the literature seem to give distrust a special status. In (Gambetta, 1988), the prevalent view of trust is that of a subjective probability, which, roughly, amounts to the likelihood (assigned by the trusting agent) that another agent will perform a task or bring about a desired situation on which the trusting agent depends. Other work along this line includes (Coleman, 1990; Marsh, 1994; Witkowski et al., 2000). Game-theoretic approaches analyze trust using the iterated Prisoner's Dilemma as a benchmark (Axelrod, 1984; Boon and Holmes, 1991). Castelfranchi and Falcone (1999; 2001) propose a more fine-grained model. It takes into account the agent's mental attitudes such as the trusting agent's beliefs about the trustee's opportunity, ability, and willingness to perform a desired task. A quantitative measure of trust has the advantage that it lends itself nicely to computing a decision whether to delegate a task to a trustee or to update the level of trust depending on the outcome of an interaction with the trustee. Gans et al.'s method for modelling trust is also different from Yu and Liu (2001)'s approach to describe trust relationships in i*. Yu and Liu (2001) propose a purely qualitative approach using softgoals with corresponding contributions.

THE CASE STUDY: TRANSFER OF STROKE PATIENTS BETWEEN WARDS

The goal of this case study was to investigate trust relationships between wards along a clinical pathway with the aid of the TCD framework described in the previous section. The study was commissioned by Southern Health, a large metropolitan health service in South Eastern Melbourne, Victoria, Australia. Southern Health provides public hospital services, aged inpatient, community and home care services, and inpatient and community mental health services across an area in excess of 2,800 square kilometres with a population of over 700,000 people (see http://www.southernhealth.org.au/). Southern Health services are provided through five major hospitals and nine community health services centres. Two clinical services directors together with operations directors at each location manage the different services. Each director reports to the chief executive, who reports in turn to the hospital board. Thus, Southern Health can be classified as a (distributed) organization rather than a network of independent partners. Our study involved the investigation of stroke patient transfers between an acute ward and a rehabilitation ward located on different sites. A mix of medical and allied health staff are involved in the transfers. These people report to different program managers, although ultimately the management responsibility for both the acute and sub-acute patients lies with the head of the Neurology program.

Stroke is the third highest cause of death, and the leading cause of chronic disability in adults in Australia (see Pollack and Disler (2002)). In our investigation we focused on the handover process of stroke patients from the acute ward (AW) to a specialized rehabilitation unit (RW). This unit is the major stroke rehabilitation facility. Stroke patient rehabilitation is a scarce resource needing a coordinated, multi-disciplinary team approach (Pollack and Disler (2002) give an overview of the different roles and stakeholders in stroke patient rehabilitation), so there is a significant amount of cooperation required within a ward, and between wards such as AW and RW. AW and RW are physically located in two different hospitals, separated by a 30-minute drive. Patel et al. (2000) claim that, given that face-to-face communication is an important part of developing and maintaining a shared understanding of team goals and maintaining trust, geographical separation is a potential obstacle to implementing good team processes. Consequently, we were interested in finding out whether the two wards managed to see each other as a team working together towards the shared goal of caring for the patient, or whether there were significant misconceptions about the other ward's work. As Suchman (1995) notes, "work has a tendency to disappear at a distance, such that the further removed we are from the work of others, the more simplified, often stereotyped, our view of their work becomes" (see also Wachter and Shojania (2004)).

Because our focus was on the trust, confidence, and distrust relationships between wards AW and RW, we wanted to capture the stakeholders' perceptions of the handover process. In this context, the stakeholders are the wards; specifically, the health professionals in the acute ward who prepare patients for discharge to the sub-acute area and those in the rehabilitation ward who carry out the patient admission procedures. Stakeholder perceptions are an important indicator of the performance of the transfer processes; in particular, the perceptions in one ward can identify failures in the process not evident to the other ward.

RESEARCH METHODOLOGY

To collect the required information, we followed the Co-MAP method described by Kethers (2002) to obtain the process information for the "a priori goal and capability analysis" postulated by Gans et al. (2003). The main advantage of this method is the strong semantic model underlying the captured data, which allows formal mapping of the data into different perspectives on the investigated process. After an initial meeting with the Nursing Director and members of the Allied Health Rehabilitation and Aged Services Program, we conducted two focus group meetings, each with a team from one ward, to capture that ward's view[2] of the interactions within the ward and with external units, including the other ward. In these meetings, the group developed informal process diagrams (see Figure 2 for an example) that focus on the interactions and information flows within and between the two wards. Information flows between agents are captured as arrows between ovals representing sender and receiver of the information. Graphical symbols are used to represent the media for information flows (for example, phone, formal document, or meeting), and the recipient's perception of the quality of the information flow (e.g., a tortoise for "too slow", or a stop sign for "does not occur at all"). A more detailed description of the different graphical symbols is given by Kethers (2002). During one of the focus group meetings, we became aware of the role of the Rehabilitation Liaison Officer (RLO) who acts as an interface between the wards, so we conducted an additional interview with her.

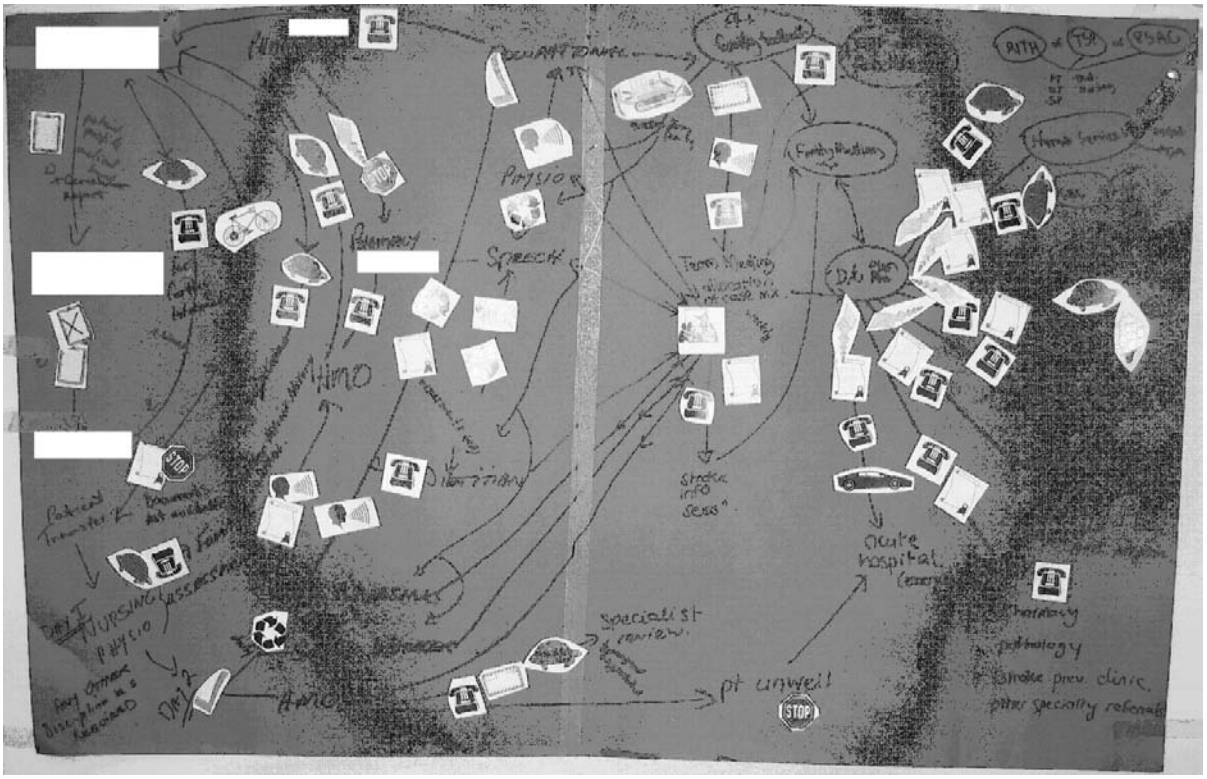
Based on the informal process diagrams, meeting notes, and additional information collected, we developed the different perspectives on the process shown in Figure 1. As a first step, we developed two strategic dependency (SD) models (see Yu (1995)), one for each ward's perspective concerning the patient transfer process. In a second step we refined our models to strategic rationale (SR) models in order to regard the actors' internal actions as well as their interactions. To identify trust, confidence, and distrust issues in a third step, we then analyzed the different diagrams by regarding the different stakeholders' (the two wards' and the RLO's) perceptions of the process, identifying conflicting views of what is really happening in the scenario, tracking the effects on trust relationships between the wards, and recognizing the effects of these relationships on the process.

APPLICATION OF THE TCD FRAMEWORK

The SD model (a detailed description is given in Yu (1995)) describes the network of relationships among agents (nodes) by specifying dependencies (links) between them. A dependency relationship enables the depender to do things that she would otherwise not be able to, but also makes her vulnerable if the dependee does not fulfil the dependencies. The model offers four dependency types: goal, task, resource, and softgoal dependencies, which differ according to the degree of freedom they leave for the dependee.

The SD models shown in Figure 3 are structured as follows: The circles show the two wards, the arcs show what one ward wants or needs from the other ward. The direction of the 'D's on an arc shows the direction of a dependency. For example, the lowermost arc in the left half of Figure 3 (RW's view) shows that RW depends on AW for a "quick reaction if a patient is unwell". Rectangles represent a resource, such as a piece of information, for example "Feedback about patient" as shown in Figure 3 (AW's view). Boxes with rounded edges represent goals that can be measured, for example in Figure 3 (RW's view), the need expressed by RW for "one contact person for each discipline" at AW. The irregular shapes represent so-called "soft goals" – goals that are

Figure 2. Informal process diagram

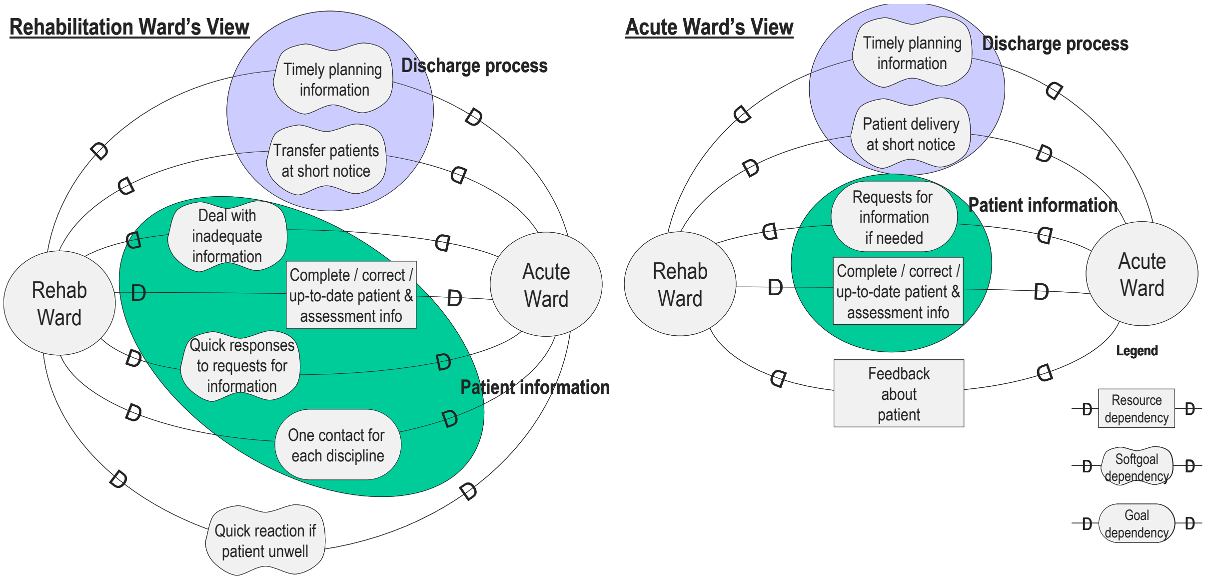


subjective and cannot be precisely measured, for example RW's requirement for a "quick reaction if patient unwell" from AW. In this case, does 'quick' mean 5 minutes or 2 hours?

The SD models show that each ward attributes different and sometimes very stereotyped goals and intentions to the other, even though the main goal for both wards should be (and is!) the welfare of the patient. As an example taken from Figure 3, for the patient transfer process, RW sees AW as trying to move patients out as fast as possible (RW's view, softgoal: "Transfer patients at short notice"), whereas AW sees RW as expecting patients to be handed over at very short notice (AW's view softgoal: "Patient delivery at short notice"); sometimes, we were told, in as little as three hours. Because the discharge documentation that has to accompany the patient has to be compiled by different staff members, by the pharmacy, etc., this extreme time pressure can lead to a lack of coordination in the collection of discharge documents. As a result, incomplete or outdated information can be transmitted from the acute to the rehabilitation ward, which is not what RW expects or wants (RW's view, resource: "Complete / correct / up-to-date patient & assessment info").

Based on the dependency diagrams, and the additional information obtained in the focus group meetings and interviews, we developed extended SR models as described by Gans et al. (2003) for AW, RW, and the RLO. SR diagrams (see Yu (1995)) describe the intentional relationships that are internal to actors, so that they can be reasoned about. Nodes of the model represent goals, tasks, resources, and softgoals, respectively, while links represent either means-ends links, or task decomposition links. The original SR mod-

Figure 3. Strategic dependency diagrams

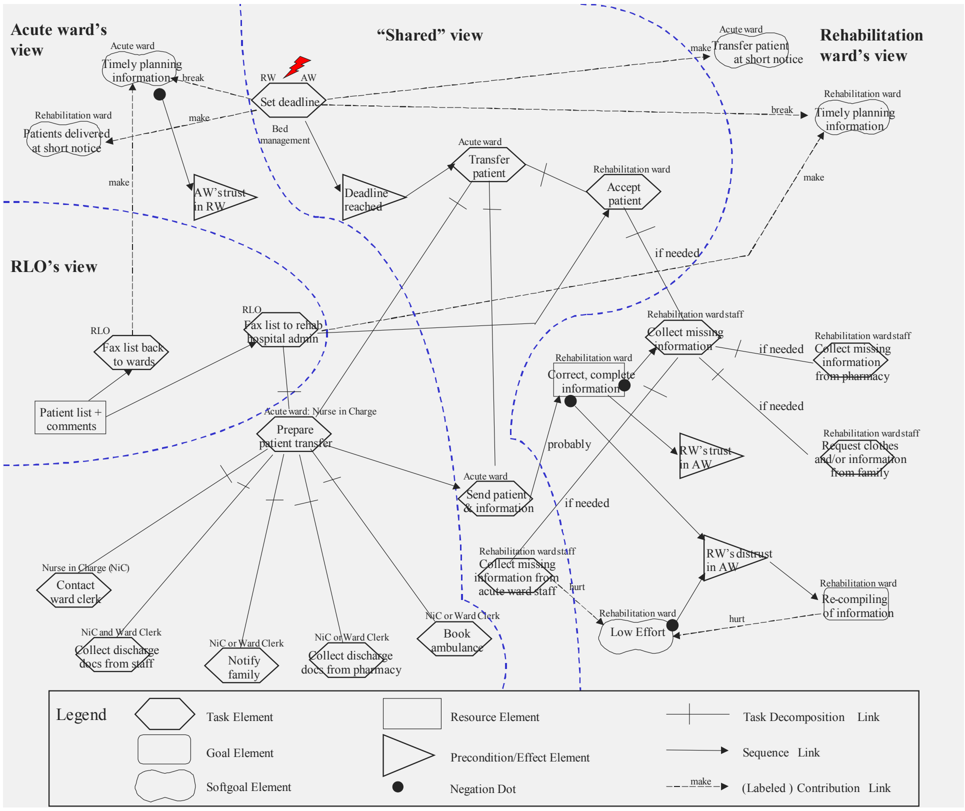


els contain only strategically relevant elements; hence, Gans et al. extended them for operational use. For example, in Figure 4, the task "Transfer patient" is decomposed into five subtasks which are timely ordered. Negation dots, e.g., at the resource "Correct, complete information", stand for a missing resource or the logical negation of a precondition, goal, or softgoal. Contribution links are labelled according to their effects on softgoals (make, break, help, hurt) and finally only if the "Deadline reached" precondition holds the "Transfer patient" task can be initiated.

Relevant excerpts from the three different views of the patient transfer process as held by AW, RW, and the RLO, respectively, are integrated into a combined SR model shown in Figure 4. Interestingly, as can be seen in Figure 4 and was stated by the RLO in the interview, AW should know in advance which patients will need to be handed over within the next few days, since a list of those patients is faxed to the wards. Thus, AW should be able to compile the discharge documentation with sufficient prior warning. In addition, the patients' complete medical record is sent, together with the discharge documents, to the rehabilitation hospital's administration, where it would be available to RW staff for a few days before admission. Also, given that the rehabilitation hospital administration receives the list of patients, RW does – at least in theory – have access to timely planning information, as well. Unfortunately, however, neither AW nor RW seem to be able to make use of this information.

The conflicts which were identified on the strategic dependency and strategic rationale diagram level, of course, affect the trust relationships. First of all, the models reveal that there was little direct and positive interaction between AW and RW, and there were no trust-building or relationship-building activities planned into the process. Information flowed from AW to RW, but there was almost no information flowing back from RW to AW. In particular, although AW mentioned that they would like to hear about "their" patients' progress in the rehabilitation ward (see the "Feedback about patient" resource dependency in Figure 3), there is no communication of patient status information from RW to AW unless some-

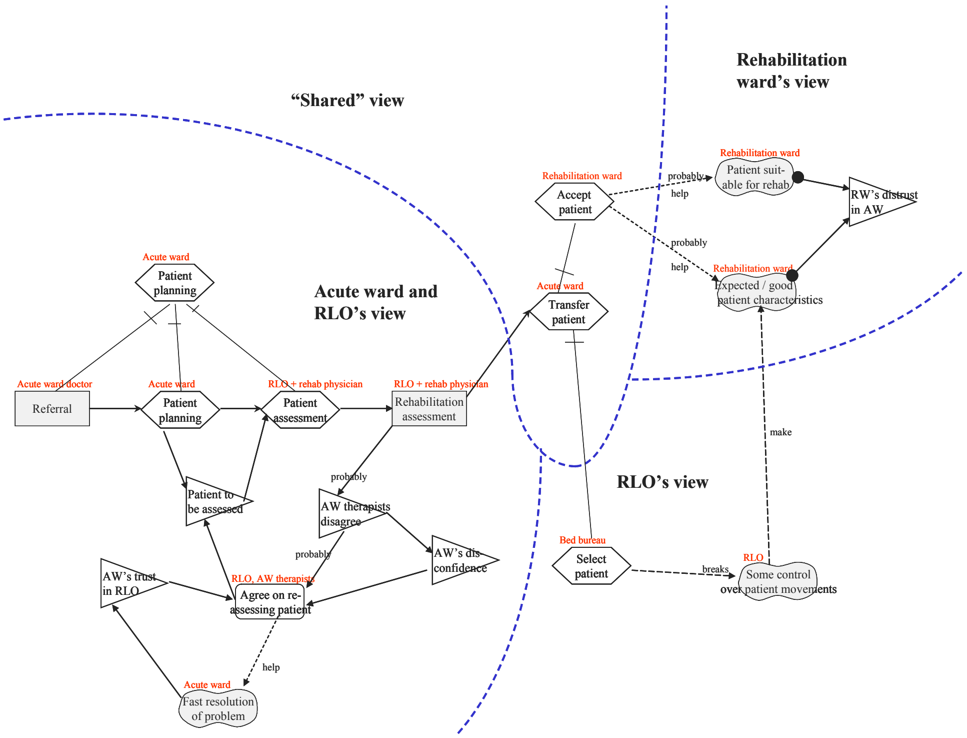
Figure 4. Combined extended SR mode: Patient transfer between wards



thing untoward happens to the patient, when RW expects (and gets) a quick reaction from AW. This is not conducive to establishing trustful relationships between the wards. In contrast to this, the physical proximity of team members within each ward (including, in the case of AW, the location of the RLO in the same building) leads to good relationships, trust, and understanding, resulting in extremely good (ad-hoc) communication and cooperation.

A main source of distrust in the patient transfer process results from the accompanying patient information documents. There are conflicting ideas about who is actually responsible for ensuring that the patient information is complete (cf. Figure 3). RW staff members consider it their right to receive complete, correct, and up-to-date information; and chasing up what is missing takes up a large amount of time, which is seen as frustrating. AW on the other hand holds the opinion that RW receives as much information as is possible under the circumstances (remember that AW sees RW as driving the timeframes for the transfer process). Thus, RW staff should be able to cope with the information they receive, and, if not, it is their responsibility to request additional information that is required. This difference in expectations creates resentment and increases distrust on both sides. For RW, this distrust means that the information coming from AW is often not trusted, even when apparently correct patient information is provided. Instead, RW duplicates AW's work by compiling the information again. As another example, consider the extended SR model of the patient assessment shown in Figure 5. The assessment of a patient is performed by RLO and a rehabilitation physician, who visit the patient on the acute ward. The outcome of that assessment determines whether

Figure 5. Combined extended SR model: Patient assessment



the patient is send to a rehabilitation ward. RW sometimes considers some of the patients that AW sends them unsuitable. However, RW does not seem to discuss these cases with AW, and has no direct access to the RLO, who is located in AW's hospital. In fact, RW staff did not mention the RLO at all during the focus group meeting. Instead, RW can get frustrated at seemingly unsuitable patients being sent from AW, and RW's distrust in AW increases.

Confidence is a less important issue here, because the metropolitan health service is a stable organization with less choice for the agents involved, and more rules and constraints than the social networks described by Gans et al. (2003). However, due to dis-confidence, by which we mean dissatisfaction with these rules and constraints, agents sometimes circumvent those rules and processes that are seen as producing the wrong results. In the patient assessment example (see Figure 5), AW therapists sometimes disagree with the patient assessment results. The therapists feel that they know the patient better, due to their long-term observation, than a doctor could from a short visit, especially if the patient has a bad day. In these cases, the therapists often use the strong relationship they have with the RLO to voice their concerns and initiate a reassessment at short notice (see the bottom left corner of Figure 5), which is not intended to happen in the clinical process. As described above, RW does not have that option.

EVALUATION AND CONCLUSION

In this evaluation of the applicability of the TCD modelling approach, we applied the framework in a more organizational setting than described by Gans et al. (2003). This means that there are more rules, constraints, and procedures than in a typical social network. This in turn leads to less freedom for the agents (individuals or wards) to change their work processes, for example by changing their delegation behaviour, according to their level of trust, confidence, or distrust in the other agents. In addition, the delegation processes were predetermined due to lack of alternatives, as well, so they did not provide many insights, either. From this it follows that we do not need to apply the more dynamic perspectives from the TCD framework, namely plans and speech acts. In this case study, SD and extended SR diagrams are sufficient to extract information on the trust relationships between the wards.

The data capture method we employed focused on recording the different parties' perceptions of the patient handover process, which we later found very useful in understanding the trust and distrust relationships between the people involved. The information flow diagrams (Figure 2) indicated not just the different agents' activities, but also, for example, where information was perceived as being too late, or of too low quality. The SD and SR diagrams (Figure 3, Figure 4, and Figure 5) resulting from the initial process diagrams, together with our meeting notes, indicated (real and perceived) conflicting goals and expectations that were not met. These lead to manifestations of distrust, which in turn lead to re-work, e.g. recompilation of information by RW, and dis-confidence, e.g. when AW staff exploit their good relationship with the RLO to circumvent the defined patient assessment process. Thus, generally, we found the TCD framework to be applicable also in this more organizational setting.

We believe that understanding and evaluating trust relationships is crucial to supporting people's work processes, and that, ultimately, any ICT aimed at improving the performance of people working together will need to take such 'soft factors' into account to be truly effective. While many aspects of this problem are still open research questions, we hope that our case study has provided some validation of the TCD framework as one methodology for investigating trust relationships in both organizational and network settings preceding, and complementing, the development of any ICT support.

FUTURE TRENDS

An integration of the findings of research on trust, distrust, and confidence in cooperation processes – as it has been presented here – into environments for computer-supported cooperative work (CSCW), such as shared workspaces (e. g. see BSCW (http://www.bscw.de)), seems a logical next step. A key point in this regard concerns addressing awareness issues (Dourish and Bellotti, 1992). Recent approaches try to tailor the awareness notifications to the current, situation-dependent needs of each collaborator (Wang et al., 2007). This fits quite well with the consideration of monitoring within the TCD framework. Gans (to appear) describes a framework of monitoring in social networks that is mainly controlled by distrust and dis-confidence. He states that discrepancies between expectations on one hand and objective as well as subjective experiences on the other hand combined with current distrust and dis-confidence steer the wish to monitor or observe ongoing activities or processes. Comparing this wish to monitor with the costs of monitoring, it leads to real monitoring activities by gathering information that are beyond the usual information flow. The new information firstly is added to the experiences made in this context, secondly influences distrust and dis-confidence, and thirdly leads to activities, for example activities that should change misleading processes.

Hence, in distrust and dis-confidence related parts of our health care domain (for example, the patient transfer) it could be interesting to ask questions of the following kind: How important could it be to observe the activities between AW and RLO? How costly is monitoring in this context and therefore how efficiency-reducing? Which conclusions can be drawn by RW besides the cultivation of distrust and dis-confidence, for instance, to what extent can RW influence, and therefore improve, the patient transfer process? Is the level of distrust or dis-confidence already above a certain threshold where self-strengthening effects take place? Here, the more dynamic parts of the TCD methodology could also provide viable input.

Furthermore, social network analysis is recently gaining more and more attention. Westbrook et al. (2007) use it as a means to understand how the impact of information and communication technologies in health care organizations can be investigated. Ongoing work tries to integrate social network analysis with the i* modelling language and the TCD approach in particular (Jarke et al., 2008). Of particular interest are the extensions that are able to take the dynamics of evolving relationships into account. First approaches (Klamma et al., 2006) that match expectations in regard to emerging structures modelled with i* with the outcome of social network analyses via a suitable pattern language already exist, but have not yet been applied to a health care setting.

REFERENCES

Avison, D., & Young, T. (2007). Time to Rethink Health Care and ICT? *Communications of the ACM*, *50*(6), 69–74. doi:10.1145/1247001.1247008

Axelrod, R. (1984). *The Evolution of Cooperation*, New York: Basic Books.

Boon, S. D., & Holmes, J. G. (1991). The dynamics of interpersonal trust: resolving uncertainty in the face of risk. In: Hinde, R.A., & Groebel, J. (eds.), *Cooperation and Prosocial Behaviour*, (pp. 190-211). Cambridge, UK: Cambridge University Press.

Castelfranchi, C., & Falcone, R. (1999). *Social Trust: A Cognitive Approach*.Presentation at the International Workshop on Agent-Oriented Information Systems, CAiSE 1999, Heidelberg. Retrieved from http://www.aois.org/99/ castelfranchi-Social-Trust-paper.doc

Castelfranchi, C., & Falcone, R. (2001). Social Trust: A Cognitive Approach. In Castelfranchi, C., & Tan, Y.-H. (Eds.), *Trust and Deception in Virtual Societies* (pp. 55-90). Norwell, MA; Kluwer Academic Publisher.

Coiera, E. (2004). Four rules for the reinvention of healthcare . *BMJ (Clinical Research Ed.)*, *328*, 1197–1199. doi:10.1136/bmj.328.7449.1197

Coleman, J. S. (1990). *Foundations of Social Theory*. Cambridge MA: Harvard University Press.

De Giacomo, G., Lespérance, Y., & Levesque, H. J. (2000). ConGolog, a concurrent programming language based on the situation calculus. *Artificial Intelligence*, *121*(1-2), 109–169. doi:10.1016/S0004-3702(00)00031-X

Dourish, P., & Bellotti, V. (1992). Awareness and Coordination in Shared Workspaces. *ACM Conference on Computer Supported Cooperative Work*, New York, NY, (pp. 107-114).

Framinan, J. M., Parra, C. L., Perez, P., & Montes, M. (2005). Guidelines for conducting Business Process Modelling as support to healthcare process management. In *Int. Conf. on Industrial Engineering and Systems Management (ISEM)*.

Gambetta, D. (Ed.). (1988). *Trust: making and breaking cooperative relations*. Oxford, UK: Department of Sociology, University of Oxford.

Gans, G. (n.d.). *An Agent-Based Modeling- and Simulation-Methodology for Strategic Inter-Organizational Networks*. Ph.D. Thesis, RWTH Aachen University, Germany.

Gans, G., Jarke, M., Kethers, S., & Lakemeyer, G. (2003). Continuous requirements management for organisation networks: a (dis)trust-based approach. *Requirements Engineering*, *8*(1), 4–22. doi:10.1007/s00766-002-0163-8

Gulati, R. (1998). Alliances and networks. *Strategic Management Journal*, *19*(4), 293–317. doi:10.1002/(SICI)1097-0266(199804)19:4<293::AID-SMJ982>3.0.CO;2-M

Jarke, M., Klamma, R., Lakemeyer, G., & Schmitz, D. (2008). Continuous, Requirements-Driven Support for Organizations, Networks, and Communities. In *3rd Int. i* Workshop*, CEUR Workshop Proceedings (Vol. 322, pp. 47-50).

Kethers, S. (2000). *Multi-Perspective Modeling and Analysis of Cooperation Processes*. Ph.D. Thesis, RWTH Aachen University, Germany.

Kethers, S. (2002). Capturing, Formalising, and Analysing Cooperation Processes: a Case Study. *10th European Conf. on Information Systems (ECIS)*, Gdańsk, Poland, (pp. 1113-1123).

Kethers, S., Gans, G., Schmitz, D., & Sier, D. (2005). Modelling Trust Relationships in a Healthcare Network: Experiences with the TCD Framework. *13th European Conf. on Information Systems (ECIS)*, Regensburg, Germany, (pp. 1321-1328).

Klamma, R., Spaniol, M., Cao, Y., & Jarke, M. (2006). Pattern-based cross media social network analysis for technology enhanced learning in Europe. *Innovative Approaches for Learning and Knowledge Sharing, First European Conference on Technology Enhanced Learning (EC-TEL)*, Crete, Greece, Springer, LNCS 4227, (pp. 242–256).

Lewicki, R. J., McAllister, D. J., & Bies, R. J. (1998). Trust and distrust: New relationships and realities. *Academy of Management Review*, *23*(3), 438–458. doi:10.2307/259288

Luhmann, N. (1988). Familiarity, confidence, trust: problems and alternatives. In Gambetta, D. (Ed.), *Trust: Making and Breaking Cooperative Relations*, (pp. 94-107). Oxford.

Luo, W., & Najdawi, M. (2004). Trust-building measures: a review of consumer health portals. *Communications of the ACM*, *47*(1), 108–113. doi:10.1145/962081.962089

Marsh, S. (1994). Trust in Distributed Artificial Intelligence. In Castelfranchi, C. & Werner, E. (Eds.), *Artificial Social Systems*, (pp. 94-112). Berlin: Springer.

Mayer, R. C., Davis, J. H., & Schoorman, F. D. (1995). An integrative model of organizational trust. *Academy of Management Review*, *20*(3), 709–734. doi:10.2307/258792

Patel, V. L., Cytryn, K. N., Shortliffe, E. H., & Safran, C. (2000): The Collaborative Health Care Team: The Role of Individual and Group Expertise. *Stanford Medical Informatics Report* (No SMI-1999-0768). Retrieved from http://smi-web.stanford.edu/pubs/SMI_Abstracts/SMI-1999-0768.html

Peterson, R. R., Smits, M., & Spanjers, R. (2000). Exploring IT-Enabled Networked Organisations in Health Care: Emerging Practices and Phases of Development. *8th European Conf. on Information Systems (ECIS)*, Vienna, Austria, (pp. 1253-1260).

Pollack, M. R. P., & Disler, P. B. (2002). Rehabilitation of patients after stroke. *The Medical Journal of Australia*, *177*(8), 452–456.

Powell, W. (1990). Neither Market Nor Hierarchy: Network Forms of Organization. *Research in Organizational Behavior*, *12*, 295–336.

Ramakrishnan, M., Sier, D., & Taylor, P. G. (2005). A two-time-scale model for hospital patient flow. *IMA Journal of Management Mathematics*, *16*, 197–215. doi:10.1093/imaman/dpi014

Saboor, S., Chimiak-Opoka, J., & Ammenwerth, E. (2007). Supporting the Systematic Assessment of Clinical Processes: the MedFlow Method. *Methods of Information in Medicine*, *46*(5), 586–594.

Schäl, T. (1996). *Workflow Management Systems for Process Organisations,* (2nd Ed.) (LNCS 1096). Berlin: Springer Verlag.

Scheer, A.-W. (1994). *Business Process Engineering – Reference Models for Industrial Companies* (2nd Ed.). Berlin: Springer Verlag.

Smit, M., McAllister, M., & Slonim, J. (2005). Public Trust and Electronic Health Records. *Conf. on Privacy, Security and Trust (PST)*.

Song, J., & Zahedi, F. (2007). Trust in health infomediaries. *Decision Support Systems*, *43*(2), 390–407. doi:10.1016/j.dss.2006.11.011

Suchman, L. (1995). Making work visible. *Communications of the ACM*, *38*(9), 56–65. doi:10.1145/223248.223263

van der Aalst, W. M. P., & van Hee, K. M. (1996). Business process redesign: A Petri-net-based approach. *Computers in Industry*, *29*(1–2), 15–26. doi:10.1016/0166-3615(95)00051-8

Wachter, R. M., & Shojania, K. (2004). Handoffs and Fumbles. In Wachter, R. & Shojania, K. (Eds.), *Internal Bleeding: The Truth Behind America's Terrifying Epidemic of Medical Mistakes*. New York: Rugged Land, LLC.

Wang, Y., Gräther, W., & Prinz, W. (2007). *Suitable notification intensity: the dynamic awareness system.* ACM SIGGROUP Conference on Supporting Group Work (GROUP), Sanibel Island, Florida, USA, November 4-7, pp. 99-106.

Westbrook, J. I., Braithwaite, J., Georgiou, A., Ampt, A., Creswick, N., Coiera, E., & Iedema, R. (2007). Multimethod Evaluation of Information and Communication Technologies in Health in the Context of Wicked Problems and Sociotechnical Theory. *Journal of the American Medical Informatics Association*, *14*(6), 746–755. doi:10.1197/jamia.M2462

Weyer, J. (Ed.). (2000). *Soziale Netzwerke. Konzepte und Methoden der sozialwissenschaftlichen Netzwerkforschung*. München/Wien, Germany: Oldenbourg.

Witkowski, M., Artikis, A., & Pitt, J. (2000). Trust and Cooperation in a Trading Society of Objective-Trust Based Agents. In Falcone, R., Singh, M., & Tan, Y.H. (Eds.), *Autonomous Agents Workshop on Deception, Fraud and Trust in Agent Societies.* Barcelona, Spain.

Yu, E. S. K. (1995). *Modeling Strategic Relationships for Process Reengineering* (Tech. Rep. No. DKBS-TR-94-6). Ph.D. Thesis, University of Toronto, Canada. Yu, E. S. K., & Liu, L. (2001). Modelling trust for system design using the i* strategic actors framework. In Falcone, R., Singh, M., & Tan, Y. H. (Eds.). *Trust in Cyber-Societies. Integrating the Human and Artificial Perspectives* (LNAI 2246, pp. 175-194). Berlin, Germany: Springer Verlag.

KEY TERMS AND DEFINITIONS

Confidence (also system trust): Trust in the network/organization as a whole that is due to the mesh of dependencies neither completely visible nor manageable by the trustor. (Luhmann, 1988)

Cooperation: Cooperation denotes the relationships between two or more organizations or parts thereof, which aim at fulfilling some shared goal, are based on written or oral (legal) agreements, and keep the partners legally independent. (Kethers, 2000)

Distrust: "The expectation of opportunistic behaviour from partners" (Gans et al., 2003)

Process: A process is a set of identifiable, repeatable actions which contribute to the fulfilment of the objective (or goal) for which the process was designed. Actions are in some way ordered, performed by actors, and possibly subject to limitations or constraints. Actions can be activities (tasks), or be related to information flows or communication. (Kethers, 2000)

Social network: An autonomous form of coordination of interactions whose essence is the trusting cooperation of autonomous, but interdependent agents who cooperate for a limited time, considering their partners' interests, because they can thus fulfil their individual goals better than through non-coordinated activities. (Weyer, 2000)

Strategic Dependency model: "The Strategic Dependency (SD) model provides an intentional description of a process in terms of a network of dependency relationships among actors. […] [It] consists of a set of nodes and links. Each node represents an "actor", and each link between two actors indicates that one actor depends on the other for something in order that the former may attain some goal." (Yu, 1995)

Strategic Rationale model: "The Strategic Rationale (SR) model provides an intentional description of processes in terms of process elements and the rationales behind them. […] [It] describes the intentional relationships that are "internal" to actors, such as means-ends relationships that relate process elements, providing explicit representations of "why" and "how" and alternatives." (Yu, 1995)

Trust: "The willingness of a party to be vulnerable to the actions of another party based on the expectation that the other will perform a particular action important to the trustor, irrespective of the ability to monitor or control that other party." (Mayer and van der Hoek, 1995)

ENDNOTE

[1] An earlier version of this paper was published in (Kethers et al., 2005).

[2] Note that the ward's view expressed in the process diagrams is not a given, but evolves as the result of much discussion during the focus group meeting, as different staff members discuss their different views of what is happening.

This work was previously published in Handbook of Research on Advances in Health Informatics and Electronic Healthcare Applications: Global Adoption and Impact of Information Communication Technologies, edited by K. Khoumbati, Y.K. Dwivedi, A. Srivastava, and B. Lal, pp. 205-220, copyright 2010 by Information Science Reference (an imprint of IGI Global).

Chapter 6.4

Analyzing an ES Implementation in a Health Care Environment

Albert Boonstra
University of Groningen, The Netherlands

ABSTRACT

At the present moment, many hospitals are going through a process of change directed at the integrated delivery of health care. Enterprise Systems (ES) are increasingly used to support this process and to manage hospitals on a coherent basis. We also know, however, that ES implementation itself, can be viewed as an organizational change process that affects many stakeholders. For that reason it is relevant to study how ES implementation takes place within hospitals and how it tends to impact the existing organizational arrangements. The purpose of this chapter is therefore to describe and analyze how ES implementation within a hospital affects the interests of stakeholders and which specific problems may arise as a result. This chapter uses the evidence of a case study to reveal some important dimensions of the organizational change issues related to ES implementation within hospitals.

INTRODUCTION

Many hospitals are going through a process in which they are changing from loosely coupled units into more integrated entities. Hospital managers are increasingly accountable for the cost-effectiveness and the quality of their organizations, which explains their need for more integration and control. To achieve this, the managers are looking for information systems that can help them to manage their hospitals on an integrated basis (Merode, van et al, 2004). This is why in recent years many hospitals have started to implement enterprise systems (Jossie et al., 2005). Enterprise systems are software packages that facilitate the integration of transactions-oriented data and business processes throughout an organization (Klaus et al., 2000). Traditionally, enterprise systems are used in manufacturing, which differs in many respects from a hospital context. It is therefore relevant to describe and analyze how ES implementation within hospitals takes place and which specific problems are faced by the implementers and managers.

In this chapter we will describe and analyze the implementation of an enterprise system in a medium-sized hospital in The Netherlands. We will analyze this implementation by focusing on the roles of the various stakeholders involved, the meaning that they attach to the system, and the actions they take throughout the project. We have chosen this perspective because stakeholders involved in hospitals differ significantly from those involved in other industries. This chapter aims to provide insight into the role that the different stakeholders involved in hospitals may play during ES-implementations. Understanding the possible impact of ES on particular stakeholder interests may help project managers and others to manage ES implementation within hospitals in a more effective way.

There are only few descriptive accounts of how groups and individuals related to hospitals interpret IS proposals in general and ES systems in particular, and how they respond subsequently (Levine et al., 1995). Especially empirical case studies that focus on the role of politics and stakeholders in relation to ES implementation within hospitals are scarce. As a result, our insight into the role of stakeholders in the implementation of IS applications within hospitals in general and that of ES applications in particular is limited. This means that we have a lack of understanding of why groups and individuals act in the way they do. Knowledge of barriers to implementation and approaches to analyze them is of importance to practitioners, such as project managers, who are involved in implementing ES within hospitals, and hospital managers, who have to decide whether to implement ES.

The chapter is organized as follows. In the next section we will explain the distinctive features of enterprise systems and describe theory and models that the research has been based on, which may help us understand the relevance of studying enterprise systems in health care environments. After that, we will describe the methodological background of the research. The following section presents the case study and then an interpretation will be given of this case study on the basis of the model. In the final section we will put the study in a broader perspective and put forward some views about the practical implications for managers responsible for ES implementations within hospitals.

BACKGROUND

Enterprise systems are software applications aimed at integrating a range of business functions in order to acquire an overview of the business based on a single information architecture (Merode, van., 2004). Starting from manufacturing and financial systems, enterprise systems may eventually allow the integration of inter-organizational supply chains (Markus et al., 2000; Fowler et al., 2003). Enterprise systems are multi-functional and cover a range of activities, such as logistics, human resources and finance. These functions are integrated in such a way that whenever data are entered into one of these functions, they become available to all related functions. Enterprise systems are modular and can be used in many combinations of modules. They link the different organizational units by coordinating the business processes.

Because these systems affect so many aspects of an organization's internal and external operations, their successful deployment and use are critical to organizational performance and survival. In the case of ES successful implementation is important, since the costs and risks of these technology investments rival their potential payoffs. Failure of enterprise system implementation projects may lead to bankruptcy (Markus et al., 2000; Davenport, 1998; McAfee, 2003). The ES implementation as described in this chapter also brought the hospital into severe problems, which almost led to bankruptcy.

This illustrates that implementing enterprise systems is a complicated enterprise, not only from a technical point of view but also from many other perspectives, including strategic, organizational, political, and cultural viewpoints. One very important issue is that a large number of stakeholders from different organizational units are involved. Since as a result the decisions are no longer taken on a local or departmental level, the question of who participates in the analysis, development and implementation of ES becomes more difficult.

We already mentioned that many hospitals are in a process of transformation, directed at the integrated delivery of health care through a more homogeneous range of health care products. Motives behind this change are a higher level of cost control, the need for organizational procedures for patients, and an increasing accountability of the hospital managers for the way in which the hospital operates. This process toward integration can be stimulated by information systems that help managers organize the central planning and control (Haux, 2006). Since enterprise systems have helped organizations in various industries to integrate and organize the real time information delivery, they are now also applied in many hospitals. Suppliers of enterprise systems have developed modules that are specifically customized for hospitals, such as patient management modules and electronic patient files. Modules used in other industries have been slightly adapted to fulfill hospital requirements (Paré et al., 2001).

The empirical research conducted for this chapter is based on interpretive (Walsham, 1993), processual (Boonstra, 2003) and integrationist (Orlikowksi, 1992) models of change. These models emphasize how various groups of people in organizations may have different interpretations of information systems, which may shape their actions and influence the implementation and evolution of such systems. The change view is rooted in social constructivism, which is focused on the meaning that people attach to a particular technology (Pinch et al., 1992). Social constructivism found its way to IS research by the so-called interpretive approaches (Walsham, 1993, Orlikowski, 1992) and emphasizes the subjective meaning that an actor ascribes to an information system, which is based on particular interests, preferences, history and so on. From this perspective, system implementation can be explained by studying the interplay of attitudes and actions of various stakeholders, which may be subject to change over time (Dawson, 1994).

Pettigrew (1988) argues that organizational change can be understood by considering the interactions among the substance, context and process of change within the organization and their continuous interplay. The implementation of change is an 'iterative, cumulative and reformulation-in-use process'. Successful change is a result of the interaction among the content or 'what' of change, the process or 'how' of change (implementation) and the organizational context or 'where' of change (the internal and external environment). He also suggests that the change agent must be willing to intervene in the political systems of the organization, and to legitimate the change in the face of competing proposals and ideas. Bennis (1984) suggests that management of change is 'management of meaning', involving the attempt to convince others of the credibility and legitimacy of particular definitions of problems and solutions, and to gain consent and compliance (Boddy, 2002).

It is well documented that the development of information systems requires the participation of the parties interested and that the willingness and the effectiveness of this participation influences the success of the resulting system. Normally these participants include developers, intended users and managers. However, in the case of enterprise systems within hospitals, this range of people and parties is much broader and crosses organizational functions, which means that the stakeholders are more loosely coupled. Identifying these stakeholders and exploring their perspectives in terms of their interests in the system and their power to 'make or break' the system is essential.

When the stakeholders are identified, their interests can be related to the enterprise system. This means that part of the analysis consists of the assessment of the stakeholders' perception of the ES. How do they interpret the ES and to what extent do they believe that it will be instrumental in attaining their objectives and that it will fit in with their values? In other words: what are their perceived interests in the system?

However, an enterprise systems does not depend solely on the interests of stakeholders but also on the power relations among the parties involved. A powerful party with a clear interest in a particular ES can apply its power to force less powerful parties to use it, regardless of their perceived interest in the system (Standifera, 2003). At the same time, it might be rather difficult for parties with a great deal of interest in a particular enterprise system, but with a lack of power to implement it successfully, if the other parties are not really interested. In this chapter, we will define power as the capacity to exert one's will over others in order to realize certain intended goals (Boddy, 2002). Since power is a capacity to exert one's will, it is possible to indicate the source of this capacity, or in relation to ES: parties may possess different sources of power to force others to cooperate and use (or not use) an ES. The power and interests of stakeholders may change during the course of a project and may affect the role they play.

To characterize this role during a certain phase we have used the stakeholder typology of Mitchell et al. (1997). They identify seven types of stakeholders: dormant, discretionary, demanding, dominant, dependent, dangerous, and definitive stakeholders. *Dormant stakeholders* have the power to influence, but this power remains unused for a certain period of time. *Discretionary stakeholders* possess legitimacy, but have no power to influence the project. *Demanding stakeholders* have urgent claims, but neither possess the legitimacy nor the power to materialize these claims. *Dominant stakeholders* are both powerful and legitimate. Their influence in the relationship is assured, since as a result of this power and legitimacy they form the dominant coalition. *Dependent stakeholders* are characterized by a lack of power, but have urgent and legitimate claims. These kinds of stakeholders depend on others to carry out their will. *Dangerous stakeholders* possess urgency and power but no legitimacy and may be coercive or even dangerous. *Definitive stakeholders* possess power, legitimacy and urgency.

METHOD

To conduct this case study, we used a diverse set of qualitative methods, including in-depth interviews, participant observation and documentary research (Ammenwerth, 2003). The initial access to stakeholders was negotiated with a staff member of the IS department. We focused the research on what we regarded as the most immediate stakeholders in the ES project. During a period of six months the authors visited the hospital five times. They conducted interviews, which lasted approximately 1- 2 hours, with members of the general management, IT, the administrative staff, the medical staff, and with external consultants. A snowball sampling strategy was used to identify the subsequent respondents. This means that later on, discussions were held with other members of staff, who were either working with or affected by the enterprise system. The interviews began with a generic question that allowed the interviewees to express how they experienced the ES implementation process. After that, more specific questions were asked about critical incidents, the specific stakeholders' interests, and the meaning they attached to the system. Handwritten notes were taken and individual reports of the interviews were made. The accounts based on these notes were presented to the interviewees and revised slightly on points of detail, if necessary. The data were analyzed by reviewing the respondents' comments, placing them on a time line and dividing them into categories based on their attitudes to the enterprise system. The data are presented in the following sections.

CASE HISTORY

The hospital studied is a medium-sized general hospital located in the western part of The Netherlands. It has 375 beds and 1250 employees. The hospital is divided into six main units: 1) clinical care, 2) ambulant care, 3) physicians, 4) facilities, 5) personnel, and 6) IT and Finance. The physicians are largely remunerated through a service-based fee, and they normally use information systems that function separately from the hospital systems to manage their practices and support their medical treatments.

Episode 1. Preparation

The initial motive to implement an enterprise system was the conclusion of a contract with the former vendor of the Hospital Information System (HIS). HIS was actually a set of separate systems that were loosely linked. The system was not being maintained appropriately and the contacts with the vendor were not very good. This is why the board of management as well as the IT department were interested in a modern product that could help them to establish an integrated, modular and adaptive hospital system. Management also had the ambition to be the first in combining the billing process of the hospital with that of the physicians. At that time, medical treatments involved two separate types of invoices: one from the hospital and one from each relevant physician. A member of the board of management argued:

We were struggling with a set of outdated systems that only supported some business functions separately. We lacked the proper management information and were in need of a system that had the potential to support all hospital processes in an integrated manner.

The hospital aimed at a system that could be adapted to the operational processes of the hospital, and not vice versa. Based on these requirements, a long list of potential vendors was reduced to a shortlist, and a multidisciplinary team selected a number of SAP modules to be implemented by an external consultancy. This consultancy claimed to be experienced in implementing SAP in hospitals. An internal IT manager said:

The consultancy convinced us that it was an expert in adapting and implementing SAP within hospital environments. The company claimed that SAP was very flexible and could be easily adapted to the specific requirements of any hospital.

Another consultancy delivered an external project leader, responsible for the implementation project. One member of the multidisciplinary team (a representative from the nurses) said about the start of the process:

We were invited by the project management to celebrate the start of the project. We all got champagne and everyone seemed to be in agreement. Management and the external consultants promised that the new system would solve all the problems caused by the old and isolated hospital systems. The organization would become a unity with one single information base for all main processes.

However, the actual participation of the hospital's administrators and physicians was quite passive. They were in fact merely bystanders or passive recipients of information about the project. Moreover, the promoters were very confident about the benefits of the system and others did not have the expertise or experience to challenge that.

Episode 2. Start

After the selection of this particular software package, four working groups were formed to prepare the implementation in more detail and to adjust the system to the organization. Technical, administrative, policlinic and billing issues were the focus points of these four groups. They were chaired by the department heads. The board of management and the project leader put a great deal of pressure on them to work fast, whereas all members, including the chairmen, had to combine the preparation of the implementation with their regular tasks. The time pressure was so high, because the hospital was no longer allowed to use its former system. Because of this time pressure, the company's communication with the prospective users was very limited. One chairman of a working group said:

The real objectives of the system did no longer seem relevant, and the only objective that remained was to get it implemented. We were all working very hard, but we could not explain why we were doing so much work only to replace one system with another. Through all of this work we lost track of the initial motives to implement the system.

In actual fact, the mutual adjustment of the various modules and the adaptation to the organization was limited. All energy was put into the technical and organizational complexities. It became clear that the external consultancy was not as experienced in implementing SAP as they had claimed to be. In other hospitals they had adjusted processes to SAP rather than the other way around. Due to the time pressure, the project manager decided to follow the same strategy here.

One member of a working group who had been involved right from the start said:

During the preparation phase, the inherent flexibility and the potential functionalities of the system were emphasized. However, when it came to implementation, we were forced to rush and make sure that the system was installed in time.

A member of the medical staff could recall about this phase:

We attended some of the meetings, but we got the impression that the system was merely a toy for the managers, and not suitable for actual use. However, we did emphasize how complex some of the processes, including the billing processes, are. But the implementers did not seem to be impressed by these remarks.

After implementation of the system, a number of problems arose. Both at the policlinic and at various other clinics, the administrative staff did not know how to use the system, since no formal opportunities had been offered for training. In addition, there was a lack of motivation to use the system, because the staff was not properly informed about the motives behind the SAP implementation. Many people also felt that the degree of user friendliness of the system was lower than that of the old system. And a few of the more conscientious employees even discovered that some output of the system was erroneous.

Episode 3. Crisis

As already mentioned, the hospital followed two billing procedures, one of the hospital and one of the medical staff. Both procedures had to be integrated into one system. Since the income of the medical staff depends directly on a well-functioning billing process, a successful change-over was crucial to them. Up to then, the medical staff had not really been involved and was hardly interested in the ES implementation. However, after a few days of system use, some people discovered that some treatments were not invoiced at all, whereas other treatments were invoiced incorrectly or double. A representative of the medical staff said about this phase:

The implementers totally underestimated the complexity of this crucial process. They assumed that by means of their so-called efficient flow charts each treatment could be invoiced in the *same way. However, the reality of our practices is very different from their world of schemes, charts and systems.*

A few ingenious administrators tried to keep the system working by so-called 'work arounds', which means that, only after having checked each invoice manually, they were sent away. These work arounds led to new problems; the medical staff as well as the patients and insurers started to complain. They believed that the hospital was no longer in control of its main financial processes. A real crisis developed when the regional press became aware of the problems. The medical staff became convinced that they were missing out on revenues. They informed the board of management that they did not have any confidence in the system and that they refused to use it any longer. The representative of the medical staff said:

Both the implementers and management were clearly not in control. They panicked.

The board of management was forced to intervene and agreed that a separate billing system was acquired beside the SAP system. This separate invoicing system was already used by some groups of the medical staff. From that moment on, all invoices were checked manually and compared with the new shadow system. At the same time, the SAP system was gradually adapted. All these problems led to the immediate retirement of the CFO. In addition, the hospital decided to sue the external consultancy for having failed to meet the main terms of the agreement. After six months, all the adaptations and extra attention seemed to have some effect. However, due to this crisis, some people think that the hospital missed out on at least 10% of its annual revenues and was very near to bankruptcy because of the implementation of this system. Various people commented that the lower administrative staff had 'saved' the implementation by using redundant systems and checking all financial flows manually. An observer said:

This project was initiated by the top and by externals, but it was realized by the loyalty of the lower administrative staff.

The crisis was overcome by using additional and redundant systems and by gradually adapting the enterprise system to the old working practices. This took approximately six months, during which the administrative staff, nurses and physicians actually adapted and succeeded in managing the operation of the system. At that time, the in-house IT department, which had been left out the preparation and implementation phase, recaptured its tasks. Externals stepped back and the normal operations were once again continued.

Episode 4. Use

After some time, the system was assimilated and the organization became used to it. However, management did not feel that it stimulated the improvement of the management information or led to a more integrated organizational structure. Because its implementation had been rushed, little attention was paid to the further possibilities of the system. For this reason a new project was started, which aimed at generating management information and reports. Only a few clinics have used the SAP system in an optimal way, and many other clinics still use only a limited number of functions. Management is not convinced that the system has helped to achieve the objectives on which the project was based.

ANALYSIS

In this section the roles and interests of the different stakeholders during this process and the meaning they attached to the system will be discussed. After that, we will interpret some successive actions that affected the process. Then we will list what went wrong during this implementation and what lessons can be learned from that. This analysis will be conducted on the basis of the theoretical backgrounds as presented in the third section.

Positions of Stakeholders

The most important stakeholders involved in this implementation project were the board of management, the external consultancy, the external project leader, the physicians, the administrators and the IT staff. Many of these stakeholders are groups with many internal varieties, but also with a relatively high level of consistency with regard to their perceptions of interests, problems, solutions and meaning in relation to this project.

The board of management had a clear interest in a successful and efficient implementation of the enterprise system. They strongly felt that one integrated system would provide them with the management information the needed. The system was intended to replace many local and outdated operational systems, which did not deliver any useful information to the board. The board of management clearly acted as a definitive stakeholder, possessing power, legitimacy and acting from a sense of urgency. After the first stages, however, they delegated a number of their responsibilities to external parties, which means that they became a dormant stakeholder.

The external consultancy had accepted the project on a fixed price basis and obviously had a clear interest in a fast and smooth implementation process. The company was hoping that it could use its previous experiences to realize an effective implementation in this case. But it underestimated the power and roles of the medical practices, which required a system that would comply with the established processes and medical practices. The external project leader, who was from another consultancy, had similar views on the interests, problems and their meaning. Both can be characterized as dependent stakeholders. They both felt a clear urgency, and they both had been given authorization by the board, but they did not really have the power to force other stakeholders to comply.

The administrators can be regarded as users of both the old and the new system. They did not have a clear interest in the new system, since they were used to the current working practices. The external implementers did not really involve the administrators in the implementation process. This was due to time pressures but also because the implementers tried to adapt the hospital processes to the system rather than the other way around. Physicians and administrators argued that the external parties underestimated the hospital's internal complexities and that they lacked a clear interest in its current processes.

The IT staff and the board of management agreed upon the desirability of a single compact and modern IT package for the whole organization. The IT department, however, lacked sufficient knowledge about such systems, and for the time being it had to be busy with maintaining the old set of systems. This is why during the implementation process IT played a background role.

In general, the medical staff want to do their work with some degree of autonomy and without too much managerial interference. In addition, they tend to seek systems that reduce their non-medical workload as much as possible. One member argued that it would be in the interest of the doctors to have loosely-coupled systems, which are tightly adapted to their own specific medical practices. This was not in line with the interests of the board of management, who wished to have an overview of all main processes. The physicians were mainly bystanders during the early stages of the project. They felt that it was an issue to be dealt with by the managers but not by them. This is why they can be characterized as dormant stakeholders; they possessed the power but neither felt the urgency nor had the legitimacy to interfere. This changed dramatically once they became aware that there were serious problems with the billing processes. They then instantly became definitive stakeholders, who clashed with the only other definitive stakeholder: the board of management.

What Went Wrong?

A number of things went wrong during the implementation of this ERP-system. The most important ones are the following:

Management and consultants showed a lack of attention for organizational change issues. In this case history, hospital management attempted to implement an integrated system in a loosely coupled organization without paying much attention to organizational change issues. Management mainly focused on their own goals, namely the replacement of the old hospital system and the implementation of a modern integrated product. They did not consider the consequences of this product for other powerful stakeholders. The external consultancy argued that it was possible to use this ERP solution not only as a replacement, but also as a solution of a number of other management problems. By doing so, they adopted an exclusive 'management rationalism' approach (Heeks, 2006), while ignoring process complexity and diversity and power of the workforce (see section 3).

The project was characterized by the rush to implement and the ambition to innovate, which led to ignorance of problems and complications. Management and implementers were in a rush since the hospital was not longer allowed to use the old hospital system. Besides, management expressed the ambition of 'being the first in combining the billing process'. This limited timeframe led to 'hard design'(Heeks, 2006) and also to sloppy thinking with regard to process details. The billing process was also much more complex than the consultancy expected and was actually too complicated to capture into the new system. The underestimation of this complexity led to errors and a decreasing confidence in the system by staff and physicians.

There was a low degree of real participation and a lack of attention to the interests of important stakeholders. Physicians and administrators reported that participation during the initiation and start phase was limited. This low degree of participation caused a lack of co-ownership and explained that physicians did feel the responsibility to co-operate in replacing their own billing systems by the new ERP-system. Physicians argued that this was a project of management and consultants so they did not feel a reason to spend time to the realization of this new system. When the actual billing procedure proved to be unreliable, physicians, as being powerful bystanders, could enter the arena and blame others for the installation of an unreliable new system.

Communications about project objectives were ambivalent and sometimes incorrect. On the one hand, management and the consultancy argued that the hospital needed a software product that would help the hospital to become integrated and to deliver consistent and up to date management information. On the other hand, they told the administrators and physicians that the system would be adapted, in order to adjust the system to the organization. This ambivalence caused misunderstanding among members of working groups and physicians. In case of adjustment, experts had to study hospital processes and to modify the system. In case of change, physicians and administrators would be more affected.

Competencies of external consultancy were not adequate. The consultancy claimed to have expertise in implementing in ERP in hospitals, but this expertise was mainly in adjusting hospital processes to systems, rather than the other way around. They also lacked expertise in dealing with organizational change processes, since they had a technical focus.

Lessons

Based on this case history, the following lessons can be learned that are relevant for vendors/consultants of hospital ERP and senior management of hospitals.

1. ERP implementation in hospitals is a combination of technology change and organizational change and should be managed accordingly. This means that project management should use expertise from both fields to implement such change successfully. Markus (2004) provides a number of useful principles for adequate project management in case of the implementation of technology combined with organizational change.
2. In case of a high time pressure or a short time frame, the objectives and ambitions of ERP implementation in hospitals should be brought back to realistic levels. After the initial implementation other projects can be started to make further steps. Since process complexity in hospitals is often high, close attention and time is needed to translate them into the system in adequate ways.
3. Active participation of key stakeholders leads to co-ownership and a responsible attitude during the various stages of implementation. Especially in case of highly affected and powerful stakeholders, such as physicians in hospitals, it is essential to secure active roles and responsibility of physicians or their representatives. Principles of 'soft design' (Heeks, 2006) should be applied in such cases.
4. Management has to be very clear and consistent to anyone affected about the objectives of ERP implementation. Especially about the choice to adjust the system to the organization or to change hospital processes to the system is very crucial. This decision determines how the project has to be managed and how participation of stakeholders has to be organized.
5. In case of process change, adequate change managers have to be in charge. In case of the use of external consultancies, management has to make sure that these consultancies have relevant expertise in realizing such change in hospitals.

CONCLUSION

Enterprise systems are not only technical artifacts, but also a reflection of management philosophies, which may or may not fit in with existing organizational arrangements. This implies that ES implementations may challenge vested interests, and may lead to opposing views of various players. Especially in hospitals, where physicians possess discretionary power to organize their processes and to manage their practices, ES may clash with their interests and viewpoints. Enterprise systems are designed to integrate functions and to standardize business processes, which were previously dispersed and diverse. The physicians affected do have the power to choose whether they wish to adopt or to reject such systems.

For these reasons it is essential for managers of ES implementations within hospitals to be aware of the ways in which ES affects the established institutional settings (Yi et al., 2006). During the initial stages of the implementation process, decisions have to be made about necessary changes in either the system or the organization, or in both. These changes can be required to meet certain needs of stakeholders in order to make sure that they cooperate and participate in effective ways. It is not acceptable if potential influential players remain passive until the actual use phase starts. This case illustrates that aggressive resistance after implementation can lead to a counter-productive crisis, which could have been prevented by a thorough analysis of the interests of the key players right from the start. Such an analysis could be followed by a discussion that leads to an agreement among the most important stakeholders upon how to implement the system and how to adapt the relevant processes. Such an agreement could be a compromise of various contrasting interests.

The chapter also shows that ES implementation within hospitals is a dynamic process. This means that certain views, which are held by stakeholders at one point in time, may change during the project. There may be various reasons why views change, including cognitive, political and opportunistic ones. In this case the physicians and administrators remained relatively passive, until problems arose during the use phase. It indicates that implementing ES within hospitals is a complex venture, in which the opportunities and limitations of the system have to be aligned with the existing and always changing organizational arrangements, including various perceptions, quests for power, leadership and subtle processes to gain support for further continuation of the project.

In this case a power vacuum (caused by the board of management) stimulated behavior that was more politically-oriented, and resulted in a lack of agreement on the direction and use of the system. Through this lack of agreement, the various stakeholders mainly followed mainly their own goals and undermined to some extent the hospital-wide explicit objectives of the project. The chapter shows that the promoters of the hospital-wide enterprise system took a too optimistic view of the power of such a system to improve the operation of the hospital's processes. In the rush to implement, no careful attention was paid to the complexities of the internal processes, the stakeholders' interests and their mutual relations. The rational image of system implementation could not conceal its poor understanding of the deeper organizational realities, such as history, culture and power.

REFERENCES

Ammenwerth, E., Iller, C., & Mansmann, U. (2003). Can evaluation studies benefit from triangulation? A case study. *International Journal of Medical Informatics*, *70*(2), 237–248. doi:10.1016/S1386-5056(03)00059-5

Bennis, W. G. (1984). Transformative power and leadership. In: TJ. Sergiovanni and JE Corbally (eds), *Leadership and Organizational Culture.* Urbana, University of Illinois Press; 1984.

Boddy, D. (2002). *Managing Projects*. London: Prentice Hall.

Boonstra, A. (2003). Structure and Analysis of IS decision making processes. *European Journal of Information Systems*, *12*(3), 195–209. doi:10.1057/palgrave.ejis.3000461

Davenport, T. H. (1998). Putting the Enterprise into the Enterprise System . *Harvard Business Review*, *76*(4), 121–132.

Dawson, P. (1994). *Organisational Change: A Processual Approach*. London: Chapman.

Fowler, A., & Gilfillan, M. (2003). A Framework for Stakeholder Integration in Higher Education Information Systems Projects. *Technology Analysis and Strategic Management*, *15*(4), 467–489. doi:10.1080/095373203000136051

Haux, R. (2006). Health information systems - past, present, future. *International Journal of Medical Informatics*, *75*(3), 268–281. doi:10.1016/j.ijmedinf.2005.08.002

Jossi, F. (2005). ERP on the Rise. Some hospitals see the advantages in a single system. *Healthcare Informatics*, *2005*, 79–80. www.healthcare-informatics.com/issues/2005/06_05/jossi.htm accessed on March 21st 2006.

Klaus, H., Rosemann, M., & Gable, G. G. (2000). What is ERP? *Information Systems Frontiers*, *2*(3), 141–162. doi:10.1023/A:1026543906354

Levine, H. G., & Rossmoore, D. (1995). Politics and the Function of Power in a Case Study of IT Implementation. *Journal of Management Information Systems*, *11*(3), 115–133.

Markus, M. L. (2004). Technochange Management: Using IT to drive organizational change. *Journal of Information Technology*, *20*(1), 4–20. doi:10.1057/palgrave.jit.2000002

Markus, M. L., Axline, S., Petrie, D., & Tanis, C. (2000). Learning from adopters' experiences with ERP: problems encountered and success achieved. *Journal of Information Technology*, *15*(4), 245–265. doi:10.1080/02683960010008944

Markus, M. L., & Tanis, C. (2000). Multisite ERP implementations. *Communications of the ACM*, *43*(4), 42–26. doi:10.1145/332051.332068

McAfee, A. (2003). When too much IT knowledge is a dangerous thing. *Sloan Management Review*, *44*(2), 83–89.

Mitchell, R. K., Agle, B. R., & Wood, D. J. (1997). Toward a Theory of Stakeholder Identifiction and Salience: Defining the Principle of who and what really counts. *Academy of Management Review*, *22*(4), 853–886. doi:10.2307/259247

Orlikowski, W. J. (1992). The Duality of Technology: Rethinking the Concept of Technology in Organisations. *Organization Science*, *3*(1), 398–427. doi:10.1287/orsc.3.3.398

Paré, G., & Sikotte, C. (2001). Information technology sophistication in health care: an instrument validation study among Canadian hospitals. *International Journal of Medical Informatics*, *63*(2), 205–223. doi:10.1016/S1386-5056(01)00178-2

Pettigrew, A. M. (1988). *The Management of Strategic Change*. Basil Blackwell, Oxford.

Pinch, T. J., & Bijker, W. E. (1992). The Social Construction of Facts and Artifacts: Or How the Sociology of Science and the Sociology of Technology Might Benefit Each Other. In W.E. Bijker, T.P. Hughes and T.J. Pinch (eds.) *The Social Construction of Technological Systems*, MIT Press, Cambridge, Ma, 1992.

Standifera, R. L., & Wall, J. A. (2003). Managing Conflict in B2B E-Commerce. *Business Horizons*, *46*(2), 65–70. doi:10.1016/S0007-6813(03)00011-9

van Merode, G. G., van Groothuis, S., & Hasman, A. (2004). Enterprise Resource Planning for Hospitals. *International Journal of Medical Informatics*, *73*(6), 493–501. doi:10.1016/j.ijmedinf.2004.02.007

Walsham, G. (1993). *Interpreting Information Systems in Organizations.* Chichester, Wiley.

Yi, M. Y., Jackson, J. D., Park, J. S., & Probst, J. C. (2006). Understanding information technology acceptance by individual professionals: Toward an integrative view. *Information & Management*, *43*(3), 350–363. doi:10.1016/j.im.2005.08.006

KEY TERMS

Enterprise System: Enterprise systems are software applications aimed at integrating a range of business functions in order to acquire an overview of the business based on a single information architecture

Power: Power is the capacity to exert the will over others in order to realize certain intended benefits.

Power (Re)distribution: Power (re)distribution is the degree to which power is distributed within and between organizations and the extent that an enterprise system changes that division of power.

Stakeholder of an Enterprise System: An individual or group who can affect or can be affected by the implementation of an enterprise system.

Stakeholder Salience Theory: Divides stakeholders in seven types depending on their degree of power, urgency and legitimacy. These types are: dormant, discretionary, demanding, dominant, dependent, dangerous and definitive.

Interest of Stakeholders: The interest of a stakeholder reflects the perception that an IOS contributes to the overall goals of the stakeholder.

This work was previously published in Handbook of Research on Enterprise Systems, edited by J. N.D. Gupta, S. K. Sharma, and M. A. Rashid, pp. 274-286, copyright 2009 by Information Science Reference (an imprint of IGI Global).

Chapter 6.5

Practical Applications of Case Management Software for Practitioners in Health and Human Services

Lesley Cooper
Wilfrid Laurier University, Canada

Dana Fox
Athena Software, Canada

Diane Stanley-Horn
Athena Software, Canada

ABSTRACT

This chapter aims to demonstrate the capabilities and practical applications of a case management software system for not-for-profit organizations. Whilst a variety of software systems are available, for the purposes of this chapter the authors will use/refer to "Penelope," a system designed by Athena, a Kitchener, Ontario software company. Penelope is a sophisticated piece of technology that can collect and analyze information on clients, services, human resources and outcomes. Although a wide range of data can be collected using this software, it cannot make decisions about what to record or how to scrutinize the data. The "what to record" and the "how to analyze and interpret" are management and clinical decisions. Effective use of case management software requires technical, management and analytical skills combined with leadership and imagination. Case management software systems and the information they provide are only as good as the planning and organizational systems in which they are used. The best starting point for practitioners and managers seeking answers to questions about their clients, services, community and policy, and to maximize the capabilities of case management software systems is the development and application of a program logic model unique to the agency in question. A program logic model focuses on the services and programs provided by the agency describing its' inputs, activities, outputs and outcomes. Understanding how to develop and apply their model allows practitioners and managers to perform tasks such as performance monitoring,

experimental and quasi experimental approaches program evaluations, and client satisfaction and outcome studies to demonstrate the effectiveness of their services to funding bodies, consumer groups, and their boards of directors whilst also providing a tool that can be used to enhance agency performance.

'To err is human but to really foul things up requires a computer'. -- Farmers' Almanac for 1978 'Capsules of Wisdom' in Oxford Dictionary of Quotations (2004, p.670:70).

INTRODUCTION

Case management software programs enable organizations to collect data describing their client population and service provision as well as the outcomes and effectiveness of these services. These programs facilitate agency collection of data about clients and the services provided to them and may be extended to enabling communication, scheduling, billing, clinical notes and evaluation tools. Case management software systems may be purchased as a propriety package or designed in house by organizations to manage their client service data. For the purposes of this chapter, we will confine our comments to the Penelope Case Management Software developed by Athena Software, based in Kitchener, Ontario. This package was designed for health and human service agencies and is based on traditional concepts of case management. In this chapter we will describe Athena's Penelope and use it to demonstrate its' capabilities and practical applications in needs studies, program evaluation, quasi experimental designs demonstrating outcomes and efficacious services.

We will focus on the practical applications of case management software for a variety of reasons. Studies on the not for profit sector reveal that agencies collect data about clients and their programs (get authors). This data collection process is traditionally paper based frequently imposing an ever increasing administrative burden with organizations committing time and substantial resources to meet the specific needs of funders rather than those of the organization and its clients. Eakin (2007, p.1) in a review of accountability and compliance requirements in Canada asserts that *nonprofits are swept up in complex, time consuming and very detailed accountability reporting systems and controls*. Whilst meeting funders' requirements, many not for profit agencies are unable to transform the data into a form suitable for purposes more immediately useful to them. These purposes encompass grant proposal development, program evaluation, fiscal monitoring, project planning, and enhancing their understanding of social problems as well as assisting with day to day management issues. Few organizations employ specialist staff to advise on using and analyzing existing data. Instead of hiring skilled staff to perform these tasks in house, they are likely to use external agencies and consultants at great expense. In this situation, the not-for-profits are at the mercy of the funders' demands and perceptions and the consultant's model of good evaluations. The clear view from the not for profit perspective is that they collect data required by their funders, but are not able to utilize this data for internal purposes because they are overstretched. Not for profits are caught in a dilemma. On one hand they are expected to collect data but on the other, the demands and costs of compliance with funder accountability requirements mean that there is little time or in-house skill to use the data for management and evaluation.

ACCOUNTABILITY REQUIREMENTS

The not-for-profit sector faces particular challenges from funding bodies which are increasingly requiring greater accountability. This accountability has two components traditional financial accountability and, increasingly, measurement of outcomes. There are rising expectations that services will be targeted at those most in need. These expectations are held by funding bodies including government and community foundations. Quite simply, funding bodies want a return on their investments. To meet these requirements organizations need access to sophisticated information systems that allow ease of data collection and the statistical and analytical capacity to use these systems to best advantage.

The United Way of America (1997) has provided an overview of various accountability demands in the sector over the past 25 to 30 years. Accountability initially focused on fiscal responsibility and documentation of how funds were spent; this focus remains a fundamental concern. A focus on the products or outputs of programs was the next step. These new measures included the number of products delivered (e.g. counseling sessions) and the number of people assisted. Whilst products delivered and people assisted are important and useful statistics, they are crude indicators of quality of service delivery. Over time, funders have focused more on service standard measures that demonstrate and ensure the quality of services and adherence to standards. Some of these standard measures include staff qualifications, staff-client ratios, specific service practices, record keeping and privacy protection. With recent reductions in health and welfare budgets, there has been a shift from looking at standards to addressing whether services were targeted to those most in need. Agencies are increasingly required to provide data that demonstrates services are delivered to those who most need them.

Key Performance Indicators (KPI's) and client satisfaction studies are more recent developments. Key performance indicators were developed by public accounting firms and include ratios of inputs, services, outputs and total costs. Client satisfaction measures have also been developed as part of overall quality assurance measures. These latter measures seek the views of clients on a range of variables including accessibility and customer satisfaction. They provide information to funders about the agency and its operations. Unfortunately these newer measures do not tell funders about the effectiveness of funded programs and whether clients are better or worse off. The current focus has moved to measurement of program outcomes and benefits for clients. Funders are now seeking quantitative results and evidence from agencies that demonstrate their service effectiveness.

Evidence of changing accountability requirements can be found by "googling" funding guidelines. Several community foundations, as part of their funding application process, ask questions about inputs, activities, outputs, and outcomes (short, medium and long term). Implicit in this request is a program logic approach. They also ask applicants to provide evidence that their proposed intervention is the most effective one to use for the intended beneficiaries. This suggests the importance of measuring outcomes, i.e., a move towards evidence based practice and research. For example, the US Department of Justice, Drug Court Discretionary Grant Program provides funding for non-violent substance abusers with a goal to reduce substance abuse and recidivism of offenders. Agencies funded under this program must provide data to measure the results of their work which includes the percent of participants who re-offend while participating in the drug court program. Specifically this means total number of participants, the number arrested on drug-related charges, the number arrested on non-drug related charges and the number of clients with drug court program violations. The funding body also wants quantitative data on clients who have successfully participated in programs. Compliance with these measures requires good information systems and the analytical skills of staff.

One recently emerging and dramatic pressure on both for profit and not for profit organizations comes from the managed care approach. Here traditional fee for service arrangements are replaced by a system where costs and services are controlled by limiting the amount and type of services provided. The focus is on reducing the costs whilst simultaneously improving quality of care by collecting and using evidence on the effectiveness of clinical interventions. For example, take a person receiving treatment funded by /an insurance company following a car accident. In earlier times, this patient may have been able to receive physiotherapy, massage therapy and chiropractic care simultaneously. This would be a costly arrangement and, as these services were provided concomitantly neither the insurance company nor the therapists themselves would know what particular interventions were successful or to what degree. By taking a managed care approach and monitoring costs and services, insurance companies might now recommend that service providers begin with one therapeutic intervention and only introduce other services after a period of time where the efficacy is demonstrated or where there is a demonstrable need and evidence to provide additional services.

In the managed care environment, providers are expected to have and adhere to explicit practice standards, to review the way their services are utilized and to address quality improvement in their work with clients. This places demands on practice management and is only possible with good electronic information systems. The managed care revolution requires that agencies and practitioners keep accurate patient records, manage their billing, write clear statements about the client's problem and set clear therapeutic goals and outcomes, develop research skills and adhere to standards of practice and established clinical protocols for a variety of clinical problems. There are parallels in the mental health system where Gregoire and Jungers (2007, p.735) expect that counselors need to provide 'a good treatment plan that includes the following elements: a clear statement of the client's problem, specific goals with measurable criteria and time frames for completion of the goals, and a clear statement of the means to be used to achieve these goals'. The elements of a good treatment plan fit with the components of the logic model as described later in this chapter.

ADMINISTRATIVE BURDENS

The process for applying and reporting on funding adds to an agencies administrative burden. In a study of not for profits in Ontario, Eakin (2007) asked agencies to rate the complexity of funding application and reporting processes from simple to complex. A simple application proposal is short with readily accessible information and straightforward program descriptions, whilst a complex proposal has time constraints, requires specific data that is not readily available and specificity on programs and outcomes. In reporting on funding, simple reporting processes require readily available information while extreme reporting requires data that is difficult to obtain, requires exercise of both management and clinical judgment, much additional data and is demanding of staff time. Many not for profit agencies rated the application and reporting process as extreme with few rating them as simple. This reporting process is made more difficult when organizations receive funding from multiple sources thus having numerous reporting requirements. All this takes time and expertise that few agencies are equipped to deal with.

Privacy legislation in Australia (Privacy Act 1988) and similar provisions in other countries require compliance with client information management standards which take account of the importance of data security and data quality, provide capacity for individuals to access and correct their personal information whilst emphasizing care in the use of sensitive information. Management information systems such as case management software programs allow organizations to collect and present information to funding bodies whilst maintaining compliance with such legislative demands.

In the health sector, evidence based practice is a standard professional expectation. Evidence based practice is the *conscientious, explicit, and judicious use of current best evidence in making decisions about the care of individual patients* (Sackett, Rosenberg, Gray, Haynes and Richardson 1996, p.71). It brings together integration of clinical expertise and compassionate care of patients with the best available evidence from research. Whilst its utility in health care has been clearly demonstrated, the development of evidence based practice in the human services is in its infancy. There are, nevertheless, promising ways in which this approach can be used for improving knowledge about service and provider users, practitioners, organizations, policy and research (Johnson & Austin 2006). It is expected that evidence based practice and research will be increasingly used in response to greater accountability requirements made by funders leading to specific demands for: outcomes measurement, increasing availability of expertise and resources for evidence based practice, and rising expectations that the not for profit organizations will manage for results.

Managed care is practiced in Canada and the USA and to a lesser extent in other countries. There are, nevertheless, pressures on all not for profit organizations to use aggregated program data to demonstrate their effectiveness. Local foundations are an increasing source of program funding for the not for profit sector. On one hand foundations with tax exemptions are expected to demonstrate results to governments and in turn, foundations demand efficiencies and outcomes from recipient organizations. Governments are result oriented, requiring information from the not for profits sector about their program, progress against objectives and specific results. They now demand that funded programs demonstrate achievement of particular outcomes and outputs as well as effective, efficient and efficacious services. Many organizations are required to achieve these requirements and conduct their own evaluations in order to receive ongoing funding. If not for profits do not have the internal capacity to undertake these evaluations, they may need to hire external consultants, an expensive exercise. Large not-for-profit organizations receive funding from multiple sources including federal, state, regional or local organizations with increasingly complex, and possibly overlapping reporting requirements. Unless organizations have, or are able to purchase the analytical and research capacity to separate inputs, activities and outcomes from various programs and transform this data into specific results, their ongoing funding may be jeopardized.

Despite these demands, governments and private funders in the US were generally dissatisfied with the research data that organizations provided to justify grant proposals and support evaluations (Stoeckler 2007, p.111). Funding is not a right or entitlement in the non-government sector. Acceptance of funding means responsibility. Funders expect that services will be directed and targeted to those most in need. It is assumed that there will be fiscal responsibility, accountability for funding and measurement of outcomes. Quality standards are expected, these including use of service protocols, adherence to practice standards, appropriate use of qualified staff, participation in quality assurance, and meeting accreditation standards. Finally governments expect that, wherever possible, practice is based on demonstration of effectiveness. Whilst these are the funding bodies' expectations it does not mean that these bodies will necessarily pay for costs associated with achieving accountability.

In summary, funder demands for greater accountability are outpacing the technical and research capacity of the not for profit sector resulting in many agencies being unable to meet the specific accountability and program evaluation demands of funders. How then can case management software be used to address funders' demands for program monitoring purposes and to develop and address the effectiveness of services? Case management software is a tool providing an organization the capacity to manage, evaluate and monitor programs, research and plan services. The utility of the software is a significant human resource consideration. It may be necessary for agencies to spend money to save money, in other words to weigh up the costs and benefits. The training and development costs could be amortized over time whilst there will be savings with a move from paper based and error prone system to collation and analysis done by the system.

To fully realize the value of software programs, their introduction requires leadership, the organizational readiness to change and the research capacity of staff to maximize the utility of information systems. The introduction of software may also entail a significant diversion of staff from management, administration and service provision to participate in the necessary training.

PENELOPE

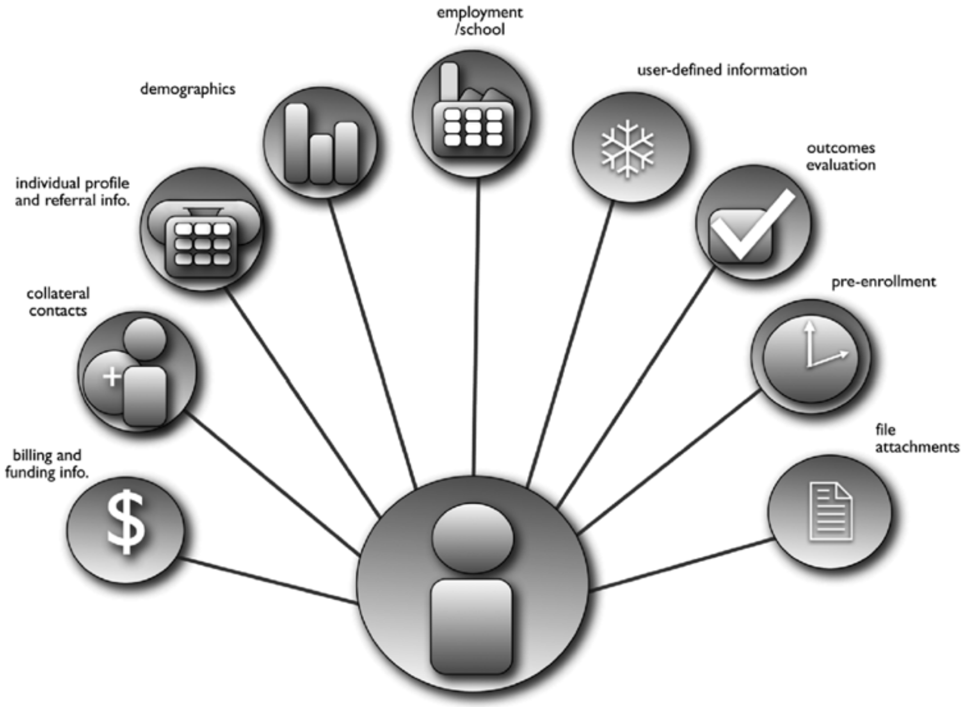
Penelope by Athena Software is a feature-rich and flexible case management and client information management solution for mental health and human service providers. The software brings together billing, clinical documentation and outcome management - into a secure and easily implemented web-based package. Penelope is a client-centric system that captures the spectrum of services a client may be receiving, from individual, family and group clinical services to educational and preventive programs. A wealth of demographic, referral, risk and bio-psycho-social information can be collected and custom recovery plans can be built into the system. In addition, the MIS (Management Information System) captures progress notes, signature forms and attachments such as images and external documentation.

At an enterprise level system, Penelope not only accommodates hundreds of concurrent users but facilitates coordination of care through assignment of providers to cases. This provider assignment can encompass different models ranging from primary or multiple providers for a single service, a multi-disciplinary team approach or a single pairing approach for one-to-many services. The integrated scheduler component captures service provision through time and also coordinates service among administrative and clinical staff; an (optional) integrated billing function accommodates a complex variety of funding and payment scenarios with efficiency and ease. Users, from clinical service providers, to reception, billing staff and management have user-defined authorized access to various aspects of the system and benefit from the specific workflow and reporting features relevant to them. By integrating all components of service provision whilst customizing the user experience the system is extremely efficient and easy to use. With little to no duplicate data entry a wealth of information can be captured, Penelope can be used to report on a wealth of information of interest to the organization as a whole in addition to complete individual case files. Program and funding utilization statistics and client and program outcomes can be related to such service characteristics as length and/or frequency of service, participation in and/or receipt of multiple services, presenting needs/diagnoses, staff and staff caseloads and attributes (qualifications, specializations), demographic variables and more. Such powerful reporting allows organizations to identify strengths and gaps in service, identify and secure recurring and additional funding opportunities and monitor progress towards internal benchmarks. This chapter will focus on this particular aspect of the software.

Core Features

The case file is a central component of the practice information system in all health and human service agencies. In a paper based office, these files hold personal and service information about individual clients and their families. The case file is also a key component in the case management software environment being stored and managed electronically rather than in a file room or cabinet.

Figure 1. Individual information



In a case management software environment, files are based on individuals participating in, or receiving services from the agency. When an agency accepts a client referral and provides a service, the agency collects, as part of the intake process, information about that individual client. This includes personal identifying and demographic information such as age, address, family size and structure, school information, income and education. The reason for referral is also a critical part of the intake process with details of the referring agency or worker, a critical part of this process being recorded in the data base. In some agencies, information about insurers or account information will also be included. Figure 1 shows the range of information that might be collected about an individual.

Table 1 shows the possible range of information for collection. Whilst user defined variables are not shown in the diagrams these variables comprise data and information unique to the agency and client group, for example in a child protection agency user defined variables may include notifications of child abuse, name and demographic information about those reporting, and reasons for reporting. This agency may also include information about foster care arrangements, names of carers and respite care arrangements.

Demographic information is supplemented by narrative documents including intake summaries, presenting information, treatment or recovery plans, progress assessment reports, details of incoming and outgoing telephone calls, social history, service provision, intervention and summary statements. The case file provides information about the individual client, case documents, intake summary and referral information and file attachments containing essential information necessary for working effectively with clients as illustrated in Figure 2.

Table 1. Range of information for collection

Individual profile	**Demographic information**	**Collateral contact information**	**Billing / account information**
First / last name Date of birth Gender Address Post code Country Phone details Site of service Contact instructions Referral source	Educational attainment Employment status Occupational type Income source Income range New Australian Country of birth Citizenship status	Full name Relationship Organization Address Post code Phone	Total invoiced Total applied receipts Total unapplied receipts Total applied write offs Balance Transaction history Debits Credits
Employment / school information	**Outcomes evaluation information**	**Pre-enrollment information**	**File attachments**
Employer name Work contact Address Phone Email Work comments	Pre / mid / post stage evaluation Surveys completed	Reasons for waiting Waiting for program Waiting for worker Comments Waiting since	Letters Reports Documents of any data type

Workers can use the system to schedule activities and appointments, and log information about whether the client has attended their appointments. Although many agencies do not bill clients or insurers, the program incorporates a system that is able to invoice and record payments, track billable services and provide for single and batch invoicing and provide summary financial information.

INFORMATION DOMAINS

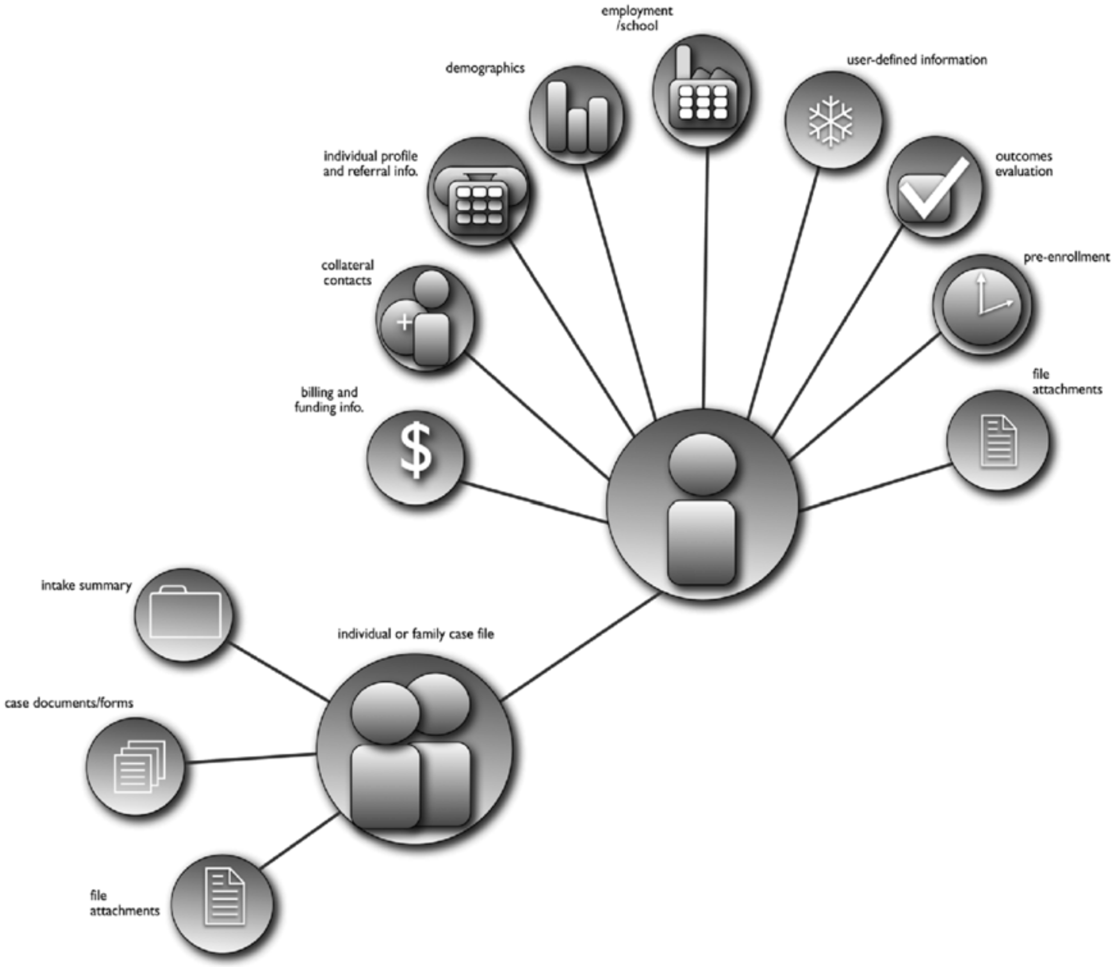
Although the Penelope case management information system provides information about individuals and cases that can enable practitioners to manage their case loads effectively and efficiently, the system, more importantly allows aggregation of information into many domains. Put simply information is collected about individual clients at the case level, program and services level and at the activity level. These information domains with examples of associated outcomes are illustrated in Table 2.

Aggregated data allows agencies to use data in a variety of different ways to serve the needs of clients, management of human and financial resources, assessing client satisfaction, program planning and managing funding requirements. Given its simplicity of use the package presents may opportunities for agencies.

WHERE TO START?

Information domains provide a conceptual framework for the collection of standard demographic and user defined information. This is the easy part of the journey. The transition from information collection to management and utilization of this information is more challenging for agencies. The transition from data collection to using data for monitoring and analysis of programs should not be feared by administrators or practitioners. It is helpful to start with some very simple questions and link these ideas to concepts and strategies in the literature.

Figure 2. Individual and case file information



- What are our questions about our programs? Practitioners have questions exploratory questions about the services provided and administrators have questions about the use of agency resources to deliver these programs. Both have questions about clients, services to community and policy. These are who, what, how and why questions. They are the questions of interest to the agency and not questions imposed by funders.
- What questions do we have about our services to clients and community and how do we measure the work we do? At the most simple level these questions relate to performance monitoring. The issues for consideration are what information is collected and how do we interpret the information in the agency.
- What are trying to achieve in our agency? This is a deliberate question about the intentions of programs and services, and expectations about the outcomes we hope to accomplish. These simple questions link to the idea of the program logic model, a map which is unique to every agency and program. What we are trying to achieve should

Table 2. Information domains

Clinical domain	**Service delivery domain**	**Outcomes evaluations domain**
Personal and family information Demographic data Employment data Collateral contact information User defined information Case documentation and notes Clinical activities	Case load statistics Activity status statistics Activity statistics Program specific statistics Presenting issue statistics Case flow statistics	Client self ratings at pre, mid, and post stages of service Percentage change over time Frequency distribution over time Qualitative feedback Client satisfaction results Outcomes reporting by program and funder13
Billing accounting information	**External reporting domain**	**Human resources domain**
Client fees / funder invoices Payments and write offs Subsidy / sliding scale information Program-specific accounting Account aging	Funder specific reporting Program specific reporting Aggregate reporting Population specific reporting	Worker hours – indirect, direct, non-case Activity status by worker Activity types by worker Case load / worker capacity data Worker involvement in specific program Billable hours

fit with agency plans, funding submissions and formal evaluations.

- How do we demonstrate the effectiveness of our intervention and use these results to change services? This is a research question. This process can be a more complicated and exhaustive when combined with complex analytical and interpretative approaches.

We therefore have four types of questions: exploratory, monitoring and interpretative, intentions and evaluative. Before understanding these questions, it is necessary to understand the concept of the program logic model which assists in understanding these questions.

Logic Model

In simple language, a logic model is a graphic representation used as a guide to convey what agency services are intending to achieve. This guide, unique to every agency provides a mechanism to communicate to funders, researchers and community about services and outcomes. At a more formal level, Frechtling (2007, p.1) defines a logic model as a 'tool that describes the *theory of change* underlying an intervention, product or policy'. This theory of change simply means that when resources and activities are combined in particular ways they will lead to intended outcomes for clients. *If* a particular set of actions are prepared, *then* specific results are expected. These logic models are important aids to assist organizations in applying for grants as they clarify the intended purpose, activities, outputs and outcomes. In addition, these models provide a framework for developing an evaluation study, setting a framework for the information to be collected and also documenting the intervention and how it worked. Logic models are not fixed as they can be developed at any time during the life cycle of the program and can be modified if the circumstances of the program change. For organizations using a case management software system, logic models provide the elements for data collection enabling compilation of relevant information, and a focus for analysis. Although this chapter will focus on technological aspects of the logic model, it should be remembered that developing logic models is a collaborative endeavor and a dynamic process involving agency staff and other stakeholders. Over time, the logic model used may need revision as practitioners work with the clients and develop new practice knowledge of activities and outcomes.

Logic model components are simple and include inputs, activities, outputs and outcomes. The inputs are resources which are brought to a program including financial, material and human resources. Some programs may have multiple funding sources whilst human resource can include volunteer support, in kind assistance or partnerships with other agencies. Activities are those action steps taken in the program to achieve its stated goals and outputs. Outputs are the results of the program such as products, services and reports produced. Outcomes are the changes to people and situations resulting from the activities and indicate that the aims of the program have been achieved. Documentation of these outcomes provides evidence of the success of the program. Outcomes can be written as short term, medium term and longer term. It is not possible here to address issues in developing program logic models but substantial online resources are available from such organizations as the United Way, Kellogg Foundation as well as print material (Frechtling 2007; Wholey, Hatry & Newcomer 2004).

Although the logic model is a clearly structured approach, its development is a dynamic and iterative process that requires involvement of all staff and takes place over time. McLaughlin and Jordan (2004, p.15) suggest that managers regard the logic model as a process that involves both program participants and other stakeholders associated with the model's implementation. Above all logic modeling is part of long term cultural change. Understanding the program logic model is fundamental in demonstrating outcome measures to funders, preparation of grant application and using data in other forms of inquiry.

The program logic model provides a structure for demonstrating outcomes to funders, a framework for funding applications, and a series of questions for formative and summative program evaluation. As a theory of change is embedded in the logic model, the model with associated outcomes allow for testing of the effectiveness of the change strategy. The particular value of the program logic model lies in program evaluation, a process that includes:

- Development of a conceptual model of the program and identification of key evaluation points
- Development of evaluation questions and definition of measurable outcomes
- Development of an evaluation design
- Collection of data
- Analysis of data
- Provision of information to interested audiences (Frechtling 2007, p.127).

WHAT ARE THE EXPLORATORY QUESTIONS ABOUT OUR PROGRAMS?

This is something that practitioners and administrators do every day although they may not describe this as an investigative, analytical and/or interpretative process. Questions about practice emerge because practitioners and administrators have hypotheses about practice and want confirmation of their intuition. There are many questions that practitioners and management may ask on a day to day basis. Generally, the software program enables practitioners and administrators to use data collected to provide the answers. Listed below are examples of the questions that may be asked.

Questions about services to clients

- How long is our waiting list?
- How quickly do we respond to urgent cases?
- How many hours of service do we provide per client?
- What is the demographic profile of our client group?
- What is the diversity of our client populations?
- How many cases of elder or child abuse have we received?

- What sorts of complaints do we receive from clients about our services?
- How many clients return for further assistance?
- What are the most common problems experienced by our clients?
- What are the health and social risk factors of our clients?
- What sort of health and mental health problems go together?
- What are the most intractable mental health concerns experienced by our clients?

Questions about resources

- How many years of experience do agency staff have?
- What is the range of staff qualifications?
- What is a reasonable workload for staff in a particular service area?
- What is the cost of group work activities and individual therapy?
- How many hours of supervision per year are provided to new and experience staff?
- What is the cost per person attending training programs?
- Are some staff more effective in working with some clients than with others?

Questions about the agency in the community

- How does our client service profile compare to similar agencies?
- What are the social problems in the neighborhoods served by our agency?
- What are the most urgent unmet needs identified by the clients and community?
- What is the network of referrals and how do we work with these agencies?

Questions about policy

- How does a particular social policy impact on the clients in the agency?
- What are the challenges for clients in accessing health and welfare services such as housing, health services or income support?
- Does the allocation of resources for services match the costs of delivering those services?

The above questions are useful but they need to be linked to a commitment on the part of the agency to engage in measuring and monitoring performance and outcomes. There are several steps in this process including:

- Obtaining and holding the support of managers and stakeholders
- Identifying the questions that the agency wants answered
- Defining the criteria to use in answering those questions
- Understanding the data that needs to be collected
- Determining how that data is to be presented and analyzed.

The steps in beginning this process are elaborated by Wholey (2004) using the concept of evaluability assessment, that is a process undertaken by the agency to determine what evaluations might be useful, explore what evaluations would be feasible and design evaluations.

WHAT ARE THE MONITORING AND INTERPRETATIVE QUESTIONS ABOUT THE WORK WE DO?

Administrators and practitioners also have questions about the quality of their services and programs and rely on quantitative descriptive accounts to track and monitor performance on a regular basis. These questions may relate to resource management, outputs, activities, productivity, service quality, customer satisfaction (Poister 2004). This information can assist agencies to manage for results. Although the data is descriptive, it can also supplement more complex evaluative tools.

Performance monitoring is an important tool in the management and planning of services bringing together collection of data, accountability requirements, theories of social change and performance monitoring measures. The aim of performance monitoring is to track performance in a timely and scheduled manner using a range of measures related to agency programs providing information to managers, stakeholders and policy makers. It can assist agencies to assess how a program is operating and the extent to which program objectives are being achieved in the service delivery. Where objectives are not fully achieved, performance monitoring can assist in rethinking aspects of delivery. Performance monitoring uses client satisfaction measures and can report on cost effectiveness and productivity.

Performance monitoring may be imposed by funders to compare services or deliberately used by agencies as part of their operations. For example; in the Australia health care system, performance monitoring is imposed with hospitals required to measure and report indicators such as patient waiting time for elective surgery or the number of patients who wait longer than 24 hours in emergency. Within a human service agency, similar measures track can what is happening with program outcomes. Measures collected are descriptive and it is not possible to attribute causation. The value of some measures can also be challenged. For example, the size of a case load may not reflect the actual workload of individual practitioners as some cases are complex and other cases have a relatively simple intervention. Similarly, the length of a hospital waiting list may mean that there is a very effective early detection of problems rather than a queue of more serious problems. Once these measures have been developed and there is clarity about their reliability, they can then be used in a variety of different ways by the agency including;

- Use of particular resources used in program areas (e.g. number of support workers needed to care for an older person in their home)
- Output measures (number of cases or clients serviced)
- Productivity measures (cost per investigation of child abuse)
- Service quality especially turnaround time, accessibility, safety, waiting time for diagnostic assessment or time from application for a pension or benefit until a decision is made and provided to the customer
- Outcomes or the extent to which a program is effective
- Cost effectiveness or the ratio of costs to outcomes (cost per discharged consumer)
- Customer satisfaction (for various aspects of service delivery such as therapy, financial assistance, child care or home help) (Poister 2004, pp.99-102).

Much of the information described above can be taken directly from the data management system. The data can be raw numbers, percentages, averages, or indexes which are generally composites representing a particular characteristic. Some performance measures require additional information for collection but this can be part of the intake, assessment and intervention process. This can include questionnaires such as the Health Status Questionnaire, measures of risk factors, social functioning, observations by therapists, follow up data on clients after a set period and surveys. It is important to bear in mind that measures should be specific and oriented to results, understandable, and be reliable, (objective and dependable) and valid (fair and unbiased).

WHAT DO WE INTEND TO ACHIEVE?

Software management programs provide agencies with a tool to record information about their clients and services and then use this information deliberately for a variety of administrative and research purposes. Unfortunately, many social service organizations do not utilize software management programs or management information systems to their full potential if indeed they do possess such programs. Stoecker (2007) notes that not-for-profits collect a lot of data but do not use much of the data collected. One step in effectively using the tool is to think systematically about programs delivered by the agencies asking what in particular is this program intended to achieve and with what results for the client group. The name given to this approach is the logic model and here agencies specify inputs, activities, outputs and outcomes.

Interpretative Approaches to Outcomes

The program logic model is quantitative in orientation. There are also qualitative evaluative approaches rather than quantitative using interpretative orientations guided by social constructivist theories. Here participants create their own understanding based on past and current experiences alone and in collaboration with others. This interpretative model allows practitioners, to learn as they proceed with the program and modify and adapt according to the clients and issues faced along the way with outcomes developed through the process rather than planned before the program commences. It is particularly relevant in service delivery when the services and problems are complex.

Although interpretive models are qualitative, there is logic to interpretative evaluation with stages that include engagement, discovery, sense making and unfolding (Netting, O'Connor & Fauri 2008, p.136). These stages are not necessarily sequential but more of a spiral progression. The process of engagement and relationship building with diverse groups, discovery and sense making happens simultaneously with a deepening of understanding with the development. Information collected in this process comes from multiple sources including qualitative and quantitative data, narratives from logs or case studies, observations, views of all participants or even the discovery of tensions and ambiguities.

When using interpretative approaches, accountability and the use of information systems pose special challenges. Funders may not like these approaches because outcomes are not clearly quantifiable and therefore hard to evaluate and compare with similarly funded programs. Nevertheless, it is possible to meet funder accountability requirements using information systems. The emergent interpretative models rely on description and documentation of multiples views, relationship building, understanding of complexity, consensus building processes, options and possibilities and the learning process. These can be documented in reflective journals, narratives of critical incidents, day journals, contact logs, methods journals, notes of meetings, and transcripts of significant meetings. These can be supplemented with various forms of quantitative data. Case management software programs can be used to store this data, make and edit notes. They can be stored in the system and retrieved for analysis by exporting them to such programs as NVIVO.

HOW DO WE EVALUATE THE EFFECTIVENESS OF OUR WORK?

There are three ways to demonstrate effectiveness: experimental, quasi experimental designs and evaluations that examine impact. Generally these evaluations are done by large scale organizations rather than the small not for profit. The gold standard for effectiveness studies is experimental randomized studies. These require that participants are randomly assigned to either a treatment group or a non treatment group, called the control group. Generally, these studies are difficult to implement. The outcomes of these groups are then compared to determine the impact of the service or intervention. Quasi experimental designs are similar to experimental designs and are more common because the allocation of subjects to groups is not random. There are several variations of randomized designs including time series based on repeated measures, before and after comparisons and post program comparisons. Finally, effectiveness is evaluated by examining changes in risk or outcomes amongst the client populations. Risk factors that include for example mental health or general health problems are measured to determine the impact of the program.

CASE MANAGEMENT SOFTWARE AND REPORTING

Software programs provide a mechanism for information collection. Penelope software allows tracking of client activity from demographic characteristics of the population and program related perspectives to clinical outcomes. A wide variety of reports can be used to answer basic practice and administrative questions and to allow performance monitoring. Custom surveys can easily be built into the system by users. In addition, the Penelope case management software system includes public domain outcome and evaluation templates that can be used in outcome studies and for inclusion in quasi experimental designs and randomized experimental studies. Examples include Brief Psychiatric Rating Scale, General Satisfaction Survey, Hamilton Anxiety Rating Scale, Global Assessment of Functioning Scale, and Family/Couple Outcomes Survey. Proprietary scales can also be used with this software.

Although this software is both powerful and flexible, the introduction and ongoing management of performance measures, outcome studies and the incorporation of experimental studies does present challenges for organizations. The United Way of America (2000) recognizing that many not for profit organizations were using performance monitoring, required the development of outcome measures as part of funding requirements. They followed up many funded organization with a survey examining the impact of this requirement. Many agencies identified outcome measurement as helpful as it enhanced record keeping and facilitated success in competing for additional funding and resources. On the other hand they identified lack of access to technical resources to solve problems and inadequate software and staff time to complete these requirements.

Introduction and effective use of case management software systems, such as Penelope will take time. There are some fundamental requirements including the involvement of all staff and stakeholders in the planning, and the support of senior management and the board of directors. Data collection methods, analysis and interpretation of results may need to be supported with additional technical expertise. The system is developed on a trial and error basis with a process of testing, evaluating and making improvements before it meets the needs of management, practitioners and funding bodies. Once established, improvements and modification will also be required. Throughout this process, a range of problems will be presented especially in relation to the quality of agency records. Hatry (2004) identified issues in relation to missing and incomplete data, aggregated data where information is not classified into useful and pertinent categories, quality control for the reasonableness of data and privacy issues.

THE FUTURE

Demonstration of effectiveness using management information systems is here to stay. Software programs to support these initiatives will increasingly be adopted with funder demands and as organizations effectively using such systems will gain competitive funding advantages. Effective software solutions in the human services sector will be ones that address a combination of priorities including cost effectiveness, ease of use, user and system security, decision support and evaluative support. In addition, flexible systems that can accommodate the diverse needs, best practices and specific logic models of human service organizations will have the greatest impact on their success.

There will be an increased public accountability for funding. This will go beyond financial accountability to include service quality and service outcomes. Performance indicators and programs outcomes are likely to be made more public enabling comparisons to be made by the clients they serve. Savvy consumers may elect to attend programs which can demonstrate the best outcomes. This is already occurring in the health sector with use of service indicators such as infection rates of particular hospitals and the community. Scrutiny of performance and outcome measures for funded programs will be undertaken with attention to the relevance, rigor, and interpretation. For example some funding bodies already specify the measures required as part of funding. With this data they are able to make comparisons between the costs and service outcomes. They may use this knowledge to determine future funding. Benchmarking is a process that allows funders to compare of performances, outcomes and associated costs for similar services. It allows examination of performance in particular periods of time, outcomes for different target groups, variations of service delivery and performance in similar organizational structures and geographical areas (Pathfinder 2003). Funders may well classify services according to what they interpret as a "good" performance although such as classification system would need to done with some care as different client groups, neighborhoods or populations may exhibit different results.

CONCLUSION

Case management software programs are sophisticated tools with practical capabilities enabling improved management performance and demonstration of outcomes. At a basic level, these software programs facilitate collection of data about clients. Agencies that do not go beyond data collection are under utilizing the system's capabilities and not getting a return on their investments. With increased accountability requirements from funders, there are expectations that the not-for-profit sector will need to demonstrate outcomes for clients. This chapter, using Penelope case management software as an illustration has provided practical examples of the way agencies can make the transition from data collection to performance monitoring and demonstration of effectiveness.

REFERENCES

Bureau of Justice Assistance. (2008). *Drug court discretionary grant program*. Retrieved October 31, 2008, from http://www.ojp.usdoj.gov/BJA/grant/drugcourts.html

Eakin, L. (2007). *We can't afford to do business this way: A study of the administrative burden resulting from funder accountability and compliance practices*. Toronto, Canada: Wellesley Institute.

Gregoire, J., & Jungers, C. (2007). *The counseling companion*. Mahwah, NJ: Lawrence Erlbaum.

Hatry, H. H. (2004). Using agency records. In J. S. Wholey, H. P. Hatry, & K. E. Newcomer (Eds.), *Handbook of practical program evaluation*. San Francisco: Jossey Bass.

Johnson, M., & Austin, M. (2006). Evidence-based practice in the social services: Implications for organizational change. *Administration* *in Social Work*, *30*(3), 75–104. doi:10.1300/J147v30n03_06

McLaughlin, J. A., & Jordan, G. B. (2004). Using logic models. In J. S. Wholey, H. P. Hatry, & K. E. Newcomer (Eds.), *Handbook of practical program evaluation*. San Francisco: Jossey Bass.

Netting, F. E., O'Connor, M. K., & Fauri, D. P. (2008). *Comparative approaches to program planning*. Hoboken, NJ: John Wiley.

Pathfinder. (2003). *Guidance on outcomes focused management: Supporting paper: Benchmarking using outcomes information*. Retrieved October 31, 2008, from http://io.ssc.govt.nz/pathfinder/documents/pathfinder-benchmarking.pdf

Plantz, M. C., Greenway, M. T., & Hendrick, M. (1997). *Outcome measurement: Showing results in the nonprofit sector*. Retrieved October 31, 2008, from http://www.liveunited.org/Outcomes/Resources/What/ndpaper.cfm

Poister, T. H. (2004). Performance monitoring. In J. S. Wholey, H. P. Hatry, & K. E. Newcomer (Eds.), *Handbook of practical program evaluation*. San Francisco: Jossey Bass.

Sackett, D. L., Rosenberg, W. M. C., Gray, J. M. J., Haynes, R. B., & Richardson, W. S. (1996). Evidence based medicine: What it is and what it isn't. *BMJ (Clinical Research Ed.)*, *312*, 71–72.

Stoecker, R. (2007). The research practices and needs of non-profit organizations in an urban center. *Journal of Sociology and Social Welfare*, *34*(4), 97–119.

United Way of America. (1997). *Outcome measurement: Showing results in the nonprofit sector*. Retrieved October 31, 2008, from http://www.liveunited.org/Outcomes/Library/ndpaper.cfm

United Way of America. (2000). *Agency experience with outcome measures: Survey findings*. Retrieved October 31, 2008, from http://www.liveunited.org/Outcomes/Resources/What/upload/agencyom.pdf

Wholey, J. S. (2004). Evaluability assessment. In J. S. Wholey, H. P. Hatry, & K. E. Newcomer (Eds.), *Handbook of practical program evaluation*. San Francisco: Jossey Bass.

Wholey, J. S., Hatry, H. P., & Newcomer, K. E. (2004). *Handbook of practical program evaluation*. San Francisco: Jossey Bass.

This work was previously published in Information Communication Technologies for Human Services Education and Delivery: Concepts and Cases, edited by J. Martin and L. Hawkins, pp. 167-183, copyright 2010 by Information Science Reference (an imprint of IGI Global).

Chapter 6.6

An e-Healthcare Mobile Application:

A Stakeholders' Analysis Experience of Reading

Niki Panteli
University of Bath, UK

Barbara Pitsillides
Nicosia, Cyprus

Andreas Pitsillides
University of Cyprus, Cyprus

George Samaras
University of Cyprus, Cyprus

ABSTRACT

This chapter presents a longitudinal study on the implementation of an e-health mobile application, DITIS, which supports network collaboration for home healthcare. By adopting the stakeholders' analysis, the study explores the various groups that have directly or indirectly supported the system during its implementation. The system was originally developed with a view to address the difficulties of communication and continuity of care between the members of a home healthcare multidisciplinary team and between the team and oncologists often hundreds of kilometers away. DITIS evolved to be much more than that and even though it was introduced 5 years ago, it is considered a novel application. Despite this, its implementation has been slow, and several challenges, including the system's sustainability, have to be faced. This chapter aims to understand these challenges and the results of the study point to a diversity of interests and different degrees of support.

INTRODUCTION

Healthcare is an environment that has been experiencing dramatic progress in computing technology in order to process and distribute all relevant patient information electronically and overall to improve the quality of care. In particular, mobile e-health involves a spectrum of information and telecommunication technologies to provide healthcare services to patients who are at some distance from the provider and also to provide supporting tools for the mobile healthcare professional. The benefits of such mobile applications are numerous, with the main one being improvements in access to medical resources and care.

Recently, the healthcare and related sectors have been found to embrace mobile technology in e-healthcare applications. Though there have also been cases of mobile workstations being implemented at small medical units to facilitate easier access to specialist medical advice (e.g., Salmon, Brint, Marshall, & Bradley, 2000), most of the applications have been introduced to support patients at home. These could either be patient centered where patients and/or caretakers are given direct access to a mobile phone for communicating with the provider (e.g., nurse, doctor, counselor, etc.), or nurse centered where nurses who visit and care for patients at home have direct access to mobile applications for communicating with other medical staff.

It follows that the practice of e-health projects is often a collaborative activity requiring extensive and interactive communication within and between members of specialized occupational groups to coordinate patient care services. This becomes necessary when dealing with patients requiring a multidisciplinary team approach to their care, and who are treated outside the hospital environment. In such a case, the team is mostly geographically dispersed and rarely sees the patient together. This requires the creation of virtual multidisciplinary teams of care whose management and coordination can be supported by technology. In the study, we aim to explore the role of diverse stakeholders in an e-health application involving virtual multidisciplinary teams of care. Diverse stakeholders get involved at different stages of the project implementation and may experience different degrees of knowledge about the system itself, its significance, and its novelty. These along with their different backgrounds, interests, and expectations may contribute to different meanings and understanding about the system, its role, and its significance, which will ultimately affect system implementation.

BACKGROUND

Stakeholders' Analysis

The role of stakeholders in IS implementation has long been recognized in the literature, though it has only been during the last few years that the identification of different stakeholders as well as the roles and interrelationships between them was found to be important for uncovering some of the complexity in system implementation (Pouloudi & Whitley, 1997).

Despite this, researchers have given different definitions to stakeholders. Sauer (1993), for example, makes reference to stakeholders as supporters, those who provide funding, information, and influence, whilst Beynon-Davies (1999) argues that there is a need to broaden this definition. As he puts it, "…not all groups with an interest in the development of an information system necessarily support that development. Some stakeholder groups may have a definite negative interest in the success of a given project" (p. 710). Following from these, in this chapter, in an attempt to keep a broad definition, stakeholders are defined as those with a direct or an indirect interest in a project.

According to Mitchell, Agle, and Wood (1997), stakeholders can be distinguished in terms of three relationship attributes: power, legitimacy, and urgency. Power is the ability to impose influence on the relationship; legitimacy is "a generalized perception or assumption that the actions of an entity are desirable, proper, or appropriate within some socially constructed system of norms, values, beliefs, and definitions" (Suchman as cited in Mitchell et al., p. 574). Finally, "[u]rgency is based on time sensitivity and criticality" (Mitchell et al. as cited in Howard, Vidgen, & Powell, 2003, p. 31). A combination of these three attributes contributes to different types of stakeholders who have different roles and expectations.

EMPIRICAL STUDY

In this section, we present the case of an e-health mobile application and adopt a stakeholders' analysis to understand its implementation process and the challenges faced.

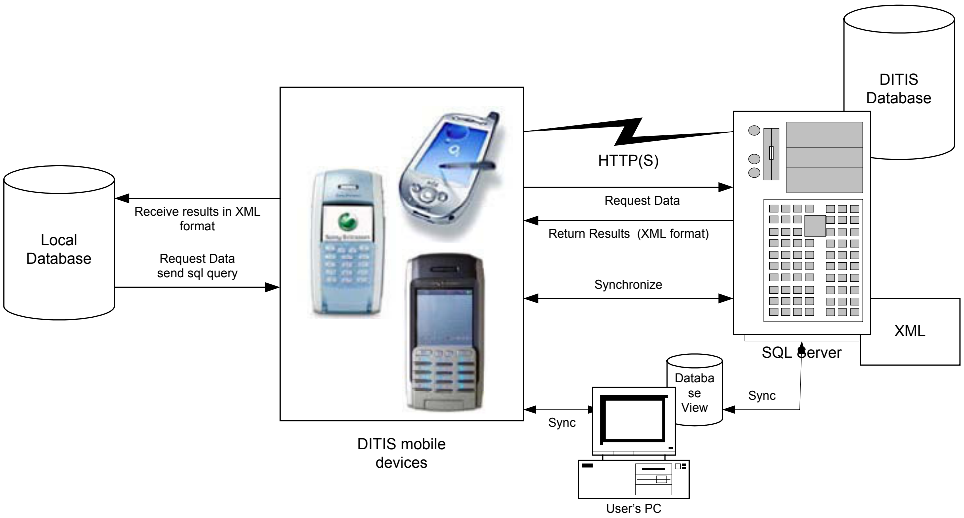
Mobile applications are an increasingly important technology for improving the quality of health services, especially at the point of care. They enable the formation of virtual teams of care, and timely, effective, and quality patient management are the expected outcomes. The role of stakeholders in supporting such innovative applications is vital.

The System

DITIS: Virtual Collaborative Teams for Home Healthcare (http://www.ditis.ucy.ac.cy) is an Internet- (Web) based group collaboration system with secure fixed and mobile (GPRS [general packet radio service], GSM [Global System for Mobile Communication], WAP [wireless application protocol]) connectivity (see Figure 1).

It enables the effective management and coordination of virtual collaborative healthcare teams. It provides a secure access to e-records from anyplace and anytime via desktop computers (at work) or a variety of mobile devices (when on the go). It includes a set of tools for effective scheduling and coordination of team members, with features including automatic notification and alerting. It makes use of supportive tools relevant to home care that improve efficiency and minimize errors. The collaboration platform is based on identified roles and scenarios of col-

Figure 1. DITIS system architecture



laboration, analyzed using the unified modeling language (UML).

The DITIS project was initiated in 1999 to support the activities of the home healthcare service of the Cyprus Association of Cancer Patients and Friends (Pasykaf). The goal of DITIS is to deliver a product that can improve the quality of the citizen's life. Contrary to today's health processing structure, which is, in all practical terms, facility-based care, this project aims to shift the focus onto home-based care, where everything is moving around the patient, supported by a team of multidisciplinary healthcare professionals. Given that the team cannot be by the side of the patient at all times, DITIS developed a collaborative software system to support dynamic virtual healthcare teams, customized for the differing needs of each patient at different times. The virtual healthcare team is supported in its provision of dedicated, personalized, and private service to the home-residing patient on a need based and timely fashion, under the direction of the treating specialist. Thus, it is expected that chronic and severe patients, such as cancer patients, can enjoy optimum health service in the comfort of their home (i.e., a focus on wellness), feeling safe and secure that in case of a change in their condition, the healthcare team will be (virtually) present to support them. The present users of the system include the healthcare professionals treating cancer patients (home-care nurse, oncologist, treating doctor, psychologist, physiotherapist, social worker, etc.) and the Pasykaf administration. It is expected that the system will be extended to other paramedical professionals, as, for example, the Pharmacist and the Cancer Registry, currently located at the Ministry of Health. Furthermore, the system can be adapted to cater to other home healthcare needs, as, for example, cardiac, renal, or diabetic patients.

DITIS deploys a novel networked system for tele-collaboration in the area of patient care at the home by a virtual team of medical and paramedical professionals, implemented using existing networking and computing components (the novelty of the system and competing approaches are briefly discussed in A. Pitsillides et al., 2005; B. Pitsillides et al., 2004). The system was originally developed with a view to address the difficulties of communication and continuity of care between the home healthcare multidisciplinary team (Pasykaf) and between the team and the oncologist often many miles apart. DITIS has through its database and possibility of access via mobile or wire-line computers offered much more than improved communication. Its flexibility of communication and access to the patient's history and daily record at all times, anywhere (in the case of home patients, outpatients, or an emergency hospital admission), has offered the team an overall assessment and history of each symptom. DITIS thus has the potential to improve the quality of life of the patient, for example, by offering the nurse the possibility of immediate authorization to change prescriptions via mobile devices, and the oncologist the possibility of assessment and symptom control without having to see the patient. It also offers the home-care service provider the opportunity to plan future services and lobby for funding by offering audit, statistics, and performance evaluation, and with these in place, the possibility for research.

The User Organization

Pasykaf, the user organization, was founded in 1986 to provide support to cancer patients and their families during their period of rehabilitation and is manned with highly qualified medical, paramedical, and nursing staff. In 1992, it started a home-care service for cancer patients. Specially trained palliative-care nurses in close cooperation with doctors (general practitioners and oncologists), physiotherapists, and psychologists attend and care for patients at home, focusing on maintaining the best possible quality of life, including medical care and psychological support.

In the context of home care, home-care professionals visit patients at home. Traditionally, the team of professionals was (loosely) coordinated by weekly meetings, or in case of some urgent event, information was exchanged by telephone calls or face-to-face meetings. Often, the same information is requested from the patient so each professional can build his or her own medical and psychosocial history and treatment notes (handwritten). Traditionally, these handwritten notes were filed at the Pasykaf district offices once the healthcare professional returned to the office. On a scheduled visit, the file had to be removed from the office and taken with the healthcare professional to the patient's house. This was inflexible and restrictive as there was no possibility of access by another healthcare professional at the same time. Furthermore, after hours, on-call professionals had to make a special visit to the office to collect the patient file (even if there was no other business with the office). For a patient visit to the hospital, especially in an emergency, there was no possibility of immediate access to the patient file from the attending home-care nurse. Therefore, there was limited possibility for continuity of care.

As with every manual system, there was limited possibility for audits and statistics, research was difficult, evidence-based medicine was not supported, dynamic coordination of the team was almost impossible, and communication overheads were very high and extremely costly in human and monetary terms. DITIS aims to address these problems in the provision of home-care services by a team of professionals.

Generally, given the limitations of the existing home-care delivery models, the need for improved ICT-supported practices emerged. Even though the context of health reform may vary across countries, major objectives are similar and include the following:

- A move toward people-centered services.
- A commitment to healthy public policy and a desire to improve the health status and quality of life of individuals and communities.
- Increased emphasis on knowledge- and evidence-based decision making, and efficiency and effectiveness in service delivery.
- A shift from facility-based health services and a focus on illness to community-based health services and a focus on wellness.
- The integration of agencies, programs and services to achieve a seamless continuum of health and health-related services.
- Greater community involvement in priority setting and decision making.

DITIS aims to support the above healthcare reform objectives. We focus our analysis on home healthcare of cancer patients, but expect our results to be applicable to home healthcare in general as well as cross-cultural and cross-border interoperability. Thus, through DITIS, we expect to assist in the delivery of better home care by offering the healthcare team services that are aimed at achieving a seamless continuum of health and health-related services despite the structural problems of home care as compared to facility-based care.

The system was initially deployed in one district, District A, and was gradually implemented in another three districts. The study has adopted the longitudinal approach in data collection for the first 5 years of the system from 1999 to 2004.

Methods and Data Collection

This research is interpretive as our aim is to capture stakeholders' interpretations of the system itself and their use of the system. To this end, our research method is qualitative in nature, examining "humans within their social settings" (Orlikowski & Baroudi, 1991, p. 14).

The fieldwork has taken place in various district sites of Pasykaf. Each site is served by a number of palliative-care nurses who visit patients regularly in their house to offer support. Data on

DITIS were collected on different stages of the implementation process.

Phase 1: The preliminary part of the research has studied the use of mobile telephones by a group of palliative-care nurses during the period of August to September 2000. Interviews with three nurses and one doctor in District A have enabled the study of nurse-to-nurse interactions and nurse-doctor interactions via the use of mobile telephones, whilst also contributed to gathering information on their level of awareness about DITIS and its potential use in palliative care.

Phase 2: This part of the study took place in May 2001 and involved the use of a structured questionnaire that was sent to DITIS developers and potential users. It aimed to explore stakeholders' expectations regarding DITIS. A copy of this questionnaire appears in the appendix.

Phase 3: The third phase of data collection took place in April 2003. By this time, DITIS was implemented in four district sites. During this phase, current users of the system in three district Pasykaf offices were interviewed: one psychologist and three nurses. The main issues explored during interviews included the participants' actual use of DITIS, their own explanation of why they use DITIS the way they do, and their understanding of what users' and others stakeholders' role should be for achieving effective DITIS use.

Phase 4: This final part of the study took place in April 2004. Interviews included users (nurses and psychologist) as well as members of other stakeholder teams. During this phase, it was found that even though DITIS has been implemented effectively with the right support from the project team, anxiety was identified at different levels with regard to its future.

Table 1 summarizes the data-collection approach adopted.

RESULTS

Overall, the data reveal that DITIS offers innumerable opportunities for palliative-care nurses and other cancer-care practitioners. DITIS is currently widely accepted as an invaluable tool in palliative care. Nurses, psychologists, and doctors acknowledge that DITIS has numerous

Table 1. Summary of the adopted data-collection approach

Phase	Time Period	No. of Interviews	Purpose
Phase 1	August-September 2000	4	Understand context of work, users' awareness about DITIS
Phase 2	May 2001	7	Users' expectations
Phase 3	April 2003	4	Level of usage & explanations given
Phase 4	April 2004	5	Stakeholders' own evaluation of DITIS

advantages and that they are willing to incorporate it in their work activities. DITIS can improve communication, coordination, and collaboration among members. Due to the huge amount of data regarding new and old patient records that need to be handled on a daily basis, DITIS enables users to access data quickly either from their office or remotely. Furthermore, it can be used as a statistical tool for producing internal reports for the district offices and the head office as well as external reports required by the Ministry of Health and other government departments.

"Pasykaf will be able to extract more information and statistics about cancer symptoms. Information about cancers and their occurrence by region will help to detect possible reasons that may be responsible about cancer (e.g. factories in the areas, etc.)" (Developer, Phase 2).

"Life will be so much easier with DITIS to fill in the gaps from unknown to known" (Nurse, District B).

Interestingly, even though technophobia was identified in Phase 1 of this study as a possible negative factor in the effective implementation of the system, it was later expressed by nurses across different district sites that participated in Phase 3 that users are generally willing to adapt the system in their day-to-day work because they expect that their tasks will be executed faster and easier, saving time and effort.

It was agreed among all participants in the study that the project was a novel one, that it was a radical departure from what existed previously, and that it was designed to be at the core of Pasykaf's activities (i.e., the provision of healthcare to home-based cancer patients).

Implementation Problems

During the first three phases of the study, there was a general feeling that DITIS had not yet been sufficiently incorporated in the daily work activities of the healthcare workers and that this would be a slow process. The main problems identified were with regard to the implementation process. A nurse in District B clearly said that this process "has been slow from all points of view" (Phase 3).

It has been widely recognized that the effectiveness of the system implementation was jeopardized due to financial resources being constrained or at times becoming unavailable. The limited budget that the project development team had to work with mainly had two major implications. First, only a small number of mobile handsets could be acquired. As a result, only nurses in one district office (District A) were given a mobile device with DITIS application, whilst other district offices have to rely only on PC- (personal computer) based applications of DITIS. The latter, however, restricts the use and the potentials of DITIS, which has been developed as a wireless application to promote virtual collaboration in cancer care. Second, limited financial resources have influenced staff availability on the project implementation team. The project has been experiencing staff discontinuities since the early stages of DITIS development. Mainly graduate students have been used for this project under the guidance of two computer-science academics, both members of the DITIS project team. Even though the latter remained the main drivers of the project, DITIS was only one of several projects that they were involved in and therefore could not give their full attention as required by the criticality of the project nature. To quote a nurse, "The system was done on borrowed time" (District A, Phase 3), indicating that for most of the implementation period, there were no full-time project members; rather, even though the system had gained the enthusiasm of several people who committed themselves to the system, none of them could make a full-time commitment. Instead, there were several temporary project members throughout the duration of the implementation process leading to staff turnover.

Therefore, the high staff turnover and the lack of full-time staff brought inconsistencies and delays in the project development.

As the psychologist who participated in the study (Phase 3) put it, "There is no person in charge and this leads to communication problems." The same person suggested that there was a need for frequent meetings to keep users informed about the state of the implementation process, alleviate doubts, and improve coordination among cross-groups (e.g., nurses, doctors, psychologists).

Based on the results of the longitudinal assessment, corrective measures were taken, including the creation of a more stable team due to the commitment of all relevant actors and availability of funding. These corrective actions were acknowledged by all the users interviewed in Phase 4 of the study. During this phase, there was a general feeling of satisfaction about the use of DITIS in the day-to-day work practices as users have by now begun seeing the benefits of the system.

> "*The system is more reliable.*"
> "*It is 100% better.*"

Despite these positive results, there appears to be some anxiety among users about the sustainability of the system. DITIS has been successful in attaining the initial goals set. However, several difficulties, some non-technical in nature, were encountered during the development and deployment of DITIS in Phase I. These are outlined below:

- Underestimation of the workload involved in order to populate the DITIS database, and misjudgment of effort for encouraging users who are used to a paper-based system to switch to a new system, which was in essence still incomplete and under construction
- Network technology limitations (e.g., WAP over GSM). The migration to new technologies (GPRS/UMTS [Universal Mobile Telecommunications System] and ADSL) is resolving many of the original technical problems: Service is always available and bandwidth is much higher.
- Deployment with mobile devices has been limited mainly due to the cost related with having each member of the home-care team have his or her own mobile device, and the pace of new device launches with enhanced functionality. Recently, 30 mobile devices were acquired and are being deployed. This will allow a number of multidisciplinary teams to operate.
- Sustainability of DITIS due to uncertain financial support. Potential funding may derive from the government through its spin-off company initiative. Another one is the Ministry of Health for its planned community-care service.

Stakeholders: Relationships and Roles

The main stakeholders of DITIS derive from inside as well as outside the user organization. A key stakeholder group consists of the nurses and other members of the medical team in the district offices, for example, psychologists who directly use the system. Gradually, the nursing team has begun to embrace DITIS and overcome the initial resistance that was mainly caused due to the delays in implementing the system.

A second group involves the university computer scientists who designed the original system and currently manage the project development and implementation. They have the intellectual property of the system and are the ones who actively promote the system to national and international organizations in order to attract funding that would enable them to continue developing and improving the system. Their interest is in "the expansion of the collaborative system for usage in other fields (e.g., cardiac home care, insurance sales, etc.) and its eventual commercialization" (interview with project leader). The cost of setting up such an infrastructure and supporting it vs. the benefits, such as quality of life and time saved, are difficult to justify in monetary terms; also, there is the potential benefit of using GPRS and ADSL (Asymmetric Digital Subscriber Line) (always connected, higher speeds) vs. the earlier GSM/WAP mobile telephone device and ISDN (integrated services digital network) for the fixed computer lines (dial-up, low bandwidth), and the costs of maintaining such a telecom infrastructure to consider. Another barrier is the high cost of handheld devices and rapid change of technology, which have hindered projects development Cyprus-wide.

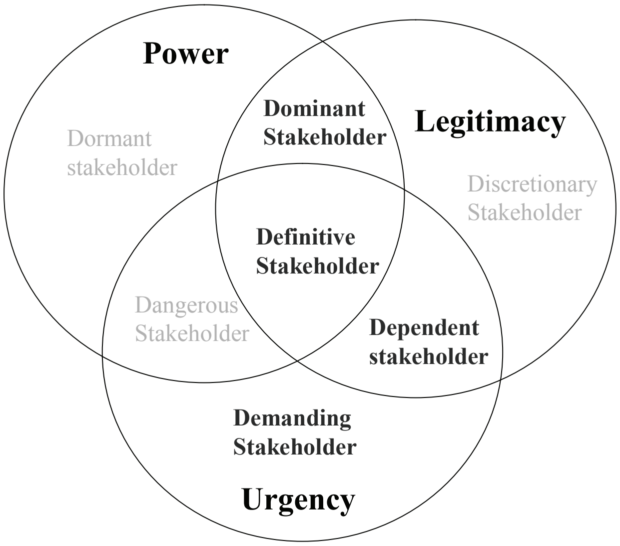
An independent commercial software organization that supported the initial idea and design of DITIS has also been a key stakeholder. This organization has recently withdrawn from the project after the first stage of its implementation as they could not see the financial viability and profitability of the project and were no longer interested in investing in mobile-based applications. Another commercial software organization with a focus on mobile e-services has recently joined the project.

Finally, an important stakeholder is Pasykaf as the user organization that hosts the system in its district offices as well as in the headquarters. Pasykaf, a charity organization, is interested in the project as it can see that the system can predominantly enable it to produce national and regional statistical information on cancer and cancer patients, which are required by the government. Our study, however, has shown that the involvement of Pasykaf management in this project has remained limited. Several users recognized that Pasykaf in particular should undertake a more active role in the implementation of the project by investing more time and administrative support.

Accordingly, the stakeholders derive from diverse sectors, and even though they all want DITIS to succeed, their expectations are different. From our data, it was found that all stakeholders agree on the important role that the system could have in cancer support.

In what follows, we describe these different types of stakeholders and identify their relevance to the DITIS project. Based on Mitchell et al.'s model (1997), Figure 2 depicts the stakeholders'

Figure 2. Stakeholder typology (Mitchell et al., 1997, p. 874)



relationship attributes and the different types of stakeholders.

Definitive stakeholders possess power, legitimacy, and urgency. The project initiators at the university fall in this group. Due to their active involvement in the design and promotion of the system, they possess both power and legitimacy whilst simultaneously are aware of the risks involved if no funding is secured. For this, they have a clear and immediate mandate to give priority to the project and have considered several options, one of which is commercialization.

Demanding stakeholders exist where there is urgency but no other relationship attribute. Within this category, we place the commercial organization that became involved in the initial design of the system. It did so for commercial interests. Due to the financial difficulties that the project faced, the company decided to withdraw their demands for commercialization and thus profitability has not been met.

Dormant *stakeholders* **are the** *stakeholders* who possess power to impose their will, but by not having a legitimate relationship or an urgent claim, their power remains unused…Dormant *stakeholders* have little or no interaction with the firm. However, because of their potential to acquire a second attribute, management should remain cognizant of such *stakeholders*, for the dynamic nature of the stakeholder-manager relationship suggests that dormant *stakeholders* will become more salient to managers if they acquire either urgency or legitimacy. (Mitchell et al., 1997, pp. 874-875)

In the case of DITIS, the dormant stakeholder is the government and other funding bodies that have shown an interest in the system. Because of their potential role in the future of the system, the project management team (university) should remain cognizant of such stakeholders. It is expected that the government's power will be exercised when there is a better recognition of the potentials of the system not only in cancer care but in the other health areas, too.

Dependent *stakeholders* **are those** "who lack power but who have urgent legitimate claims as 'dependent,' because these *stakeholders* depend upon others [e.g., other *stakeholders*] for the power necessary to carry out their will" (Mitchell et al., 1997, p. 877). Nurses represent this type of stakeholders. Their voice has mainly been represented through Pasykaf (management) itself, and, as it was found in the study, their interest in the system is predominantly for efficiency and accuracy in statistical analysis.

Dominant stakeholders are both powerful and legitimate. Their influence in the relationship is assured since by possessing power and legitimacy they form the dominant coalition. In our case, we find that Pasykaf itself belongs to this group of stakeholders as it represents the only host of the system. However, as a charity organization, it has been unable to fund the project itself and therefore its position has remained weak and the management team needs to look elsewhere for financial support. It is expected that when other funders are found, for example, the government, or with the commercialization of the system, the power of Pasykaf will be reduced as other host organizations will emerge, such as those for cardio-care support.

Other stakeholder groups that were identified in Mitchell et al.'s (1997) framework and shown in Figure 2 but not found in our own study are as follows:

- Discretionary stakeholders possess legitimacy, but have no power for influencing the firm and no urgent claims.
- Dangerous stakeholders possess urgency and power but no legitimacy; this may result in the use of coercive power.
- Non-stakeholders possess none of the attributes and thus do not have any type of relationship with the rest of the group.

Accordingly, it is found that in the case of DITIS there were five different distinct types of stakeholders. The diversity in their views, which is expressed in the reasons they give to the legitimacy of the system, as well as the perceived urgency and their ability to influence the system have all contributed to different degrees of support. In this study, apart from the commercial organization, all the other stakeholders have been positively supportive of the implementation process. They have been doing so differently, however, with some, such as the university team, taking a more active role in securing funding and hosting the project team whilst others, such as Pasykaf, remaining more passive. This passiveness is not, however, due to a lack of interest but rather due to other priorities.

FUTURE TRENDS

The potentials of mobile applications in e-health are tremendous. They could be used for supporting health professionals in offering care through improved e-tools (e.g., for improved access to patient records by all health professionals, improved collaboration, and streamlined workflow), which are especially useful for the community-care environment. However, even though mobile technology is a key factor for enabling the formation of geographically proximate medical teams at the point of care, their effective implementation depend not only on the level of support provided to users, but also by the extent to which there is a shared understanding and support among diverse groups of stakeholders.

An important contribution of this study is an examination of the role of diverse stakeholders on the implementation of such a novel e-health initiative. With a growing recognition that e-health can make an impact on the provision of healthcare as well as that e-health applications are becoming even more global, investigating the diversity that may exist among the various stakeholders is becoming vital for their success.

CONCLUSION

This chapter presents a longitudinal study on the implementation of an e-health mobile application, DITIS, which supports network collaboration for home healthcare. Our study has found that users' support has gradually improved over the last years as they have been increasingly exposed to the system capabilities and have recognized the advantages of the system in their day-to-day work for both administrative and consultation purposes. Another reason for this is that the nurses have gained participation in the project team with periodical meetings with the project manager and developers. Yet, the future of the system is uncertain as future funding to gain sustainability may not be available. Such a complex and novel system has not gained shared support by all parties concerned, with one company dropping out (while another one joined) and others not taking an active role. The long-term solution is commercialization, which is currently pursued, but as with any new ideas and products, there is considerable risk involved. The study has adopted the stakeholders' analysis (Mitchell et al., 1997) and found that there are different relationship characteristics among the key stakeholders who show diversity in interests, expectations, and levels of involvement in the system implementation.

DITIS has appeared to act as a useful fuel for improving patient records and promoting an integrated approach that has a direct impact on the quality of treatment and healthcare support to home-based cancer patients. However, even though this is a novel application and despite the fact that it was introduced 5 years ago, the implementation has remained slow and the system has not yet been able to secure its place and its future in the health sector; rather, it has gradually been making an impact on the healthcare support provided by some nurses and medical staff. Lack of organization ownership makes the future of the system uncertain. What has enabled it to survive was the enthusiasm of some key individuals, mainly the university team and those users who could see the direct benefits of the system on the quality of cancer care. Speedy commercialization of the system seems to be the solution for its long-term survivability, and this is the current focus. In the meantime, DITIS is at present being deployed for its healthcare collaboration and patient-management aspects in the context of two EU- (European Union) funded e-TEN (deploying Trans-European e-services for all) market validation projects (HealthService24 and LinkCare) involving trials for cardiac-patient monitoring.

REFERENCES

Beynon-Davies, P. (1999). Human error and information systems failure: The case of the London ambulance service computer-aided dispatch system project. *Interacting with Computers, 11*, 699-720.

DITIS: Virtual Collaborative Teams for Home Healthcare. (n.d.). Retrieved July 2005 from http://www.ditis.ucy.ac.cy

Howard, M., Vidgen, R., & Powell, P. (2003). Overcoming stakeholder barriers in the automotive industry: Building to order with extra-organizational systems. *Journal of Information Technology, 18*, 27-43.

Mitchell, R., Agle, B., & Wood, D. (1997). Towards a theory of stakeholder identification and salience. *Academy of Management Review, 22*(4), 853-887.

Orlikowski, W. J., & Baroudi, J. J. (1991). Studying information technology in organizations: Research approaches and assumptions. *Information Systems Research, 2*(1), 1-28.

Pitsillides, A., Pitsillides, B., Samaras, G., Dikaiakos, M., Christodoulou, E., Andreou, P., et al. (2005). DITIS: A collaborative virtual medical team for the home healthcare of cancer patients. In *M-health: Emerging mobile health* (pp. 247-266). Kluwer Academic/Plenum Publishers. Springer: New York.

Pitsillides, B., Pitsillides, A., Samaras, G., Christodoulou, E., Panteli, N., Andreou, P., et al. (2004). *User perspective of DITIS: Virtual collaborative teams for home-healthcare: Vol. 100. Current situation and examples of implemented and beneficial e-health applications* (pp. 205-216). IOS Press: The Netherlands.

Pouloudi, A., & Whitley, E. A. (1997). Stakeholders identification in inter-organizational systems: Gaining insights for drug use management systems. *European Journal of Information Systems, 6*, 1-14.

Salmon, S., Brnt, G., Marshall, D., & Bradley, A. (2000). Telemedicine use in two-nurse-led injuries units. *Journal of Telemedicine and Telecare, 6*(Suppl. 1), 43-45.

Sauer, C. (1993). *Why information systems fail: A case study approach.* Henley on Thames, UK: Alfred Waller.

Suchman, M. C. (1995). Managing legitimacy: Strategic and institutional approaches. *Academy of Management Review, 20*, 571-610.

APPENDIX

DITIS Implementation Project, May 2001

Please take a few minutes to answer the following questions. I would appreciate if you return the completed questionnaire to me by e-mail.

Thank you very much for your contribution.

Please tick that which most identifies your involvement in the DITIS project.

Designer/Developer: ☐
User (Nurse): ☐
User (Doctor): ☐
Other (please specify): ☐

What do you think the main benefits would be for implementing DITIS within Pasykaf?

After implementation, how do you expect DITIS to be used on a day-day to basis?

What would you expect the results of the pilot study to be? Please identify in your answer those factors that you think might enable or constrain the success of this pilot.

This work was previously published in Web Mobile-Based Applications for Healthcare Management, edited by L. Al-Hakim, pp. 101-117, copyright 2007 by IRM Press (an imprint of IGI Global).

Chapter 6.7

Business Associates in the National Health Information Network:

Implications for Medical Information Privacy

Edward J. Szewczak
Canisius College, USA

Coral R. Snodgrass
Canisius College, USA

ABSTRACT

This article examines the role of the business associate of healthcare providers (BAHP) in the National Health Information Network. Current Health Insurance Portability and Accountability legislation has little to say about BAHPs and their potential impact on medical information privacy. For the good of the business enterprise, managers who are BAHPs or who supervise BAHPs need to be aware of the potential pitfalls of ignoring medical information privacy and take a proactive stance in protecting medical information privacy within the National Health Information Network. Among the approaches that managers can adopt include creating legal contracts between a business and BAHPs, proactively adopting more effective transmission security technologies, and insuring that BAHPs properly dispose of medical information after their use. Such proactive approaches will help to insure that the business is protected against a serious data breach that may result in popular and/or legal challenges to the business.

INTRODUCTION

In his 2004 State of the Union address, President George W. Bush stated that, by computerizing health records, it would be possible to avoid dangerous medical mistakes, reduce medical costs, and improve medical care (The White House, 2006). Drawing on a report from the Institute of Medicine (2001) and on the conclusions of a panel of IT experts, Kaushal *et al*. (2005) reported that the creation of a national system of electronic health records and a National Health Information Network electronically connecting electronic heath records to healthcare providers, insurers, pharmacies, laboratories and claims processors will be possible at a cost of $156 billion. Four companies (Accenture, Computer Science Corporation, IBM and Northrop Grumman) have been selected by the Department of Health and Human Services to develop regional versions of the National Health Information Network with a view toward developing interoperability in the near future. A report from the Office of the National Coordinator for Health IT (Rishel, Riehl & Blanton, 2007) suggests that the National Health Information Network will be a: "network of networks" that will securely connect consumers, providers and others who have, or use, health-related data and services, while protecting the confidentiality of health information. The NHIN will not include a national data store or centralized systems at the national level. Instead, the NHIN will use shared architecture (services, standards and requirements), processes and procedures to interconnect health information exchanges and the users they support (p. 2).

Electronic health records contain an individual's medical information that can take many forms such as text, photographs, video, x-ray, sound, etc. One definition of information that is directly relevant to medical information privacy is data that have been evaluated to be relevant and useful for making particular decisions or classes of decisions (King and Epstein, 1976). Though the account was originally provided for the context of business management decision making, it is clearly applicable to the situation of various medical practitioners as well as a business associate of a healthcare provider (BAHP) such as an insurance agent, a billing agent, a consultant, or a transcriptionist. Generally speaking, a BAHP is anyone who works closely with a healthcare provider in non-treatment contexts in both healthcare related businesses as well as non-healthcare related businesses. (The term "private contractor" is also used to describe BAHPs in government, for example, by the Veterans Administration.) For example, a BAHP may be interested in developing patient profiles with a view toward customized marketing aimed at a particular profile or class of related profiles.

Despite government efforts to ensure medical information privacy, no comprehensive national strategy to safeguard medical information privacy has been developed and implemented (Koontz & Melvin, 2007). As such, the National Health Information Network poses a real threat to individuals' medical information privacy (Szewczak, 2007). This article considers the role of the BAHP in the context of the National Health Information Network, identifies potential threats to individuals' medical information privacy, and proposes solutions to management challenges presented by the current and future availability of medical information made possible by the National Health Information Network.

THE MEDICAL RECORD

Traditionally medical data were collected and stored as records in physician's offices and in hospitals. Often the data were recorded manually and retrieved manually. Patient data forms the medical record and its contents (Electronic Frontier Foundation, 1993). Medical records may contain patient personal data such as name, address, age, next of kin, names of parents, date and place of birth, marital status, religion, history of military service, Social Security number, and name of insurer. Medical records also contain medical data such as complaints and diagnoses, medical history, family history, previous and current treatments, an inventory of the condition of each body system, medications taken now and in the past, use of alcohol and tobacco, diagnostic tests administered, and findings, reactions and incidents. Records may also contain subjective information based on impressions and assessments by healthcare workers such as mental ability and psychological stability and status. In addition to data about the patient's current condition, a patient's medical record may also contain the results of genetic research and testing that enable predictions of future medical conditions and the prospects of developing specific medical problems.

Typically the creation and maintenance of medical records was done manually by healthcare professionals. But IT has changed this practice (Kilman and Forslund, 1997). Notes hand-written by doctors and nurses are being put into electronic form in the name of faster, more extensive access to needed information. Healthcare companies are competing to get doctors to write prescriptions over the Internet and to persuade people to place their personal health records on the Internet (Consumer Reports, 2000). Companies have made available software that an individual can use to create an Internet-based "personal health record" that can be used to organize family medical histories, including medical conditions, medications and allergies. These personal records may be transmitted to healthcare professionals over a computer network (Rubenstein, 2005; Lawton & Worthen, 2008).

Medical records are available online to medical practitioners for the purposes of decision making and improving healthcare as well as medical research. They are also available to other users and institutions in non-treatment contexts. Medical records are used to conduct federal government-mandated medical community audits of physician competency and performance. They are also used by insurance companies in the assessment of an applicant's eligibility for health and life insurance and in claims processing to detect medical fraud. Medical information is also used by private employers, educational institutions, credit investigators, and law enforcement agencies for a variety of non-medical reasons. It is in these non-treatment contexts that the BAHP plays an important role.

MEDICAL INFORMATION AND PRIVACY

Cate (1997) identified a number of conceptions of what constitutes privacy from the literature. Privacy has been viewed as an expression of one's personality or personhood, focusing on the right of the individual to define his or her essence as a human being; as autonomy – the moral freedom of the individual to engage in his or her own thoughts, actions, and decisions; as citizens' ability to regulate information about themselves, and thus control their relationships with other human beings; and as secrecy, anonymity and solitude. In the area of medical information, the definition of privacy as "the claim of individuals, groups, or institutions to determine for themselves when, how, and to what extent information about them is communicated to others" (Westin, 1967, p. 7) is appropriate. This article will focus on medical information exclusively, though the problems and challenges of information privacy are not necessarily unique to medical information (Szewczak, 2009).

The Westin definition is consistent with the confidential relationship between doctor and patient. Confidentiality refers to how data collected for approved purposes will be maintained and used by the individual, group or institution that collected it, what further uses will be made of them, and when individuals will be required to consent to such uses. In this regard, privacy may be construed as a balance struck by society between an individual's right to keep information confidential and the societal benefit derived from sharing the information for the purposes of medical research and public health management, and how the balance is codified into legislation giving individuals the means to control information about themselves (Office of Technology Assessment, 1993; Rindfleisch, 1997).

As personal information, medical information has a special status. As Krzysztof & Moore (2002) observe:

Medical information about the individual patient is considered highly private, and the general public is extremely fearful about disclosure…. We all enjoy the benefits of medical research conducted on other patients, but we are very often reluctant to contribute or release our own information for such purposes. When medical data are published it is expected that the researchers will maintain the dignity of the individual patient, and that the results will be used for socially beneficial purposes (p. 15).

This observation has been supported by various public opinion polls conducted since 1993 that have uncovered a basic concern people have about the privacy of their medical records and how these records may be used (Electronic Privacy Information Center, 2006). Major areas of concern are:

- Employment/career advancement. People are concerned that employers may use personal health information to limit job opportunities. They are also concerned that medical information will be used for many non-health purposes, such as determining promotions and job advancement.
- Insurance eligibility. People are concerned that insurance companies may use personal health information to deny an application for various kinds of insurance coverage (e.g. medical insurance such as long-term disability insurance).
- Computerized versus paper records. The trend toward computerizing the healthcare system and keeping records electronically threatens medical information privacy. People feel more secure when medical records are kept in paper form.
- Genetics research. People do not want medical researchers to be allowed to study an individual's genetic information without obtaining the individual's consent.
- Medical records security. People feel protecting the confidentiality of medical records is essential to healthcare reform. Weak data security may lead to leaks of sensitive health information. People also think that insurance companies get more information from doctors than is needed.
- Mistrust of government. People worry that existing federal health privacy rules protecting patient information may be reduced or ignored in the name of efficiency. In addition, people fear that government agencies and researchers are allowed to see medical records without a patient's permission.

One might think that legislation addressing the issues and problems of safeguarding medical information would have solved many of the problems involving the mishandling of medical information. However, the effectiveness of legislation in establishing and maintaining medical information privacy is questionable at best, despite legislative efforts to the contrary. Federal and state governments have attempted to deal with privacy issues in ways that satisfy the needs of various stakeholders such as doctors, insurance companies, researchers, law enforcement, and data processing firms as well as individuals. The result has been various legislative measures that provide legal compromise. For our purposes, the most significant measure is the Health Insurance Portability and Accountability Act (HIPAA) of 1996.

HIPAA provides the first comprehensive set of federal regulations of health information. It provides for two rules related directly to medical information privacy: the Privacy Rule (45 Code of Federal Regulations 164.500 – 164.534) (Federal Register, 2002) and the Security Rule (45 Code of Federal Regulations 164.103 – 164.318) (Federal

Register, 2003). It is the Privacy Rule that is most relevant to the issue of medical information privacy. The Security Rule will be discussed briefly later in this article in a discussion of transmission security technology as a management challenge. Interested readers are referred to the Health Information Technology website of the Department of Health and Human Services (www.hhs.gov/healthit/healthnetwork/background/) for current details of the National Health Information Network technical implementation.

The HIPAA Privacy Rule provides the federal floor of privacy of protected health information in the U.S. It only applies to medical records maintained by "covered entities" (healthcare providers, health plans, and health care clearinghouses/data processing firms) in any form (electronic or non-electronic, including oral). It allows more stringent state laws to continue in force. An individual has a number of rights under the Privacy Rule including the following (adapted and expanded from Electronic Privacy Information Center, 2008):

To access, inspect and copy protected health information held by hospitals, clinics, health plans and other "covered entities" with some exceptions

To Request Amendments to Protected Health information held by Covered Entities. To request an accounting of disclosures that have been made without authorization to anyone other than the individual for purposes other than treatment, payment and "health care operations" (i.e., medical practice evaluations for accreditation conducted by organizations such as the Joint Commission for the Accreditation of Healthcare Organizations and the National Committee for Quality Assurance)

To Request Restrictions on Uses and Disclosures of Protected Health Information. The HIPAA Privacy Rule does not prohibit the disclosure of protected health information when such disclosure is required or permitted by other federal law. For example, the Gramm-Leach-Bliley Act does not prohibit the sharing of information among affiliated companies (such as banks and brokerages, which are not covered entities). So an individual's credit card account transactions may include data about where an individual goes for healthcare, and this data may be shared among affiliated companies and is not protected by HIPAA. The HIPAA Privacy Rule also explicitly includes exceptions to the rules for use and disclosure. In fact, there are a number of uses and disclosures of information for which an authorization or opportunity to agree or object is not required (for example, for judicial and administrative proceedings, and for law enforcement purposes), including the use of protected health information for marketing purposes (which, according to the Department of Health and Human Services, may be too difficult to distinguish from treatment purposes) (Privacy Rights Clearinghouse, 2007).

The HIPAA Privacy Rule is particularly difficult to implement when it comes to managing BAHPs under contract who perform an action on the healthcare provider's behalf and to whom the healthcare provider is releasing protected health information. These business associates often have free access to a patient's protected health information. They include people such as insurance agents, billing agents, consultants, and transcriptionists. If a healthcare provider discovers that a BAHP has breached or violated a contract with respect to safeguarding protected health information, the healthcare provider must take reasonable steps to remedy the problem or terminate the contract. If the contract cannot be terminated, the healthcare provider must report the problem to the Office of Civil Rights, which may exact civil penalties against the business associate. Criminal penalties can approach $250,000 and/or 10 years imprisonment if the offense is committed with intent to sell, transfer or use protected health information for commercial or personal gain, or for malicious harm (Federal Register, 2006; Wilson, 2006).

However a healthcare professional may not know that a BAHP has breached or violated a contract with regard to safeguarding protected health information. Because HIPAA does not prohibit the sharing of protected health information among various covered entities or their BAHPs, protected health information could be used in ways other than for treatment or billing. For example, an individual could be charged higher loan rates because of some piece of data in his/her medical record, and it would be impossible to prove the data were shared because there is no required disclosure audit for non-covered entities.

In addition, data networks may be Internet-based and global in reach. Individual health records may be transmitted overseas and handled by a subcontractor (a kind of BAHP) in ways the individual is completely unaware of and would object to under any circumstances (Consumer Reports, 2006; Ferris, 2008).

Another related security challenge is the data breach. A hacker, a BAHP, an ex-employee, or even a trusted employee can steal data from a computer system and offer them for sale to interested parties. Data breaches are not all that uncommon in today's technology-oriented world. A case in point is the 2005 LexisNexis data breach with 310,000 possible consumers affected. In some cases computer programs were used to generate IDs and passwords matching those of legitimate customers. In other cases hackers used computer viruses to collect IDs and passwords from infected machines as they were being used (Washington Post, 2005). Another case is the 2007 TJX data breach with 45.6 million credit and debit card numbers stolen over a period of 18 months by an unknown number of intruders. TJX was hit by several lawsuits after disclosing the data breach. It settled many of the suits to a total of about $250 million (Computer World, 2007, 2008).

Finally, if the history of dotcom business is any guide, companies that run into financial difficulties may choose to sell customer data to meet obligations, even though the companies have published privacy policies. As the following details, such customer data may contain individuals' medical information.

PUBLICLY AVAILABLE SOURCES OF MEDICAL INFORMATION

There are a number of sources of an individual's medical information, including medical databases, company and government databases, public records, and consumer volunteered information. In the case of databases, the information is structured formally so as to facilitate system organization and maintenance. In instances when database organization is lacking, the information will be stored in unrelated files. All of these sources will be accessible in the National Health Information Network.

Medical databases will be major sources of medical information on the National Health Information Network. However a database is implemented, the electronic health records comprising it will be accessed by many interested parties over the National Health Information Network.

One of the largest central databases of electronic health records is the Medical Information Bureau (MIB). It is shared by insurance companies to obtain information about life insurance and individual health insurance policy applicants. If the applicant reports a condition that the insurer considers significant, or if the results of a required examination, blood test, or urine test raise questions for the insurer, the insurer will report that information to the MIB. MIB electronic health records consist of codes indicating a particular condition or lifestyle (such as the individual smokes cigarettes). As such, MIB does not include the totality of an individual's medical record (Privacy Rights Clearinghouse, 2007).

Another example is the Children's Hospital of Philadelphia (CHOP). CHOP is collecting DNA profiles on as many as 100,000 child patients in order to develop an anonymous database that researchers can use to study children's genetic profiles. Research results may reveal which genes underlie problems affecting children such as diabetes, obesity, asthma and cancer. This research could lead to the development of diagnostic tests and drugs. By linking genetic information to electronic health records, CHOP may obtain research funds and patents and forge partnerships with drug companies (Regalado, 2006).

Another recent development in the storage of medical information is the creation of electronic warehouses by Microsoft and Google where individuals can store their health records and make them available to health care providers. Neither company is considered a covered entity, so neither is subject to HIPAA rules (Steinkraus, 2007).

There are a number of benefits as well as disadvantages of medical databases (U.S. Department of Education, 2006). Among the benefits are:

- A patient's medical information would be immediately available to an attending doctor, including life saving information
- Researchers would be able to track certain diseases as well as patients' responses to certain drugs
- Medical databases would allow for better organization and more legibility of medical files
- Electronic health records may be more secure than paper records since security systems can monitor medical databases

Among the disadvantages of medical databases are:

- Employers may access medical information about their employees which they might use to deny employment or job advancement
- Insurers may use medical information to deny insurance to people they consider to be high risk
- Digitizing medical records will allow many more people legitimate access to medical records, with the increased possibility that the information may be misused by one or more of them

It is important to note that, in general, inaccuracies in databases are widespread and that the ability of individuals to detect these inaccuracies is limited (Straub & Collins, 1990). In addition, the problem of missing values – values accidentally not entered or purposely not obtained for technical, economic or ethical reasons – is widely encountered in medical databases since medical data are collected as a byproduct of patient care activities rather than rigorously collected and evaluated for use in research (Krzysztof & Moore, 2002). These inaccuracies and omissions only accentuate the disadvantages of medical databases.

Inaccuracies also exist in non-medical databases. It appears likely that businesses may acquire medical information that is contained in company databases as a result of acquiring these databases in the course of merger/acquisition activities. It is also likely that they may also have access to medical information in other companies' databases in the course of maintaining friendly strategic alliances with these companies. In addition, BAHPs are in a position to collect and store medical information in company databases for use in business decisions (for example, determining loan rates). As was discussed earlier, HIPAA does not prohibit the sharing of protected health information among various covered entities or their BAHPs. There are a number of security risks to medical information may come from inside a business as well as from external sources. Though a BAHP may try to safeguard an individual's medical information privacy, it may be jeopardized by a number of internal security risks such as accidental disclosures, insider curiosity, releasing medical information to outsiders for revenge, spite or profit, and uncontrolled support functions (Rindfleisch, 1997).

Government databases at the federal, state and local levels contain personal (including medical) information. The federal government maintains electronic files on hundreds of millions of Medicare claims. State governments collect and store medical data on their citizens, including registries of births, deaths, immunizations, and communicable diseases. Many states mandate collection of electronic records of every hospital discharge, and maintain registries of every newly diagnosed case of cancer. Most of these databases are available to any member of the public who asks for them and can operate the database software required to read and manipulate them (Consumer Reports, 2000).

Although many of these government database records are stripped of information which could be used to identify individuals (such as Social Security numbers), it is still possible to link the records to private sector medical records using standard codes for diagnoses and procedures employed by the United States healthcare system. The codes are usually included on insurance claims and hospital discharge records. In addition, a patient's anonymity may be compromised by the fact that personally identifiable health information is needed for a variety of research purposes (e.g. to check for duplicate records or redundant cases, and for longitudinal studies) (Electronic Privacy Information Center, 1999). Straub & Collins (1990) relate how a user can retrieve information about a specific person from large statistical databases with a small number of unsophisticated queries. As a case in point, a computer privacy researcher at Carnegie Mellon University was able to retrieve the health records of the governor of Massachusetts from an "anonymous" database of state employee health insurance claims by knowing his birth date and ZIP code. The researcher demonstrated that she could do the same for 69% of the 54,805 registered voters on the Cambridge, MA voting list (Consumer Reports, 2000).

Electronically available public records (e.g. court records) are also a source of an individual's medical information (Ogles, 2004). An individual's medical record may be entered into court documents (say, if an individual sues over payment claims) which are available on-line. Public records also have a connection to junk mail, since state counties have sold information from public records to commercial companies that then repackage it and resell it to other companies and individuals (Leach, 2004). Junk mail in itself may not be overly troublesome to an individual. But what these companies and individuals may do with public record information in addition to creating and sending junk mail is cause for some concern.

Much personal health information that is available to the public is volunteered by individuals themselves, by responding to 800 numbers, coupon offers, rebate offers and Web site registration. The information is included in commercial databases like Behavior-Bank sponsored by Experian, one of the world's largest direct-mail database companies. This information is sold to clients interested in categories of health problems, such as bladder control or high cholesterol. Drug companies are also interested in the commercial databases (Consumer Reports, 2000). With the implementation of the National Health Information Network, this interest will be heightened as hospitals link up electronically with doctor offices' records (Landro, 2006).

BAHP often want access to medical information for data mining purposes. Data mining of medical data offers the health care industry the ability to address issues related to fraud detection and abuse, to profitability analysis, to patient profiling, and to patient retention management (Payton, 2003). However, patients are often unaware that their medical information is being used for data mining purposes, making it unlikely that patients will object to the practice. The challenge to organizations that conduct data mining with medical information is how to respond when and if patients become aware of the data mining. For some patients, the awareness will make no difference; for others, the reaction may be very negative.

MANAGEMENT CHALLENGES OF MEDICAL INFORMATION

Since companies have relatively easy access to individuals' medical information, the adequate protection of the privacy of this information must be considered an important management challenge, especially in the context of the National Health Information Network.

For healthcare-related businesses, the requirement to safeguard patients' medical information is specified by HIPAA. In their dealings with BAHP, healthcare-related businesses should create legal contracts between the business and any BAHP given access to individually identifiable medical information requiring the BAHP to safeguard the data. Ongoing internal review of data access records should be performed in order to uncover possible security violations (Saul, 2000).

For businesses in industries other than healthcare, the challenges center on how to adequately safeguard an individual's medical information acquired in mergers/acquisitions, from public records, from customer volunteers, or simply in the course of doing business (for example, hiring new employees). Though it is not required by law, businesses should attempt to respect as much as is relevant and possible the rights of individuals under the HIPAA Privacy Rule. In particular, businesses should honor individual requests to restrict the use and disclosure of medical information. It is not simply a matter of behaving ethically. Calculating the impact of a potential loss of medical information from a security breach is very difficult. Customer backlash in response to a business' failure to safeguard medical information is a very real and potentially costly possibility (e.g. a grassroots protest in the form of a boycott of a company's goods and services). Another possibility is an expensive class action lawsuit that could last a protracted period of time and result in monetary damages. Given how strongly people feel about the privacy of their medical information, either form of customer reaction could also damage the business' public reputation, especially if the reaction attracts the attention of the various news reporting agencies.

In addition, proactive managers should take the initiative in surpassing HIPAA in two important areas: use of transmission security technology, and treatment of BAHPs. In fact, the proactive manager will intentionally surpass the baseline requirements of HIPAA, thereby realizing the enhancement of individual medical privacy protection.

Use of transmission security technology. The HIPAA Security Rule (45 Code of Federal Regulations 164.103-164.318) provides security standards and implementation specifications for three kinds of safeguards (administrative, physical and technical) to protect protected health information in electronic form. It also divides the implementation specifications into required and addressable (i.e., not required but recommended). Covered entities have a certain amount of flexibility in implementing addressable specifications. In deciding which security measures to adopt, the covered entity must consider its own size, complexity and capabilities, its technical infrastructure, hardware and software security capabilities, the costs of the security measures, and the probability and criticality of potential risks to electronic protected health information. For example, covered entities may choose to adopt encryption as a technical safeguard for the transmission security standard, but since encryption is given as an addressable implementation specification, it is not required by HIPAA but simply recommended.

HIPAA is not specific as to the exact technology that should be used to implement transmission security, since technology changes and progresses in ways that are difficult to predict. The current implementation of transmission security will most likely involve the use of firewalls, user authentication, encryption/decryption, anti-virus software, and anonymizers (Cheng & Hung, 2006). These implementation choices will be replaced as newer and more effective technologies become available.

The proactive manager should actively pursue the most effective transmission security technologies available, and not simply wait for Congress to update HIPAA with respect to more effective technological requirements.

Treatment of BAHPs. Any amended HIPAA legislation should explicitly consider the role of BAHPs in safeguarding medical information privacy. For healthcare-related businesses, the requirement to safeguard patients' medical information is specified by HIPAA. This includes the following activities (Saul, 2000):

- Develop policies to evaluate and certify that appropriate security measures are in place in the business
- Create legal contracts between the business and any business associates given access to individually identifiable medical information requiring the business associates to safeguard the data
- Develop contingency plans for response to emergencies, in a data backup plan and a disaster recovery plan
- Establish a system of access control that includes policies for the authorization, establishment and modification of access privileges
- Perform ongoing internal review of data access records in order to uncover possible security violations
- Supervise systems personnel responsible for systems maintenance activities
- Train system users in system security, including user education on virus protection, monitoring login failures, password management, and how to report discrepancies or suspicious activities
- Establish termination procedures for when an employee leaves the business (voluntarily or involuntarily) or whose data access privileges are revoked

For non-healthcare-related businesses, while BAHPs are bound by HIPAA regulations that limit their use of medical information to what they need to provide their services to the contracting agency, stricter rules are needed to ensure that the information is properly disposed of after use. Though data breaches are not always caused by BAHPs, the keeping of data long after their usefulness is ended could result in a data breach affecting many innocent people. Though BAHPs may be technologically savvy in their use of National Health Information Network technology, this may not always be the case. Despite a BAHPs best intentions, data breaches may be the result of a BAHP not having the technical or procedural skills to safeguard medical information in the environment of an emerging technology. Managers must be wary of a BAHP's technical competence and demand proof that the BAHP is qualified to effectively safeguard medical information.

Lastly, management of the relationship with BAHPs becomes even more problematic when the BAHP is located outside of the United States. There is ample evidence to show that there are substantial differences among nations concerning the value of privacy and the sanctity of respecting the legal obligations to control access to information. As an example, the most recent review by the United States Trade Representative's office on the protection of intellectual property rights cites continued and excessive violations of intellectual property in many of the same countries where many BAHPs are located (Office of the United States Trade Representative, 2008). This is in spite of years of work by the World Trade Organization to protect intellectual property and very stringent rules and penalties written into all new trade agreements. Thus it would seem unlikely that simply relying on written agreements to protect medical information would be prudent. Managers are advised to be very careful in choosing companies outside of the United States for the handling of medical information.

There are sources of information that can be used to assess the potential for the loss of control of medical information. International organizations, such as the World Bank, maintain websites that report on assessments of riskiness for ventures in various parts of the world (World Bank, 2008). Universities, such as Michigan State University, also maintain websites that provide information on the state of international business activities around the world (Michigan State University, 2008). Trade Associations also maintain directories of subcontractors. Managers are well advised to visit all such sources of data before entering into a relationship with a firm outside the United States.

CONCLUSION

Given the potential for mishandling medical information acquired in the course of doing business, management must exercise vigilance in the safeguarding of this information. Though many businesses are not typically interested in acquiring and dealing with medical information, the possible negative consequences of mishandling medical information that is acquired from various sources cannot be ignored. This basic reality will only become magnified once the National Health Information Network is implemented, making it technologically possible to inadvertently disseminate medical information nationally as well as internationally. Companies whose employees act as BAHP in various capacities must be particularly vigilant to ensure the integrity of individuals' medical information. Management must move to preempt negative consequences before serious damage to the reputation of the business occurs as a result of BAHP mishandling medical information.

REFERENCES

Cate, F.H. (1997). *Privacy in the information age*. Washington, D.C.: Brookings Institution Press.

Computer World. (2007). www.computerworld.com/action/article.do?command=viewArticleBasic&articleId=9014782; retrieved March 26, 2008

Computer World. (2008). www.computerworld.com/action/article.do?command=viewArticleBasic&articleId=9070281&taxonomyId=148&intscr=kc_top; retrieved March 26, 2008

Electronic Frontier Foundation, (1993). www.eff.org/Privacy/Medical/1993_ota_medical_privacy.report; retrieved June 8, 2006.

Electronic Privacy Information Center. (1999). www.epic.org/privacy/medical/GAO-medical-privacy-399.pdf; retrieved May 17, 2006.

Electronic Privacy Information Center. (2006). www.epic.org/privacy/medical/polls.html; retrieved April 17, 2006.

Electronic Privacy Information Center. (2008). www.epic.org/privacy/medical; retrieved October 16, 2008.

Federal Register. (2002, 2003, 2006). www.archives.gov/federal-register/index.html; retrieved June 10, 2006.

Ferris, N. (2008). Foreign hackers seek to steal American's health records. www.fcw.com/online/news/151334-1.html: Retrieved February 4, 2008.

Institute of Medicine. (2001). *Crossing the quality chasm: A new health system for the 21st century.* National Academy Press: Washington, D.C.

Kaushal, R., Blumenthal, D., Poon, E.G., Ashish, K.J., Franz, C., Middleton, B., Glaser, J., Kuperman, G., Christino, M., Fernandopulle, R., Newhouse, J.P., Bates, D.W., and the Cost of National

Health Information Network Working Group. (2005). The costs of a national health information network. www.annals.org/cgi/reprint/143/3/165.pdf: retrieved February 4, 2008.

Kilman, D.G., & Forslund, D.W. (1997). An international collaboratory based on virtual patient records. Communications of the ACM. 40(8), 111-117.

King, W.R., & Epstein, B.J. (1976). Assessing the value of information. *Management Datamatics*. 5(4), 171-180.

Koontz, L.D., & Melvin, V.C. (2007). Efforts continue but comprehensive privacy approach needed for national strategy. Testimony before the Subcommittee on Information Privacy, Census, and National Archive Committee on Oversight and Government Reform of the U.S. House of Representatives. www.gao.gov/new.items/d07988t.pdf: Retrieved June 28, 2007.

Krzysztof, J.C., & Moore, J.C. (2002). Uniqueness of medical data mining. *Artificial Intelligence in Medicine*. 26(1/2),1-24.

Landro, L. (2006). What drugs do you take? Hospitals seek to collect better data and prevent errors. *The Wall Street Journal*. May 23, D1.

Lawton, C., & Worthen, B. (2008). Google to offer health records on the web. *Wall Street Journal*. January 28, D1f.

Leach, S.L. (2004). Privacy lost with the touch of a keystroke? www.csmonitor.com/2004/1110/p15s02-stin.html: retrieved March 23, 2005.

Michigan State University. (2008). globalEDGE.msu.edu.

Office of the United States Trade Representative. (2008). www.ustr.gov/assets/capitaldocument_Library/Reports_Publications/2008/2008_Special_301_Report; retrieved June 21, 2008.

Office of Technology Assessment. (1993). Protecting privacy in computerized medical information. www.wws.princeton.edu/ota/disk1/1993/9342/9342.pdf: retrieved August 6, 2006.

Ogles, J. (2004). Court documents not fit for Web? www.wired.com/news/privacy/0,1848,65703,00.html; Retrieved February 7, 2005.

Payton, F.C. (2003). Data mining in health care applications. In Wang, J. (Ed.), *Data mining: Opportunities and challenges*. Hershey: Idea Group Inc, 350-365.

Privacy Rights Clearinghouse. (2007). www.privacyrights.org/fs/fs8a-hipaa.htm; retrieved June 16, 2006.

Regalado, A. (2006). Plan to build children's DNA database raises concerns. *The Wall Street Journal*. June 7, B1f.

Rindfleisch, T.C. (1997). Privacy, information technology, and health care. *Communications of the ACM*. 40(8), 93-100.

Rishel, W., Riehl, V. & Blanton, C. (2007). Summary of the NHIN prototype architecture contracts. www.hhs.gov/healthit/healthnetwork/resources/summary_report_on_nhin_Prototype_architectures.pdf : retrieved August 14, 2007.

Rubenstein, S. (2005). Next step toward digitized health records. *The Wall Street Journal*. May 9, B1f.

Saul, J.M. (2000). Legal policy and security issues in the handling of medical data. In Cios, K.J. (Ed.), *Medical data mining and knowledge discovery*. Heidelberg: Spring-Verlag, 17-31.

Steinkraus, D. (2007). Whose records? Does medical privacy law hinder privacy? www.journaltimes.com/articles/2007/11/14/life/doc47372faec1ca6741856824.txt: Retrieved December 7, 2007.

Straub, D.W., & Collins, R.W. (1990). Key information liability issues facing managers: Software piracy, proprietary databases, and individual rights to privacy. *MIS Quarterly*. June, 143-156.

Szewczak, E.J. (2007). The national health information network and the future of medical information privacy. *Communications of the International Information Management Association*. 6(4), 33-46.

Szewczak, E.J. (2009). E-technology challenges to information privacy. In M. Khosrow-pour (Ed.), *Encyclopedia of information science and technology*, 2nd Ed. Hershey,PA: Idea Group, Inc. 1438-1442.

U.S. Department of Education. (----). www.lbl.gov/Education/ELSI/privacy-main.html; retrieved April 26, 2006.

Washington Post. (2005). www.washingtonpost.com/wp-dyn/articles/A45756-2005Apr12.html; retrieved March 26, 2008.

The White House, www.whitehouse.gov/news/releases/2004/01/20040120-7.html; retrieved June 3, 2006

Westin, A.F. (1967). *Privacy and freedom*. New York: Atheneum.

Wilson, J.F. (2006). Health insurance portability and accountability act privacy rule causes ongoing concerns among clinicians and researchers. *Annals of Internal Medicine*. 145(4), 313-316.

World Bank. (2008). www.worldbank.org.

World Bank. (2000). Who knows your medical secrets? *Consumer Reports*. August, 22-26.

World Bank. (2006). The new threat to your medical privacy. *Consumer Reports*. March, 39-42.

This work was previously published in International Journal of E-Business Research, Vol. 5, Issue 2, edited by I. Lee, pp. 48-62, copyright 2009 by IGI Publishing (an imprint of IGI Global).

Section VII
Critical Issues

This section addresses conceptual and theoretical issues related to the field of health information systems, which include issues related to privacy, security, and quality. Within these chapters, the reader is presented with analysis of the most current and relevant conceptual inquires within this growing field of study. Particular chapters address the impact of privacy legislation on patient care, quality assurance approaches to healthcare, and improving the quality of healthcare research data sets. Overall, contributions within this section ask unique, often theoretical questions related to the study of health information systems and, more often than not, conclude that solutions are both numerous and contradictory.

Chapter 7.1

Exploring Information Security Risks in Healthcare Systems

Amy Ray
Bentley College, USA

Sue Newell
Bentley College, USA; Warwick Business School, UK

INTRODUCTION

The volume and severity of information security breaches encountered continues to increase as organizations, including healthcare organizations, struggle to identify more effective security policies and procedures. Publicly available guidelines such as GASSP or ISO17799 that are designed to facilitate development of effective security policies and procedures have been criticized for, among other things, inadequate attention to differences in organizational security needs (Baskerville & Siponen, 2002), and for inadequate attention to the social dimensions of security problems (Dhillon & Backhouse, 2001). In this contribution, we argue that the diversity of organizational security needs, as well as the need to recognize the social dimensions to security problems, will continue to grow as companies move away from employing unique, proprietary approaches to software and network development, in favor of adopting standards-based plug-and-play applications, and related standards-based methods and technologies designed to enable interorganizational as well as local systems interoperability.

We use complexity science and adaptive structuration theory to support our arguments that current security management policies and procedures focus on what technologies are used, and on planned systems use to the exclusion of unplanned—but real—emergent use and emergent development of systems. A more holistic approach to security that adapts to emergent systems developments—and most importantly, addresses alternative, emergent uses of systems—is needed, we argue. Throughout the article, we use examples from the healthcare sector to illustrate our points. We do this because Electronic Health Record (EHR) systems that will enable information to be shared across a variety of organizations (local doctors' offices, hospitals, health insurance providers, research organizations, and so on) and users (doctors, administrators, nurses, researchers, and so on) are at the early stages of adoption in many countries, so that much can be gained by starting with an informed view of what can lead to security risks, so that policies and practices are adopted that can protect the information that is being shared.

BACKGROUND

Software development has been described as a "craft" industry, because software applications are developed one at a time, and labor is by far the most significant cost of any development project. Various *standards*—or generally agreed-upon activities, methods, functions, protocols, interfaces, systems, equipment, materials, services, processes and products (De Vries, 2005)—have been introduced and employed in efforts to reduce the labor costs associated with IT projects, especially in terms of standards designed to facilitate creation of Web applications (e.g., TCP, HTML, HTTP, XML, SMTP, UDDI, SOAP).

These standards are generally referred to as Web standards or Web-based standards, and their power to provide interoperability between two or more systems has been established for decades. However, while these standards have benefits, it is important to recognize that using standards has an unintended consequence. More specifically, it can be argued that, as a result of *successful* use of Web-based standards for local systems development and systems integration, overall systems architectures are more complex, ultimately resulting in an environment of greater information security risk. In the next section, we explain why standards-based development and integration increase the overall complexity of the systems architecture, and subsequently consider how this influences emergent use and architectural complexity, and so information security risk.

INFLUENCES ON ELECTRONIC HEALTHCARE RECORD SECURITY

IT Standards-Enabled Planned Systems Development and Complexity

At a local level, using IT standards simplifies the process of connecting one computer to a network of other computers. For example, employing Web standards, countless computers and computing devices around the world are connected, making the Web infinitely multidimensional and nonlinear. However, while Web standards simplify individual systems integration efforts, they potentially increase the complexity of the overall system architecture by enabling connections among heterogeneous systems.

Complex systems are defined as systems that interweave components in such a way that they display variation without being random, and result in a structure that is more than the sum of its parts (Lissack & Roos, 2000). Complexity science research has shown that many highly complex systems—including systems as diverse as the central nervous system, the biosphere, the stock market, telecommunications systems, and human immune system—are not only multidimensional and nonlinear, but are also made up of many selfsimilar components or properties that, in turn, enable development of more complex systems. EHR systems are good examples of such complex systems.

A number of healthcare data standards (e.g., medical code, individual and entity, and transaction processing standards) are now in place for electronic transmission of administrative data as a result of the Health Insurance Portability and Accountability Act of 1996 (HIPAA). Insurance claims data for a patient may be filed on a laptop computer or handheld device in a physician's office, processed by a claims manager from a terminal at an HMO, and otherwise accessed from any authorized device by a user with legitimate (or stolen) authorization. The challenge of mapping the network of authorized access points to HIPAA information grows as the network grows, and the network grows as the application of standards grows. In addition, in order to comply with HIPAA, many healthcare organizations have outsourced claims processing to healthcare clearinghouses (Ivans, 2003), increasing the complexity of the flow of data, as well as increasing the number of individuals with access to patient data. Thus, applying HIPAA transaction standards to systems integration efforts in healthcare simplifies the process of filing an insurance claim, but increases the complexity of the overall network architectures in healthcare.

Web Standards and Emergent Systems Development and Use

In an organizational or interorganizational context, Web-based standards are used to develop information systems applications in support of particular business processes. However, considerable research now exists which illustrates how actual use of IT is often different from the intended use. Users improvise by adding applications to the original system in order to support local practices (Ciborra et al., 2000; Pozzebon & Pinsonneault, 2005), and/or by simply using the system in ways not initially anticipated (Orlikowski, 2000). structuration theory (ST) (Giddens, 1979) and adaptive structuration theory (AST) (DeSanctis & Poole, 2004) are proven as useful frameworks for demonstrating how technologies are adapted and used by individuals within organizations. ST and AST address how social structures are changed via the interaction between a user and a technology, thus helping to explain the emergence and evolution of system use. In this sense, the real nature of a technology and its consequences emerge from the actions of individuals as they engage with and use the technology in practice (Orlikowski, 2000). These consequences can only partially be planned for in advance, and will vary across time and space as context, history, and process impacts the ways in which users develop knowledge through their reflective practice with the technology.

We again turn to healthcare to provide another example of this phenomenon. Since EHR are typically enabled by Web-based—as well as propriety—standards, and are employed by a highly diverse set of users, they are prime candidates for emergent development and use. EHR are designed to support documentation of clinical healthcare. However, physicians, researchers, nurses, insurance company employees, pharmacists, and many others are users of these systems, so it is reasonable to expect that different uses of the systems will emerge across user groups. For example, insurance companies are in the very early stages of adopting pay-for-performance systems to reward physicians based on information collected from EHR about the efficacy and efficiency of care provided to patients. Similarly, researchers are searching for new opportunities to use data available in the standardized, categorized formats enforced by EHR. In fact, EHRs are actually examples of emergent systems' development efforts as they emerged from foundational efforts to create standards for HIPAA (Fedorowicz & Ray, 2004).

The following are examples of simple, emergent uses or developments that can have a dramatic impact on the complexity, and thus manageability, of the overall information systems:

- A nurse adds a wireless network within a department without notifying the IT personnel.
- An individual doctor loads a set of organizational data on a USB drive to take home and analyze on a home computer.
- A sales manager finds that an application designed for one use (repeat orders) is also useful for another purpose (individualized marketing).

The purpose of these examples is to show that system connections and uses are dynamic, rather than to say that they cannot be secured. If uses are known, then effective security policies and procedures may be put in place. However, in an environment where uses are regularly and frequently emerging, existing security policies and procedures may quickly become inadequate, as discussed in the following section.

Architectural Complexity and Information Security Risk

We have presented arguments that standards-enabled systems development and integration methods ultimately increase the complexity of organizational systems' architectures, and support unintended emergent systems development and use. Current security frameworks do not factor in the consequences of emergent systems and system uses, which exacerbates problems noted by other researchers of inadequate attention to differences in organizational security needs (Baskerville & Siponen, 2002) and inadequate attention to the social dimensions of security problems (Dhillon & Backhouse, 2001).

The use of well-understood standards to develop uniquely complex systems creates a triple threat for security managers. First, standards are well-documented and well-understood, which means that any known flaws are typically documented. Documented flaws, for example the ability to exploit knowledge about the IP standard to spoof an IP address, means that hackers—as well as security professionals—have access to this knowledge. Second, the growing complexity of overall systems architectures that result from standards-enabled extension and integration translates into decreasing abilities to understand and manage systems. Since security managers may not even be aware of emergent systems developments and uses, rendering the ability to set effective policies for secure use impossible. Third, the complexity of systems in an environment where systems managers may not be aware of every development and use can contribute to an insecure environment by allowing hackers more points of access to exploit, as well as potentially providing more opportunities to cover their tracks when using unknown access points into systems.

Information security guidance is typically either strategic-level guidance based on organizational goals and primary uses of data, or focused on highly detailed technical issues, such as protecting access points with effective passwords, protecting networks with properly configured firewalls, and appropriate use of encryption. The latter category dominates organizational spending, and using terminology from complexity theory may be referred to as a reductionist approach where security management strategies involve application of solutions to small fractions of a system at a time (e.g., passwords to secure access to an application, firewalls to protect network traffic, and so on). Evidence suggests that reductionism also drives IT security investment (Ernst & Young, 2005). Even strategic security guidance such as HIPAA and ISO17799 make recommendations based on consideration of methods for securing systems components rather than considering the vulnerabilities based on alternative uses of technology, or from considering risks associated with the overall architectural choices supporting the information systems infrastructure. Reductionism is clearly necessary, but it is also increasingly insufficient for effective security management, because, as we have demonstrated in this contribution, it ignores the ways in which systems architectures and uses are dynamic and increasingly complex.

FUTURE TRENDS

In most countries, national health record development efforts are in their early stages, so there is time to consider the full gamut of potential risks, and to design these systems with appropriate measures of protection, both technical and organizational. However, there is little research that has focused on the creation of security policies in contexts that are emergent, rather than static (Baskerville & Siponen, 2002). Instead, most approaches to security, as we have seen, are reductionist in nature. These reductionist approaches are always going to be limited for the reasons discussed above. Instead, what seems to be important is to develop holistic approaches to security, which encompass social, as well as technical, elements, and which is dynamic, so that security issues are considered each time a new use is adopted, even if this use is not formally instigated. This could include, for example, dynamic monitoring for changes in systems architectures, and comprehensive training to not only educate users about risks from intended uses of systems, but to also provide them with methods for considering risks associated with emergent uses of systems.

In considering how this could be approached in an organizational context, it is important to identify who will be responsible for championing this more holistic approach. One new management position in many organizations with complex systems is the Information Systems Architect, whose job responsibilities include approving new systems development projects, and using whatever tools and processes are necessary to remain knowledgeable about the true architecture of the existing information system. For example, the information systems architect might employ network monitoring tools on a regular basis to ensure that rogue wireless networks are identified and appropriately controlled. We suggest here that either the Information Systems Architect also have security management responsibilities, or that key security managers such as Chief Security Officers at least occasionally adopt a practice of considering security risk management from a holistic perspective to complement existing reductionist security policies and practices. We further suggest that much work needs to be done to ensure that security policies are reviewed and updated frequently, and that appropriate steps are adopted for ensuring that security policies and practices are as adaptive as the complex, emergent systems they must protect. A good starting point is to consider developing metapolicies for adaptive development of security policies, and when they are needed (Baskerville & Siponen, 2002). In keeping with our analysis, it is also important to emphasize the principles of security management during training, so that the various users of complex systems such as electronic health record systems will build in their own security practices as the system evolves, even when the emergent applications have inherent security gaps. Metapolicies would be useful for establishing this practice as well. Research exploring the best ways to achieve this holistic understanding and appreciation of the importance of securing data in large complex EHR systems is clearly going to be an important challenge for the future.

CONCLUSION

Our research contributes to the literature by demonstrating the potential domino effect of Web standards-enabled systems integration and development efforts. Standards facilitate rapid development of planned and emergent systems, but can ultimately lead to overall systems architectures that are very complex to manage. When this happens, organizations are at increased risk of security breach. Including security features in individual application design will only be effective to the extent that the interactions between multiple applications in the larger system have all been anticipated during the design process, and that the system is used only in ways that were originally intended. As our contribution suggests, neither of these conditions is very likely. This suggests the need for a more holistic approach to security management.

We have presented numerous examples in this article to support our analysis, but much research is still needed. We believe such research is critically important, given the early stages of Web standards-enabled systems development efforts and the potential for either tremendous gain or tremendous chaos, especially in the context of highly complex interorganizational healthcare systems. This research agenda is not only theoretically important, but also tremendously important from a practical point of view, especially in industries where data processed is of a sensitive nature, such as in healthcare. Here, the development of electronic heath record systems that connect a wide variety of disparate organizations and users is in its infancy. Developing approaches now which can help to secure these systems from security breaches is likely to provide huge cost savings, avoiding, for example, litigation claims when a patient's data has been inappropriately divulged, or simply human misery when an individual is unable to get a job because an unethical employer has managed to extract some private data from a health record. Research which can identify approaches to security management that take into account the problems associated with system complexity, as outlined in this article, would thus be very timely.

REFERENCES

Baskerville, R., & Siponen, M. (2002). An information security metapolicy for emergent organizations. *Logistics Information Management*, *15*(5/6), 337–346. doi:10.1108/09576050210447019

Ciborra, C., et al. (2000). *From control to drift: The dynamics of corporate information infrastructures.* Oxford: Oxford University Press.

De Vries, H. (2005). IT Standards Typology. In K. Jakobs (Ed.), *Advanced topics in IT standards and standardization research*. Hershey, PA: Idea Group Publishing.

DeSanctis, G., & Poole, M. (1994). Capturing the complexity in advanced technology use: Adaptive structuration theory. *Organization Science*, *5*(2), 121–145. doi:10.1287/orsc.5.2.121

Dhillon, G., & Backhouse, J. (2001). Current directions in IS security research: Toward socio-technical perspectives. *Information Systems*, *11*(2), 127–154. doi:10.1046/j.1365-2575.2001.00099.x

Ernst, & Young. (2005). *Global information security survey.* Retrieved February 6, 2006, from http://www.ey.com

Fedorowicz, J., & Ray, A. W. (2004). Impact of HIPAA on the integrity of healthcare information. *International Journal of Healthcare Technology and Management*, *6*(2), 142–157. doi:10.1504/IJHTM.2004.004954

Giddens, A. (1979). *Central problems in social theory.* London: Macmillan.

Holland, J. (1995). *Hidden order: How adaptation builds complexity.* Addison Wesley.

Ivans. (2003). *Provider survey: Claims processing and connectivity in the emerging HIPAA/CMS environment*. Retrieved February 6, 2008, from http://www.ivans.com

Lissack, M., & Roos, J. (2000). *The next common sense: The e-manager's guide to mastering complexity.* London: Nicholas Brealey.

Orlikowski, W. (2000). Using technology and constituting structures: A practice lens for studying technology in organizations. *Organization Science*, *11*(4), 404–428. doi:10.1287/orsc.11.4.404.14600

Pozzebon, M., & Pinsonneault, A. (2005). Global-local negotiations for implementing configuarable packages: Learning from IT research. *Organization Studies*, *26*(9), 1353–1376. doi:10.1177/0170840605054621

KEY TERMS

Complex Systems: Systems that interweave components in such a way that they display variation without being random, and result in a structure that is more than the sum of its parts.

Complexity Science: The study of complex systems, broadly defined.

Emergent Use: The use of systems in ways not initially anticipated, stimulated by users improvising to add applications to the original system in order to support local practices. Emergent use can be planned or unplanned.

Holistic Information Security Approaches: Security management strategies that encompass social as well as technical elements, and which are dynamic so that security issues are considered each time a new use is adopted, even if this use is not formally instigated.

IT Standards: Generally agreed-upon activities, methods, functions, protocols, interfaces, systems, equipment, materials, services, processes, and products that have been introduced and employed, in efforts to reduce the labor costs associated with IT projects.

Metapolicy: Establish how policies are going to be created in an ongoing way.

Reductionist Information Security Approaches: Security management strategies that apply solutions to small fractions of a system at a time (e.g., passwords to secure access to an application, firewalls to protect network traffic, and so on.).

This work was previously published in Encyclopedia of Healthcare Information Systems, edited by N. Wickramasinghe and E. Geisler, pp. 573-577, copyright 2008 by Medical Information Science Reference (an imprint of IGI Global).

Chapter 7.2

Security-Aware Service Specification for Healthcare Information Systems

Khaled M. Khan
Qatar University, Qatar

INTRODUCTION

With the rapid advancement of Web-based technologies, healthcare information systems are becoming increasingly heterogeneous in terms of their architecture, composition, and runtime characteristics. A healthcare system can be composed of several stand-alone service components, such as Web services available from various distributed sources for runtime execution. We use the terms *Web services* and *service* interchangeably in this chapter to refer to the same concept. A healthcare application system can be composed of multiple autonomous geographically dispersed software services. A healthcare software service is autonomous as it has its own executable code and uses its own data or files. The composition of a healthcare system can be dynamic or static, depending on how services are connected to each other to provide the services. Some of the services are downloaded directly from the Internet and executed dynamically with the application system. The use of independent services in the healthcare information system is appealing because it supports reusability of code and far efficient utilization of network resources, and it might be cost efficient.

Despite the benefits and usefulness of service computing, the characteristics of third-party services also present tremendous challenges for healthcare information security. As services are reused in far greater scale, there is a need for ensuring the security properties of third-party services to the composite healthcare system. Security is a systemwide property referring to the entire system composed of several services. Security architecture alone at the individual service level cannot protect a system unless the conformity of the security properties is checked with the enclosing application system in terms of required and ensured security properties. This issue of conformity of security properties between the individual service and the enclosing healthcare system has far-reaching implications because failure of this would seriously undermine the privacy of the patients and the reliability of the healthcare providers. Let us give a brief scenario (Han & Khan, 2006) in order to magnify the seriousness of the issue.

Consider a Web service that can generate various test data such as X-ray data, MRI images, CT scan images of the patients, and so forth. Another Web service uses these data as input and generates diagnosis reports to other Web services, which could ultimately produce prescriptions and prognoses of the patients' problems. Finally, the prescriptions are sent to another Web services that supplies medicines to the patients. In this scenario, we can see that the confidentiality and integrity issues of patient data are critical. Similarly, the authenticity of the service provider is an important issue, because the generated output of one service determines the outcome of the treatment produced by another service. Note that all these services are completely independent in terms of their development, their formation, and, most importantly, their security provisions. Different Web services have different security requirements as well as assurances during run-time processing of various sensitive patient data. The fundamental question is how service computing can cater various security requirements of different healthcare services in a composed federated e-healthcare system.

To address this question, this chapter proposes a framework of composing security properties for services used in healthcare information systems. It proposes a generic architecture of our proposed security-aware services and discusses the related issues. In contrast to most of the current initiatives that focus on incorporating existing security techniques into service computing, we see a great need and potential to develop a new framework for security-aware service composition in healthcare systems. The main objective of this chapter is to define a process that would enable us to compose various security properties of a federated healthcare information system that is assembled from various independent third-party software services.

BACKGROUND

The current practice of using software services in healthcare systems does not have any compositional process for properly evaluating the conformity of security properties between third-party services. This could dangerously lead to compromise to the enterprisewide security requirements of the healthcare systems, such as the confidentiality of patient data and the reliability of the services. Consequently, this risky practice of compositing systems of third-party services without due attention to the conformity of security properties could result in the degradation of system security. This practice virtually forces healthcare systems integrators to take undue risks by composing a system in order to achieve global services. Generally speaking, most systems integrators have neither the time nor the resources to examine the security properties of candidate software services. The required security functions that a healthcare system requires may not comply with the provided security profiles of a service.

A thorough examination of related literature reveals that very few research works in this area have been reported. Most research initiatives focus on how to make the individual services secure or how to make the enterprise systems more secure. In our opinion, these cannot solve the problem of "mutual" security conformity among various services

Web services paradigm is based on the Simple Object Access protocol (SOAP), the Web Services Description language (WSDL), and the Universal Description Discovery and Integration (UDDI). The Extensible Markup Language (XML) is the basic mechanism behind all of these technologies. Attempts have been made to extend WSDL to encode quality of services (QoS) properties (Curbera, Khalaf, Mukhi, Tai & Weerawarana, 2003) such as security, performance, and reliability. The aim was not to compose QoS properties along with the service composition, but rather to describe the QoS properties of Web services. None of the standards for XML-based definition language, such as Business Process Execution Language for Web Services (BPEL4WS) (Andrews et al., 2003), XML Process Definition Language (XPDL) (Kappel et al., 1995), Web Services Security Languages or WS-Security (Seely 2002), and Business Process Modeling Language (BPML) (BPMI, 2003), addresses the issue of the composition of security services to engineer the security properties of the composed Web services. WS-Security addresses Web service security by using existing security standards and specifications.

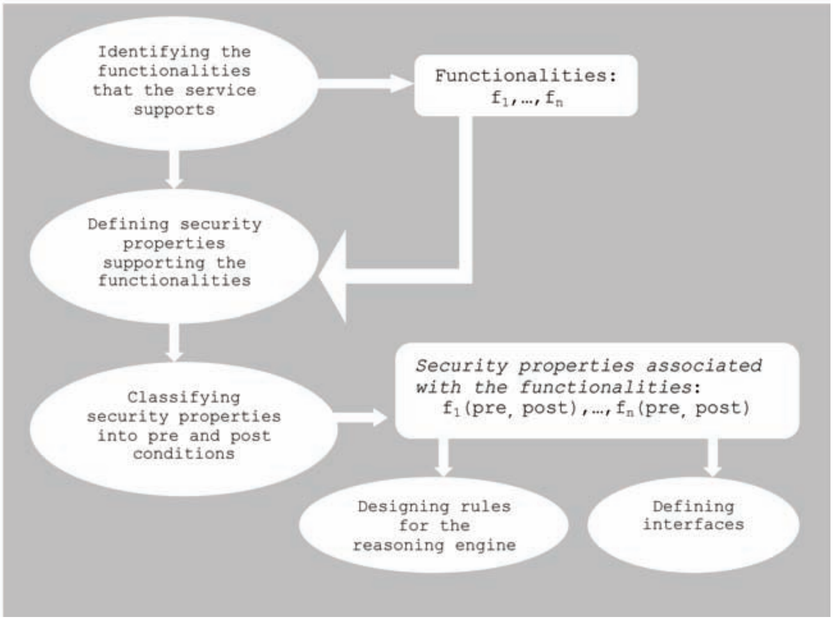
OUR FRAMEWORK

A healthcare software service may provide several functionalities; each may have quite different types of security properties from the others. For a software integrator, it is hard to predict what security properties a functionality supports unless they are well expressed with the interface of the functionality. Security properties are used for various reasons such as to authenticate a system, to authorize, and to ensure confidentiality and integrity. Examples of security properties can be passwords, private keys, secret keys, public keys, shared keys, and digital signatures. The protection of the service and its data and instructions is usually implemented with one or more security functions.

The security properties used to protect a functionality may have distinct security properties for a particular scenario. Security properties could also be grouped into two types based on their role in a functionality: security *precondition* and security *postcondition*. In order to verify whether the security precondition is met by the services user who wants to use the functionality, a reasoning engine is needed.

Based on these preliminaries, we can define the following types of *attributes* of a software service: (i) *the service has one or more functionality*; (ii) *a functionality may be protected with security functions*; (iii) *the security function is composed of security properties*; (iv) *the security properties can be classified as precondition or postcondition of the functionality*; and (v) *a reasoning engine is needed to verify the compliance of the security precondition and postcondition*.

Figure 1. A framework for specifying security attributes of the service



Addressing the compositional security concerns discussed in the previous sections, we propose a framework for specifying these attributes at the architectural level of a service, as depicted in Figure 1.

The framework proposed in Figure 1 shows five distinct tasks. The task for identifying the functionalities of a service involves enlisting the associated functionalities of the service. For example, a *prepare diagnosis report service* may include functionalities such as *receiving pathological data*, *providing diagnosis report,* and so forth. In the next task, each of the identified functionalities is associated with its security properties. For example, *receiving pathological data* function may be supported with the encryption and digitally signed security functions. In task four, the employed security functions are classified into security precondition or postcondition of the function. For example, *providing diagnosis report* function may have encryption and digitally signed as its two security postconditions. The receiving pathological data function could have a security precondition such as encryption of the data. The specifying of security precondition and postcondition could be achieved by using the security characterization approach proposed in Khan and Han (2003). The designing rules for the reasoning engine function involves issues on how to check the conformity of the security precondition as well as postcondition. It could be a rule-based approach or any other approach. The final task defines the interfaces so that other applications or services may contact the service.

In our approach, the security properties are associated with the interface of the services in such a way that the other services or application systems could read the security properties along with the functionality of the service. The approach could also provide a mechanism so that the application could check the conformity between the application and services. The output of this framework could be a service with its functionalities mapped with the associated security precondition and postcondition, as shown in Figure 2.

The diagram depicts that a healthcare service provides two distinct functionalities to other services of applications. Each functionality has its own security precondition and postcondition. The service has one common interface to access the functionalities of the service. The employed security properties are mapped with the functionality that a service supports. In order to use any of these functionalities, other services or application systems must comply with the security precondition of the candidate functionality. In return, the functionality ensures the specified security postcondition.

CONCLUSION

The chapter has outlined the problems related to the issue of compositional security of healthcare software services at runtime. It has proposed a high-level framework to develop security-aware healthcare software services. A security-aware service has its functionality mapped with an associated security precondition as well as postcondition. In order to get the service of a functionality, other application systems or services are required to meet the security precondition of the functionality. In return, the healthcare service ensures security postcondition to the application systems. The chapter argues that different healthcare information systems may require from the services different types of security functions in order to protect the information. Our approach advocates a need-based, security-aware composition; that is, a healthcare application can only be composed with a service that could comply with its security requirements. Similarly, a service may also require certain security properties to be satisfied by the enclosing healthcare system in order to receive the service. We acknowledge that further investigations need to be done in order to build a complete framework. The framework also needs to be tested in a real-world situation.

REFERENCES

Andrews, T., et al. (2003). Business process execution language for Web services. Specification Version 1.1, IBM.

BPMI. (2003). *Web services*. BPMI technical report.

Curbera, F., Khalaf, R., Mukhi, N., & Tai, S., & Weerawarana. (2003). The next step in Web services. *Communications of the ACM*, *46*(10). doi:10.1145/944217.944234

Han, J., & Khan, K. (2006). Security oriented service composition and evolution. In *Proceedings of the IEEE Asia Pacific Conference on Software Engineering, IEEE Computer Society*, Los Alamitos, California, 171–178.

Kappel, G., Lang, P., Rausch-Scott, S., & Retschitzegger, W. (1995). Workflow management based on objects, rules, and roles. *IEEE Computer Society Data Engineering Bulletin*, *18*(1), 11–18.

Khan, K., & Han, J. (2003). A security characterisation framework for trustworthy component based software systems. In *Proceedings of the IEEE Computer Software and Application Conference, IEEE Computer Society*, Los Alamitos, California, 164–169.

Seely, S. (2002). *Understanding WS-Security*. Technical report, Microsoft.

KEY TERMS

Healthcare Service Functionality: A functionality provided by a service is a task offered by the service to its environment. A healthcare service may have one or more functionalities to offer. The client healthcare application system could use these functionalities at runtime.

Healthcare Services: A platform-independent, self-contained software with defined functionality that can provide healthcare related computing services. It provides a standard way to integrate mechanism with healthcare applications over the Web. A service can perform one or more functionalities for the complex healthcare application system.

Security-Aware Service: A service that has its own security requirements to be satisfied by the service user; in return, it guarantees certain security requirements. The approach also provides a mechanism to verify the compliance of the security requirements of the service as well as the service user.

Security Function: The implementation of a security policy as well as a security objective. It enforces the security policy and provides required capabilities. Security functions are defined to withstand certain security threats, vulnerabilities, and risks. A security function usually consists of one or more principals, resources, security properties, and security operations.

Security Postcondition: An ensured security property is a postcondition in a sense that it is the responsibility of the service or the application system to maintain the committed security assurances during the composition.

Security Precondition: An invariant in a sense that other entities must satisfy this before a composition takes place. It is a precondition the service user must ensure to the service provider that the required security properties are met and their validity is ensured before a service can be obtained.

Security Property: An implementation element used in a security function. A set of security properties can form a security function. A security property is an element at the lowest level of the implementation.

Security Reasoning Engine: Verifies the security compliance between a service and the service user. The reasoning engine could use rules that comprise a set of criteria that could be used to assess security properties between two services. A security reasoning engine tests whether a security function has the desired security properties.

This work was previously published in Encyclopedia of Healthcare Information Systems, edited by N. Wickramasinghe and E. Geisler, pp. 1236-1240, copyright 2008 by Information Science Reference (an imprint of IGI Global).

Chapter 7.3

The Impact of Privacy Legislation on Patient Care

Jeff Barnett
University of Victoria, Canada

ABSTRACT

This article looks at how privacy legislation in Canada may interfere with patient care and the use of electronic health records. A review of the literature shows that legislation across Canada is not uniform and varies to the degree in which it addresses issues of privacy and confidentiality. What is not clear is what impact legislation has on the movement towards electronic health records? A case study was undertaken to look at a specific project involving the design of an electronic health record as a means of sharing information between physicians and prostate cancer patients. Through interviews with those associated with the project, it was clear that legislation itself was not a barrier. The problem was that the legislation was open to interpretation. The author hopes that an understanding of the issues raised by this article will lead to further discussion and research on this topic.

INTRODUCTION

Patient privacy is a topic of great interest both in Canada and internationally. Many health conferences and academic journals often have several papers devoted to this topic. This issue has gained more attention in the last five years as there is a continuing trend in health care towards more electronic capture and sharing of information between providers and patients. It has been recognized that health care has typically been behind other industries, such as, airlines and banking, when it comes to embracing its users in the sharing of electronic information. Patients and their health care providers have expressed an interest in sharing of information to facilitate optimal patient care. Unfortunately, as more patient information is made available electronically, there is an increased potential for loss of privacy and confidentiality.

In Canada most provinces have legislation to ensure that there are safeguards in place to protect confidentiality and security of sensitive personal data. However, it may be that this legislation is too restrictive and interferes with patient care activities. Many initiatives, such as those led by federal and provincial governments, are looking at novel ways of providing access to and sharing of electronic patient information. Often these initiatives involve the use of the Internet or some form of information and communication technology (ICT). These initiatives may run into issues with current legislation, to the extent that they never get off the ground or at best are significantly delayed in implementation. In general, the topics presented usually deal with how to be compliant with legislation or how to go about addressing issues related to privacy. Little has been discussed that addresses how legislation may have an impact on patient care. Indeed, there is scarce information in the literature that looks at how the legislation in any particular jurisdiction may have an impact on novel approaches to the delivery of care.

The aim of this article is to look at a new and innovative project for the sharing of information for prostate cancer patients in the Canadian province of British Columbia (BC). A case study was undertaken in order to examine whether current legislation has had an impact on this project, known as the Provider Project.

BACKGROUND

The Provider Project

The British Columbia Cancer Agency (BCCA) provides cancer care programs for the people of BC, including prevention screening, early detection, diagnosis and treatment services, support programs, community programs, research, and education. BCCA, along with seven other provincially mandated health care agencies, is a member of the Provincial Health Services Authority (PHSA), which is responsible for governing, managing, and funding this group of health care agencies and services.

BCCA is committed to providing all patients with access to a full range of quality cancer services, regardless of where they live. To serve the people of BC, BCCA has a complete network of facilities, such as regional cancer centres, community cancer centres, research centres, and foundations. There are five regional cancer centres located in Victoria, Vancouver, Kelowna, Surrey, and Abbotsford. Through these five cancer centres located around the province, various cancer care programs are provided to patients, including assessment and diagnosis, chemotherapy and radiation therapy, counseling services, and follow-up care.

One of the many types of cancers treated at the BCCA is prostate cancer. Prostate cancer patients are often exposed to a variety of treatment options such as surgery, radiotherapy, hormonal therapy, and, rarely, chemotherapy. Prostate cancer is often referred to as a chronic disease. This is because the tumour is slow growing and with currently available treatments, patients remain very active and alive for many years after diagnosis. Caring for these patients during treatment is complicated and often involves a multidisciplinary approach to care. The members of the care team are usually radiation oncologists (specialized physicians), radiation therapists, nurses, pharmacists, social workers, and, most importantly, primary care physicians.

More recently with the increasing involvement of patients in shared decision making, patients have become very active members of their own care team. This is especially true for prostate cancer (PC) patients. Several studies have indicated that these patients are keenly interested in their care and are often very active in seeking out information. However, with the complexity of their care, gaps in information between PC patients and their care team can exist. It has been demonstrated that a growing number of patients now refer to the Internet as a source of information in order to fill those gaps. However, the Web sites dealing with PC are often generalized and do not provide patient specific information. PC patients, just like other patients with a chronic disease, need information pertinent to their condition. More recently, attempts have been made to develop personalized Web-based electronic health information as an innovative method of delivering patient specific information. The Provider Project is an initiative led by a physician at the BCCA'S Vancouver Island Cancer Centre. The Provider Project has been designed to provide a prototype Web-based patient electronic medical record system geared specifically for PC patients. This project has been ongoing for the last five years. The issues around privacy and confidentiality have been a major obstacle in getting this project launched. The vision of Provider Project is to give a group of PC patients access to a subset of data in a customized version of their current paper based and electronic medical record held at BCCA. However, the main challenge has been in dealing with issues of privacy and confidentiality.

In BC, in particular, there are two pieces of legislation that have direct authority as far as privacy and patient care in BC are concerned. One is the BC Freedom of Information and Protection of Privacy Act, or FOIPPA. This Act of the Province of BC was introduced in 1997. The main purpose of this act is to "make public bodies more accountable to the public and protect personal privacy by *preventing the unauthorized collection, use or disclosure of personal information by public bodies*" (emphasis is added here because this is where there has been controversy about what constitutes "unauthorized collection or disclosure").

A second important piece of legislation in BC is Bill 73, which is an amendment of the BC Freedom of Information and Protection of Privacy Act. It was drafted in response to the U.S. Patriot Act, a Federal Act of the United States that "allows access to personal information located in Canada that is involved in outsourcing of public body functions to a US linked contractor." Bill 73 came into law in October of 2004. Bill 73, in effect, eliminates access to any personal information outside Canada. It states, "A public body must ensure that personal information in its custody or under its control is stored only in Canada and accessed only in Canada." Again, the interpretation of this act has invoked controversy as to what constitutes access and storage. All health authorities and public bodies in BC, and many of the research bodies, are grappling with the implications of both pieces of legislation. Any clinician or program leader creating new initiative involving the collection of patient data may be required to fill out a Privacy Impact Assessment (PIA) document and, quite often, a "Bill 73" Impact statement.

Bill 73 had no effect on the Provider Project and is outside the scope of this article.

METHODOLOGY

Research Design

The research design used in this article consisted of a case study of the Provider Project that was broken out into three tasks:

- The first task involved a literature review to determine the major issues surrounding privacy legislation and how they may impact patient care. This was limited to North America with a focus on Canadian Law, as there are many differences in legislation between Canada and the United States.
- The second task was to interview two experts. These individuals were selected for their advice and knowledge in the area of privacy legislation and their knowledge of the Provider Project. One of these experts is a legal specialist from the University of Victoria. The other is a senior privacy officer

with the PHSA. The intent of the discussions with the experts was to gain a clear understanding of the relevant legislation in BC and any other legislation that may have an impact on the Provider Project.

- The third phase of this project employed several instruments to collect information about the privacy and confidentiality issues faced by the Provider Project during this phase. One of the main techniques used was structured interviews with the project sponsor and other stakeholders associated with the Provider Project.

Data Collection

The structured interviews were centred primarily on the understanding and interpretation of the main issues related to the privacy and confidentiality of patient data. The main focus of the interviews was to look at the challenges and potential roadblocks the stakeholders had experienced in this project. Here the intent was to obtain key factors and "lessons learned" in putting together a project of this nature. In-depth interviews with two experts in privacy were undertaken. The lead physician and members of the Provider Project were interviewed in depth. A record of each interview was recorded using a recording device. Consent to use the device was obtained prior to its use. Once the interviews had taken place, the recordings were reviewed and a transcript of each interview was created using Transana Software (Transana version 2.10 open source software from the University of Wisconsin). After the transcripts were written up, themes and keywords were identified using the software.

Secondary Data Sources

In addition to the interviews, the case study also involved direct observation and documentation review. Direct observation included attending formal team meetings of the Provider Project as to understand how issues of privacy impact the project. As well, with the permission of the investigator, passive observations also took place whereby the researcher sat in on discussions with Patient Information Management and Information Technology Staff at the BC Cancer Agency.

Several key documents were also reviewed:

- The Provider Project Plan
- An Executive Summary of the Provider Project prepared for the BCCA Executive
- The Privacy Impact Assessment (PIA) for Provider
- Provider team meeting minutes
- Other Provider Project documentation and e-mail communications between the various stakeholders

RESULTS

Review of Privacy Legislation in Canada

Most of the Canadian provinces have legislation covering the protection of personal information, in the form of a Freedom of Information and Protection of Privacy Act (FOIPPA, 1997). Some provinces like Saskatchewan and Alberta have legislation that is specific to personal health information, in the form of health information acts. As provincial governments develop these acts and implement policies addressing the protection of health information, it remains unclear as to what effect legislation has on patient care and an already complex health care system.

The world of research has been struggling with these issues for some time and there are many papers in the literature that deal with health research and patient privacy. The use of health information for research purposes is largely governed by the federal Personal Information Protection and Electronic Documents Act (PIPEDA), enacted in 2000. This is a federal act that sets out 10 principles of privacy provisions based on the Canadian Standards Association's Model Code for the Protection of Personal Information*,* recognized as a national standard in 1996.

In the research arena, several authors in Canada, North America and Europe have identified how legislation has an impact on research. McCarthy suggests that efforts to protect patient privacy may come into conflict with the ability to produce timely and valid research to safeguard and improve health (McCarthy, Shatin, Drinkard, Kleinman, & Gardner, 1999). The use of health records for research is well known, but Upshur suggest that more strict rules and strengthening of consent legislation may have adverse effects on health services research. He argues that it may also lead to an "authorization bias" in health services research (Upshur, Morin, & Goel, 2001). Earlier work by Gordis and Gold (1980) emphasizes the value of using medical records in research particularly for diseases like cancer, cardiovascular disease, and pediatrics. Yet, there are very few examples in the literature where the use of personal data for research purposes has caused harm to Canadians (Upshur et al., 2001). A further discussion of legislation and privacy issues related to health care research is beyond the scope of this review.

When it comes to health care delivery and health care information, we are only now just exploring the issues that are being brought by the movement to electronic health records (EHRs) and the exchange of health information by electronic means. In Canada, federal bodies, such as Canada Health Infoway, are pushing towards the goal of EHRs for all Canadians. All across Canada there are many new and innovative projects. The main aim of these projects is to improve the access, quality, and productivity of Canada's health-care system. Many projects involve new and innovative approaches to patient care which involves the interchange of patient information in an electronic format. E-health is becoming an accepted part of health care. Back in 2002 Richard Alvarez, the current head of Canada Health Infoway, who was at that time the President and CEO of the Canadian Institute for Health Information (CIHI), suggested that e-health now focused on the consumer, as we have evolved to a new consumer centric model for health care. He maintained that Canadians are demanding more from their health-care system and wish to become more involved, yet at the same time, they are increasingly concerned about privacy issues (Alvarez, 2002).

This poses an essential paradox, in that the needs of patient and their care must be balanced with their concern for privacy. A commentary in the *Canadian Medical Association Journa1* suggests that "A paradox looms: Canadians demand high-quality, accessible, and efficient health care *and* privacy for their personal health information" (Upshur et al., 2001). Yet, has this contradiction always been here regardless of whether health information is kept in an electronic or paper format? Prior to the advent of e-health initiative, privacy breaches did occur and usually involved individuals finding medical records in a back alley. Whenever a breach like this has occurred it would always make front-page news, but invariably not last long in the public eye. After the initial shock and dismay, the issue would die and be regarded as an isolated occurrence. With the advent of ICT in health care and the need for health care reform, there is a demand to look more closely at privacy issues. Some authors suggest that the issues of privacy and confidentiality of health information have always been with us. The only thing that has changed is the move from paper to electronic data capture. Berger states that "having one's electronic medical records accessible to any interested employee in a hospital or clinic (or to members of their family when the hospital allows telecommuting) is not that much different than having the various papers, charts and notes stuck in a manila folder in a filing cabinet that anyone in a white coat can access." In his book *Database Nation*, Garfinkel documents several major cases in the United States where personal health information was abused (Garfinkel, 2001). All the cases he documents have nothing to do with electronic records, but are results of unethical actions or mistakes made by health care providers. He goes on to suggest that the introduction of computerization into health care poses several threats that could severely impact patient privacy. These are based on the assumption that electronic records can be more readily accessed than paper records and are less secure. However, several authors have argued that this is not necessarily the case. In fact, there are many articles that suggest moving to electronic records will improve security. Morrissey suggests that handling patient data electronically may actually be more secure than paper based records (Morrissey, 2006). In his paper entitled "A day in the life of a Medical Record," he demonstrated how relatively unsecured a paper chart can really be. He goes on to say that, short of putting it in a locked filing cabinet, it will never be as secure as an electronic record can be made.

Health care in Canada and around the world continues to evolve into a multidisciplinary and multiple-agency networking approach (Weitz, Drummond, Pringle, Ferris, Globerman, Hebert, et al., 2003). There is a greater degree of service coordination in order to meet the complex needs of individuals. The move toward electronic health records and electronic patient records, coupled with the advancement in technologies, especially the Internet, are fueling this. The irony is that as regionalization continues across Canada and small health-care groups are collapsed into larger health care networks, the demand for information sharing intensifies. The so called health care networks are being created in order to gain efficiencies and thereby save scarce health care dollars. Yet, this is not enough. The health care system is also under increasing pressure to do more with less and ICT is seen as one of the ways to help solve these problems (Weitz et al., 2003).

Patients as consumers of health care are also demanding more and have become more informed. Physicians and other health care providers are expected to keep their patients well informed while, at the same time, keeping patient information confidential. Keeping patients informed is one of the main expectations in the consent process. The Canadian Medical Association has developed a privacy code that defines both confidentiality and consent within the scope of medical practice (Canadian Medical Association, 1998). It states:

Confidentiality, confidential mean that health information that is confided by a patient is to be kept secret and not disclosed or made accessible to others unless authorized by patient consent. A breach of confidentiality occurs whenever a health professional discloses or makes health information available to others without or inconsistent with the patient's consent.

Consent means a patient's informed and voluntary agreement to confide or permit access to or the collection, use or disclosure of his or her health information for specific purposes. Express consent is given explicitly, either orally or in writing. Express consent is unequivocal and does not require any inference on the part of the provider seeking consent. Implied consent arises where agreement may reasonably be inferred from the action or inaction of the individual and there is good reason to believe that the patient has knowledge relevant to this agreement and would give express consent were it sought.

This is where discussion about consent and confidentiality of health information gets mired in debate. Weitz et al. (2003) suggest that the argument comes back to the balance between protecting the individual's rights to privacy and autonomy while, at same time, allowing providers access to information they need to care for their patients.

In Canada, legislation has been brought in as an attempt to provide a framework of how health information can be collected, shared, and accessed. However ,there is a problem in Canada, in that there is a patchwork of federal statutes, provincial legislation and codes of conducts of the various health care professionals (Bennet, 1996). The type and extent of legislation varies from province to province and has a different impact on users of health care depending on the province they live in. As stated previously, most Canadian provinces have legislation covering the protection of personal information in the public sector, in the form of FOIPPA.

The approach across Canada is far from uniform. The different rules, practices, and customs within the various provinces, health districts, hospitals, and clinics do not allow for consistent, effective practices for sharing of data or protecting patient privacy (Berger, 2002). Clearly this is a problem for health care delivery. Saskatchewan, for example, has the Health Information Protection Act that actually allows individuals to refuse to have their information stored in an electronic format in the Saskatchewan Health Information Network (SHIN). Patients also have the right to restrict access to other providers of health. Weitz suggests that Saskatchewan's act may be one of the most limiting in Canada, as individual rights may place unreasonable limits on what type of health information providers can access.

In Canada, the current state of privacy suggests that, aside from legislation, there is already some infrastructure in place. A survey undertaken by Infoway in 2002 indicated that 9 out of 10 organizations require staff to sign confidentiality agreements and 4 out of 5 regulate access of employees and physicians to clinical records. On the other hand, over 50% have policies regulating remote access to clinical records and less than 50% have policies governing patient consent to information sharing (Canada Health Infoway, 2002). The concept of an electronic record is well supported by the Canadian public. An Ekos survey by Infoway suggested that 85% of Canadians do support electronic health records. The same survey showed that Canadians say the following will make them feel more comfortable about electronic health records (Canada Health Infoway, 2002):

- Find out when and who accessed their record 71%
- Serious criminal offense for unauthorized access 64%
- Clear and accessible privacy policy 61%
- Ability to access, verify, and correct record 57%
- Supported by their doctor 57%

When it comes to information sharing and patient perception, there is very little data available in Canada. Weitz suggests that there is a lack of public input into the discussion (Weitz et al., 2003). He suggests that little is known about how patients feel about this issue. In 1997 Saskatchewan's Minister of Health sent out consultation packages to the public, health providers, district health boards, consumer groups, special interest health groups, researchers, MLAs, and the media. This package was intended as part of a public consultation process on the protection of health information (Saskatchewan Health, 1997). When the respondents were asked specifically about information sharing, over 95% agreed that health information necessary for treatment should be available to service providers where and when they need it. In addition, 89% agreed that hospitals, health boards, physician's offices and others should be able to exchange health information when it is important for health services. Ironically, Saskatchewan has legislation in the form of the Health Information Act that is more restrictive than some of the other provinces, such as BC. Sometimes the public may be consulted on issues such as this, but do not ultimately have some bearing on the text of legislation. The consultation process may be more of a public relations exercise.

A similar survey done in the Netherlands on inpatients suggested that patients expect that members of their health care should be able to share vital personal health information without their consent for that communication (Klop, van Wijmen, & Philipsen, 1991). In the provinces like Alberta and Saskatchewan that have legislation governing health information, the legislators have tried to take this into account. The legislation that sets out the rules regarding disclosure of information, particularly between health care providers, was created with intent to clarify how disclosure may come about and with less legal or regulatory obstacles. The use of ICT in health care has grown rapidly over the past decade, but legislation is only now trying to keep pace. It is ironic that health information legislation addressing disclosure has come about in response to advances in technology. Yet as previously mentioned, the issues it addresses have always been with us and are not entirely new. A paper chart in a hospital can be accessed by any staff member or anyone walking into the hospital.

Initially, some provincial legislation was considered too restrictive and not practical to implement. For example, when the Health Information Act (HIA) was first introduced in Alberta, section 59 required consent from individuals before information could be disclosed. This section stated that for consent to be valid it must include:

a. An authorization for the custodian to disclose the health information specified in the consent.
b. The purpose to which the information may be disclosed.
c. The identity of the person to whom the health information may be disclosed.
d. An acknowledgement that the individual providing the consent has been made aware of the reasons why the health information is needed and the risks and benefits to the individual of consenting or refusing consent.
e. The date the consent is effective and the date if any on which the consent expires.
f. A statement that the consent may be revoked at any time by the individual providing it.

Section 59 was repealed in 2003 because it was felt that it was too costly to comply with this legislation. Physicians and other health care providers felt that they had to spend extra time obtaining patient consents. The Alberta Privacy Commissioner in fact suggested that getting consent to provide information to a provincial EHR would be too costly and impractical. Cornwall, in *Connecting Health,* looked at Alberta's Pharmaceutical Network and found that physicians were spending an inordinate amount of time explaining the system to patients (Cornwall, 2002). This was largely driven by the current legislation and the physicians' fears around legal liability. Shaw suggested that the desire to provide provincial health networks where information can be shared is bogged down by the lack of privacy legislation in some provinces (Shaw, 2000). He suggests that some projects are slow to move ahead and are suffering because policy is not keeping up with technological change. He raises the suggestion that some projects may be suffering from policy paralysis.

As the EHR is gradually being developed in each province, policy makers, both in government and in health authorities, will continue wrestling with the issues of privacy and confidentiality. However, it is important to point out that in order to make the roll out go smoothly, several authors suggest that the public must be consulted. The success of Newfoundland's provincial patient registry is in part due to the involvement of stakeholders and getting a good understanding of the privacy issues way up front. Rather than waiting for legislation to be created by the provincial government the project leaders created privacy guidelines that they shared with their stakeholders which were then presented to the government.

Reis writes that legislation specifically for health information is still relatively fresh, as are the projects associated with information sharing. A balance must be struck between the need to protect the privacy and confidentially and the ability to administer the new systems coming into place (Reis & Moysa, 2005).However, she notes that in some provinces, such as Ontario, current provisions of legislation places the burden of implementing appropriate security measures on the custodians of information. This is where problems may occur, as it places the onus on the custodians to create reasonable safeguards. Failure to do so could be subject to investigations by provincial privacy commissioners (Reis & Moysa, 2005).

Interviews

Over the summer of 2006 interviews took place with the two privacy experts and members of the provider team. Each of the interviews lasted over 1 hour. The two privacy experts were given the same interview instrument. This was slightly different than the one administered to the members of the provider team. A set of 10 questions was given to the privacy experts and a different set of 10 questions was administered to the team members. As the questions were open-ended, there was a great deal of discussion between the interviewer and the interviewee. Once the interviews were recorded, a transcript of the interviews was created and this was analyzed using the Transana software. From the interviews with both the team members and the experts, the following themes were apparent:

- Privacy legislation in BC is highly subject to individual interpretation
- Challenges around staff and resources had an effect on provider
- There is a need for better regulatory interoperability between jurisdictions
- Protection of patient information is not well defined
- Patient consent is an over-riding principle
- BC lacks a Health Information Act similar to Alberta

Privacy Legislation Can Be Highly Subject to Individual Interpretation

All of the interviewees stated that the current privacy legislation can be open to interpretation, depending on the individual's biases and background. In the case of the BCCA the legislation that was always referred to in regard to Provider was FOIPPA. Although this legislation has been around since 1996, there appears to be a difference of opinion as to how it affects use of patient information in health care. What is important to note is that this piece of legislation does not mention keywords like patient, health record, or electronic record. The Act does not, in fact, specifically address health information. So it is not surprising that it is subject to interpretation. In the case of Provider, FOIPPA was used initially as a reason not to allow for the release of information in the early stages. The stakeholders all echoed the comment that the initial resistance to allow for the transfer of patient information came from individuals within BCCA who said it could not be done because of privacy concerns and FOIPPA. As the Provider project evolved, it became clear that there was a willingness on the part of senior IT staff at the BCCA to move ahead. The issues around release of information became more focused on the release of information by electronic means. BCCA had policy that allows for the release of patient information directly to the patient. Like most health care institutions, patients are able to go to the health record department and request their paper chart. They could sign a release of information form. This would allow health records staff to give out a copy of all or part of their health record. The Provider proponents were well aware of this, but felt that if the patient signed a release, they could also have that information released in an electronic format. Here in theory, if the patient was consenting to the release of information, the format should be irrelevant. Initially Provider team members were told that this was not possible due to privacy legislation. Subsequent requests for the release of the information in an electronic form were denied, not due to legislation, but by the simple fact that health records staff were not set up to provide information in an electronic format. It became clear that no one at BCCA or PHSA was interested in looking at Provider as a new way of delivering information to patients. To be successful it had to become a research project. As with any research project, it had to have an ethics review and approval by the BCCA, which it obtained successfully. In addition, the project team was required to fill out a Privacy Impact Assessment (PIA) document as part of the process. The intent of a PIA was to ensure that a new program or initiative avoided any violation of the relevant legislation and could mitigate any security risks. As Provider moved into a design phase, issues of privacy were still a prime concern. The members of the project team were initially given limited advice on how to best deal with privacy and confidentiality issues. In the end the team obtained legal help from an expert in the area of health law, who helped draft the PIA. This PIA addressed many potential issues that the Provider project could encounter. Doing the full PIA was time consuming and required several iterations before it was acceptable to senior management at BCCA. Even then, it did not help solve the issue of electronic transfer of information.

Challenges Around Staff and Resources Had an Effect on the Provider Project

One of the issues that came up during the interviews was that the Provider Project started to evolve at a time when BC was undergoing health restructuring. The project was initially discussed with the Chief Information Officer (CIO) at BCCA. At that time, BCCA was a semi-autonomous body that reported directly to the Ministry of Health. Under restructuring it became an agency under PHSA. The departments of Information Management and Information Technology at BCCA were merged into centralized departments of PHSA. The CIO of BCCA became the CIO of PHSA. One of the managers in information management in BCCA became the Corporate Director for Information Management at PHSA. Both individuals were familiar with the Provider project, but once they assumed new roles, they took on corporate projects and priorities. The Provider project was not seen as a high profile project and it was felt that there were limited or no IT resources that could be devoted to the technical tasks that were required in the project. At one point the main investigator for Provider offered to fund PHSA IT staff to work on the project, but this request was not acted upon.

The main issue for the project that required assistance from IT was getting some specific information out of the Cancer Agency Information System (CAIS). CAIS is BCCA's electronic patient record that contains an electronic version of most information contained in the paper chart. The main pieces of data required for Provider residing in CAIS were specialized lab values, such as Prostate Specific Antigen (PSA), appointment data, radiation therapy treatment, and records of drug therapy. The intent was to have this data transferred electronically into Provider for specific patients. Help was requested from PHSA IT to accomplish this. In the end, because IT support from PHSA was not forthcoming, due to issues related to workload and concerns about privacy, the Provider team abandoned this approach. In its place they came up with an approach by which patients who had consented to be part of the Provider project would obtain a paper copy of their information through the release of information process. This would be manually entered into Provider by a research assistant. This process was outlined in the PIA and agreed to by PHSA.

There Is a Need for Better Regulatory Interoperability Between Jurisdictions

As mentioned in the literature review, privacy legislation has been enacted at the federal and provincial levels. Different provinces have different statutes and regulations concerning the exchange of patient information. This varies from province to province. The problem can be compounded within a province where different health authorities or regional health districts have jurisdictions over an organization. These health authorities may have different rules and procedures. Provider was initially planned when the BCCA was an agency of the Ministry of Health and had its own policies and procedures around patient information. When BCCA became part of PHSA, it was governed by the rules and regulations of PHSA. Overlying both organizations was the provincial FOIPPA legislation. In addition, Provider eventually moved into a project involving researchers from the University of Victoria (UVIC). UVIC had policies and rules that had to be taken into consideration as well. Of particular concern was the proposed electronic transfer of information from the BCCA to the university. The computers that would house the Provider project were located in a secure computing facility at UVIC. The intent was to transfer pertinent data from BCCA to the university. A collaborative agreement was reached between BCCA and UVIC to allow for the handling and sharing of data. This was all part of the PIA. UVIC was willing to allow for the information exchange to take place electronically, but PHSA would not, for reasons already discussed. One of the difficulties for the Provider Team was that there was a great deal of confusion about the need for data sharing agreements vs. a collaborative research agreement between the University of Victoria research office and PHSA. Several discussions took place, which created a delay for the project. In the end, no agreement was reached between PHSA, UVIC, and the Provider team. An alternate possibility was discussed with regard to getting lab data into Provider. It was thought that because most of the lab data in CAIS originated from labs outside of BCCA, this data could be obtained from the original source. Patients seen at the Vancouver Island Cancer Centre as part of the Provider project routinely would be getting their lab test done at labs in the city of Victoria. The lab test results were generally available within the Vancouver Island Health Authority (VIHA). One possibility considered was lab data originating in VIHA could be obtained directly from VIHA, rather than going through BCCA/PHSA. However, it was felt that the security and privacy issues that would arise in dealing with another organization would further complicate and delay the project.

While discussions between the Provider team and PHSA were taking place, there were no other data sharing agreements in existence between organizations that would allow for innovative projects like Provider to take place. Health authorities in BC were relatively new and were starting to develop policies and procedures around health information. Only within the last few years has there been a move for the privacy officers in each of the health authorities to get together to share information. In the past, privacy officers were operating in an ad hoc fashion addressing only what they found out about, as opposed to being proactive.

Protection of Patient Information is Not Well Defined

A good deal of the discussion around the Provider project centre on the protection of patient information. As mentioned, the Provider proponents did complete a PIA. In general, the point of doing a PIA is to perform an appraisal of the possible effects that a particular activity or proposal may have on privacy. The Provider team used a PIA template designed by PHSA. This template states that a project would require that PIA be completed if "transition from paper-based system to electronic system (even if it involves no new uses, collection, disclosure or flow of data)." It also states that this should be completed for information sharing to/from other systems, public bodies, or agencies.

The PIA written for the Provider project did take this into account. In spite of this, the transfer of information from BCCA to the Provider Web site could not take place electronically. The Provider team settled on having information transferred from the paper based chart. One of the points that came up in the interviews with Provider team members was the comment that it was difficult to believe that a paper based process was any more protective of patient information. FOIPPA is vague in this regard as section 30 of the act states, "A public body must protect personal information in its custody or under its control by making reasonable security arrangements against such risks as unauthorized access, collection, use, disclosure or disposal." It does not specifically address the issue of paper vs. electronic. All interviewees appreciated that having patient information in an electronic format raises a different set of issues, but the legislation focuses on the fact that a public body must protect the information. One of the experts suggested that electronic transfer can be made more secure than a paper process. Yet, the perception existed that the opposite was true.

FOIPPA also mentions that disclosure can take place provided that the patient has consented in writing. Again, it does not say how that disclosure can or cannot take place. This was a central problem for the Provider team. Consent for the release of information was to be obtained from the patient, but the interpretation of the legislation was that it could not be released electronically.

Patient Consent Is an Overriding Principle

Ironically, one of the reasons that Provider came about was to address the information needs of prostate cancer patients. A literature review and survey by Provider's proponents suggested that this group of patients was highly information seeking. They contended that prostate cancer patients are motivated to be involved in their care and obtain as much information as possible about their condition. The patients surveyed by the proponents of Provider were all keen to participate in the project and all desired access to their health information. Both experts interviewed agreed that patient consent was an important issue. Both stated that if patients consent, legislation should not prevent transfer of the information. They felt that current legislation in BC does not provide any barriers. Both also stated that there may be other issues, such as workload or lack of procedures, that would be more of a barrier. But more often than not, the legislation is used as a "scapegoat." The legal expert interviewed suggested that once consent has been given, there was no legislative or regulatory reason that data from BCCA/PHSA could not be used to populate Provider. Both experts agreed that informed consent should be the overriding principle but more often than not it is overlooked. Both experts also stated that consent is not the piece of paper that the patients signs, it is an ongoing process involving the patient and from which the patient can withdraw at any time. This sometimes gets forgotten and issues irrelevant to the consent process evolve to become barriers. In the case of Provider, all interviewees agreed that patients were very supportive of the project and were keen to have information about their disease available in a timely fashion. This echoes what is reported in the literature about patient access to health information (Denton, 2001; Hassol, Walker, et al., 2004; Pai & Lau, 2005).

BC Lacks a Health Information Act Similar to Alberta

An issue that came up with both experts is that BC lacks legislation similar to other provinces like Alberta. Both FOIPPA and the private sector legislation, called the Personal Information

Protection Act (PIPA), make little reference to health care and electronic records. On the other hand, Alberta has legislation, called the Health Information Act (HIA or the Act), which became law on April 25, 2001. This legislation protects the privacy of Albertans and the confidentiality of their health information. It attempts to balance the protection of privacy and confidentiality with the need to enable health information to be shared and accessed where appropriate, to provide health services, and to manage the health system. The legislation also provides individuals with the right to access their own information and to have that information protected from inappropriate collection, use, and disclosure. At the same time it defines who are the custodians of the health information and provides a legislative framework for how those custodians can collect, use, and disclose health information. BC does not have similar legislation. The experts agreed that this is one reason why the existing legislation can be subject to interpretation and is often referred to as a "moving target." Although the Act may be lacking in some situations or considered overkill, it does specifically cover electronic records and electronic databases. Most importantly, one of the main reasons for its existence is "to enable health information to be shared and accessed, where appropriate, to provide health services and to manage the health system." This Act, as pointed out by the legal expert, sits at the provincial level and sets out a legislative framework for all health regions in Alberta. For the Provider, similar legislation in BC may not have assisted in getting it off the ground more quickly, but the perceived legislative barriers around privacy would not have occurred. It would also provide a framework for the health authorities, so that issues of privacy and sharing of health information would not be subject to interpretation by individuals within each authority.

DISCUSSION

The concept of providing patients access to all or part of their health records is not new. Several papers (Denton, 2001; Hassol et al., 2004; Mathhews & Johnson, 2002; Smith & Protti, 2001) have appeared in recent years that discuss the concept of the Personal Health Record (PHR). Indeed, there are many Web sites in the U.S. where patients can interact with their care provider and track their own health care. The spectrum is quite wide, all the way from reading disease information to actually monitoring treatment outcomes such as lab results. One example is Epic System's MyChart which is used by many hospitals and clinics throughout the U.S. At Fairview Health Services in Minneapolis, patients use MyChart (http://www.fairview.org/mychart/) to perform many functions such as read lab results, schedule appointments, access family records, and communicate with providers just to name a few. There are many examples of this type of PHR in the U.S., but in Canada it is very limited. However, one site stands out and this is the Grand River Hospital in the Waterloo region. They have created a patient portal called My Care Source (https://mycaresource.grandriverhospital.on.ca/portal/). As with Epic's MyChart, patients are enabled to access information and tools to help manage their care. There is an argument that this type of information should be available in Canada. Perhaps the personal health record is the ultimate patient centric approach and should be driving the process. But clearly it is not as yet. There are papers in the literature that support the notion that patients are interested. An early study in 2001 by Denton (2001) suggested that patients are interested in keeping some sort of personal record. The author surveyed 330 patients who had been provided a commercially available electronic personal health record (EPHR). Over 90% of the respondents felt that they should keep some sort of EPHR. One important aspect of this study was that 63 respondents were happy to have an EPHR, but they did not want the computer that housed the

EPHR connected to the Internet due to Internet fraud. By comparison only, four respondents were comfortable with their information being on a computer connected to the Internet. A more recent study by Hassol of the MyChart system (Hassol et al., 2004), used in the Gesinger Health system, suggested that patients have a positive attitude to online access to their EHR and only a minority had concerns about privacy and confidentiality.

On a national level the creation of Canada Health Infoway came in 2001 and the move to electronic health records was boosted by the release of the Romanow report in 2002. Canada began to embark on a journey towards developing an electronic health record. At the same time, some clinicians and researchers were also looking at the concept of a patient centred care. Several authors recommended that patients must be at the centre of the health system and must be treated as partners by health professionals, "as equals with different expertise" (Coulter, 2002). Provider was an attempt at creating a form of a patient health record or PHR for a group of prostate cancer patients. At the time the concept of a PHR was very new and IT departments and managers did not really know how to deal with it. The project raised several issues around privacy and security, which were highly subject to interpretation, as current legislation on BC was vague.

Through discussions with the experts and various stakeholders, it was evident that the Provider project was started in at a very challenging time. It was important for the project team to be aware of the issues around privacy, but there was confusion as to what the issues were and, more importantly, how to resolve them. As already stated, privacy legislation does not specifically address issues around patients, electronics records, or the manner in which information can be disclosed. What FOIPPA does state under section 33 is, "A public body must ensure that personal information in its custody or under its control is disclosed only as permitted under section 33.1 or 33.2."

Section 33.1 states that: A public body may disclose personal information referred to in section 33 inside or outside Canada as follows:

a. in accordance with Part 2;
b. if the individual the information is about has identified the information and consented, in the prescribed manner, to its disclosure inside or outside Canada, as applicable." However, the initial advice given was that the transfer of information from the electronic record in CAIS to Provider could not take place due to privacy concerns. An important question in this regard was that no one clearly had an idea of what the privacy concerns were and how the legislation prevented the transfer of data from the electronic record required for Provider. At first, the issue was whether this data could ever be obtained and then the issue changed to whether it could be obtained in an electronic format. The advice that the proponents eventually got was that transfer of this information could take place, but not by electronic means. Throughout the years, when Provider was discussed and planned, records of Provider meetings and e-mails indicated that managers and agencies voiced concerns about privacy legislation and this prevented the project from moving forward. Yet the existing legislation, FOIPPA, had no direction mentioned of electronic health records or patient privacy. The act is written in general terms and was subject to interpretation. This indicates that the legislation was actually not a barrier to Provider, as was suggested by senior managers in IT. This lack of clarity might have been reduced if BC had legislation similar to Alberta, as has been mentioned. Some may argue that legislation is not perfect, but at least it has set out the legislative groundwork that would have been of great assistance to the Provider team. Others may also suggest that BC health

information legislation would come with its own interpretations by people and biases.

One could also argue that the desires and wishes of the patients were not being addressed and this may be considered another issue of balance. Here, patients had been consulted and were interested in a new approach to their care. They were willing to take part in a pilot study and would consent to the transfer of information. In spite of this expressed desire on the part of the patients, the Provider Project has been slow to evolve.

It is important to state that once a legal expert was consulted and brought into assist with the writing of a PIA, the barriers began to fall. The advice from the legal expert ensured that the PIA addressed any of the issues that could possibly be questioned by individuals with regard to FOIPPA legislation. More importantly, her legal expertise was used to clarify what the pertinent issues were and how to proceed once the PIA was written. Her help was invaluable because it was based on knowledge of the relevant legislation and not subject to bias or personal opinion. However, the fact that it took a great deal of time to do this was an indication that there was and still is a "legislative void" in BC. Today most of the health authorities in BC in fact do have Privacy Officers, who are charged with the task of being familiar with the current legislation and policies of the health authority. These individuals belong to the Information Privacy and Security Working Group (IPSWG), where information is shared and current projects within each health authority are discussed.

Yet, without legislation similar to the other provinces, there is still the potential for interpretation and bias when dealing with these issues. Gostin suggests in reference to a similar situation in the U.S. "The lack of a uniform policy on interstate dissemination of health care information imposes hardships on almost everyone" (Gostin, 1997). This is very similar to Canada, in that different provinces have different legislation. Should this be dealt with at a federal level? Gostin thinks so, as he argues that "National safeguards that protect the privacy of health care information should be based on fair information practices. Federal legislation should establish uniform and comprehensive privacy protection of health care information. Privacy protection should cover all health care information regardless of its form (paper, microfilm, or electronic), location (in storage, transit, or archives), or user or holder (government, provider, or private organization)."

In Canada this is a challenge in that most Canadian health care issues fall under the jurisdiction of the provincial government. Could more health information acts in Canada help solve some of the problems highlighted in Provider? Plater Seeley, and Dixon (1998) suggest that the provincial "FOIPPAs make protecting privacy one of their stated purposes, privacy issues are secondary to enhancing the flow of health information in HIAs." As information technology becomes more complex and the demands by consumers to address complex health concerns the issue of access to and sharing of increases, information will become more complex.

CONCLUSION AND RECOMMENDATIONS

The Provider Project encountered several challenges as it grew from a concept in response to a patient care need. Throughout its development, issues around protection of personal privacy were very much on the minds of those involved. As an isolated innovative concept that grew into a research project, it encountered several hurdles from inception to proposal. The main point of this case study was to look at the impact that provincial legislation had on the project. In doing this research, it was clear that several issues need to be addressed:

- Health organizations will need to look at the logistics for the release of patient data electronically when it is requested by patients or researchers. In the case of Provider, information requested for the project Web site is available as part of an electronic chart. Patients taking part in the project are expected to obtain access to their own information, which they could get through a release of information request. However the only way those patients could get their own information was in a paper format. No mechanism exists to provide this information electronically. Although Provider is a small scale project with a small number of select patients, this is worrisome for projects on a larger scale.
- Legislation itself did not prevent Provider from moving forward. Rather, it was how the legislation was interpreted or how individuals felt it should be applied that impacted the project. The apparent lack of specific health care legislation had an impact on this project. Although the health information acts of provinces like Alberta may not be the perfect solution, they could clarify the process of information exchange and disclosure between different organizations. This would help to minimize the amount of interpretation, opinion, and bias with regard to how and when information can be released.
- FOIPPA legislation recognizes that a balance is required between individual privacy vs. the public good. Two specific goals of the legislation are to establish strong and effective mechanisms to protect the privacy of health information and to enable health information to be shared where appropriate to provide health services. The degree to which this balance is achieved is directly related to the degree of control patients have over their information. It identifies what can be collected and used with or without the specific consent of the patient.
- Further research into the privacy legislation and its impact on patient care is needed, as there are many projects moving forward that have the potential to encounter some of the issues that the Provider Project ran into

REFERENCES

Alvarez, R. C. (2002, September 17). The promise of e-health: A Canadian perspective. *Proceedings of eHealth International 2002, 1*(1), 4.

Bennett, C. (1996). *Regulating privacy in Canada: An analysis of oversight and enforcement in the private sector* (Paths to Better Health Final Report of the Advisory Council on Health Infostructure). Ottawa: Health Canada Publications.

Berger, E. (2002). Attitudes to privacy, health records and interconnection: Implications for healthcare organizations. *Hospital Quarterly, 5*(4), 40–5, 2.

Buckovich, S. A., Rippen, H. E., & Rozen, M. J. (1999). Driving toward guiding principles: A goal for privacy, confidentiality, and security of health information. *JAMIA, 6*(2), 122–133.

Canada Health Infoway. (2002). Pan-Canadian EHR survey phase I: Results and analysis. Ottawa: Canada. Retrieved June 10, 2008, from http://www.longwoods.com/view.php?aid=17335

Canadian Medical Association (1998). Health information privacy code. *CMAJ, 159*, 997–1006.

Carter, M. (2000). Integrated electronic health records and patient privacy: Possible benefits but real dangers. *The Medical Journal of Australia, 172*(1), 28–30.

Cornwall, A. (2003). *Connecting health: A review of electronic health record projects in Australia, Europe and Canada.* Sydney: Public Interest Advocacy Centre. Retrieved June 10, 2008, from http://www.piac.asn.au/publications/pubs/churchill_20030121.html

Coulter, A. (2002). After Bristol: Putting patients at the centre. *BMJ (Clinical Research ed.), 324*(7338), 648–651.

Denton, I. C. (2001). Will patients use electronic personal health records? Responses from a real-life experience. *JHIM, 15*(3), 251–259.

Freedom of Information and Protection of Privacy Act (FOIPPA) (1997). Retrieved June 10, 2008, from http://www.qp.gov.bc.ca/statreg/stat/F/96165_00.htm

Garfinkel, S. (2001). To know your future. In *Database nation: The death of privacy in the 21st century.* Sebastopol, CA: O'Reilly & Associates, Inc.

Giokas, D. (2004). *Privacy implication for the interoprable EHR.* Retrieved June 10, 2008, from http://www.rileyis.com/seminars/sept04/GiokasSept04.pdf

Goldman, J., & Hudson, Z. (2000). Virtually exposed: Privacy and e-health. *Health Affairs (Project Hope), 19*(6), 140–148.

Gordis, L., & Gold, E. (1980). Privacy, confidentiality, and the use of medical records in research. *Science, 207*(4427), 153–156.

Gostin, L. (1997). Health care information and the protection of personal privacy: Ethical and legal considerations. *Annals of Internal Medicine, 127*(8 Pt 2), 683–690.

Hassol, A., Walker, J. M., et al. (2004). Patient experiences and attitudes about access to a patient electronic health care record and linked Web messaging. *Journal of the American Medical Information Association, 11*, 505–513

Health Information Act, Alberta (1999). Retrieved June 10, 2008, from http://www.oipc.ab.ca/hia/
Hollaman, L. (2002). Practical realities: Potential impact of the draft privacy of personal information act on healthcare providers. *Hospital Quarterly, 5*(4), 46–48.

Klop, R., van Wijmen, F. C., & Philipsen, H. (1991). Patients' rights and the admission and discharge process. *Journal of Advanced Nursing, 16*(4), 408–412.

Kosseim, P. (2003). The landscape of rules governing access to personal information for health research: A view from afar. *Health Law Journal, 11*, 199–215.

Matthew, I. K., & Johnson, K. B. (2002). Personal health records: Evaluation of functionality and utility. *JAMIA, 9*(2), 171–180.

McCarthy, D. B., Shatin, D., Drinkard, C. R., Kleinman, J. H., & Gardner, J. S. (1999). Medical records and privacy: Empirical effects of legislation. *Health Services Research, 34*(1 Pt 2), 417–425.

Morrissey, J. (2006). A day in the life of a medical record: Lifting the veil on the security of today's paper-based environment. The National Alliance for Health Information Technology. Retrieved June 10, 2008, from http://www.nahit.org/dl/A_Day_in_the_Life.pdf

Pai, H., & Lau, F. (2005). Web-based electronic health information systems for prostate cancer patients. *The Canadian Journal of Urology, 12*(3), 2582–2591.

Plater, S., Seeley, E., & Dixon, L. A. (1998). Two routes to privacy protection: A comparison of health information legislation in Canada and the United States. *Journal of Women's Health, 7*(6), 665–672.

Policy and Planning Division, Saskatchewan Health. (n.d.). *Consultation paper on protection of personal health information*. Retrieved June 10, 2008, from http://www.health.gov.sk.ca/adx/aspx/adxGetMedia.aspx?DocID=286,94,88-,Documents&MediaID=126&Filename=protection-of-person-health-information.pdf

Reis, N., & Moysa, G. (2005). Legal protections of electronic health records: Issues of consent and security. *Health Law Review, 14*(1),18–25.

Robinson, D. M. (1994). Health information privacy: Without confidentiality. *International Journal of Bio-Medical Computing, 35*(Suppl), 97–104.

Rozovsky, L. E., & Rozovsky, F. A. (1985). The computer challenge: More data, less privacy. *Canadian Doctor, 51*(3), 46–48.

Shaw, A. (2000, March). Provincial health networks slowed down by the lack of new privacy legislation. *Canadian Health Care Technology.*

Smith, J. R., & Protti, D. J. (2001). Personal health records (part II): A potential model for Canada? In *Proceedings of Healthcare Information Management and Communications 2001.*

Tapp, A. (2004). CNPS: Respecting your privacy rights. *Canadian Nurse, 100*(4), 36–37.

Upshur, R. E., Morin, B., & Goel, V. (2001). The privacy paradox: Laying Orwell's ghost to rest. *CMAJ, 165*(3), 307–309.

Weitz, M., Drummond, N., Pringle, D., Ferris, L. E., Globerman, J., Hebert, P., et al. (2003). In whose interest? Current issues in communicating personal health information: A canadian perspective. *The Journal of Law, Medicine & Ethics, 31*(2), 292–301.

Willison, D. J. (1998). Health services research and personal health information: Privacy concerns, new legislation and beyond. *CMAJ, 159*(11), 1378–1380.

This work was previously published in International Journal of Information Security and Privacy, Vol. 2, Issue 3, edited by H. Nemati, pp. 1-17, copyright 2008 by IGI Publishing (an imprint of IGI Global).

Chapter 7.4

Privacy Management of Patient-Centered E-Health

Olli P. Järvinen
Finnish Game and Fisheries Research Institute, Finland

ABSTRACT

This chapter introduces the privacy management framework as a means of studying patient-centered e-health. The chapter raises some important issues in regards to the privacy domain of e-health and offers a privacy framework to look at the issue that addresses some of the concerns people and industries have regarding privacy. The framework does not neglect the important distinction between the different interests affected by e-health. It acknowledges the voluntary nature of the way in which individuals have surrendered control over personal information in exchange for the benefits that information technology brings. Because the applications of information technology are logically malleable, there are sufficient strategic reasons to suggest that privacy management as a concept and practice will survive, and that to ignore privacy issues might be fatal for the success of PCEH.

INTRODUCTION

Transactional and interactive patient-centered e-health (PCEH) has many direct impacts on health service. Most e-health Web sites are pitched publicly as tools that give individuals greater control over their lives and their healthcare. Electronic health information on the Internet can be easily accessible to many different people. A health provider's ability to quickly access a customer's entire medical record, assembled from various sources, can facilitate diagnosis and eliminate medical errors, such as prescribing incompatible medications. Health records are kept and shared for diagnosis and treatment of the customer, payment of healthcare services rendered, public health reporting, research, and even for marketing and use by the media. Individuals can interact with doctors and other participants in chat rooms and by e-mail, and they can obtain healthcare services, such as second opinions and medical consultations, and products such as prescription drugs, online (Choy, Hudson, Pritts, & Goldman, 2001).

Unfortunately, such information practices may conflict with individuals' desires to be shielded from unauthorized use of their personal information. All of these activities involve the exchange of information with or without the consent of the individual, and with or without their knowledge. Mouse clicks and keystrokes are frequently recorded by online health organizations. That means information about which Web sites he or she visits, how long he or she stays there, and where he or she goes afterward are recorded. The majority of data exchange is visible to the individual, but there are many methods through which a Web site can gather information without the individual being aware, including cookies and data-mining. Whenever he or she visits a Web site, a large amount of information may easily become available to the Web site. When transactions are stored and exchanged using electronic services, personally identifiable information become more widely accessible and potentially vulnerable. Even when a customer orders a medicine from an online pharmacy, transactional information about the purchase is recorded, and information about that particular transaction can be (and frequently is) used for future business decisions and actions (Järvinen, 2005).

The ability to provide differentiated, consistently superior service on the Internet will be crucial to the survival of healthcare providers and affiliated organizations, and the customer vulnerability is exceptionally high, due to the sensitive nature of information. The protection of individuals' personal health information is not an option but a necessity, but the study of 39 U.S. health providers' privacy policies submits that health providers' Web sites are still at relatively early stages in their privacy issue evolution (Järvinen, 2005). Many practices suggest privacy is not a fundamental priority for those organizations. Most Web sites do not meet fair information practices—such as providing adequate privacy notice, giving customers some control over their information, and holding business partners to the same privacy standards. Every analyzed Web site had a privacy policy, but the responsibility is left to the customer to read and understand the entire privacy policy at every visit. Many of the analyzed privacy policies contained technical and confusing language (i.e., unnatural language) that makes it difficult for the customers to fully understand what they are agreeing to.

When the ethical problems involving e-health are considered, none is more paradigmatic than the issue of privacy. Given the ability of information technology to widely gather, endlessly store, cheaply transfer, efficiently sort, and effortlessly locate information, we are justifiably concerned that e-health may provide the means to invade our privacy and reveal information that is harmful to us. Information and knowledge easily cross cultural, institutional, organizational, and many other boundaries, and e-health application and its context may be so novel that there are no convenient customs or laws established anywhere to cope with privacy issues. A vacuum in terms of privacy practice may occur in every culture. The key detail of the Internet is that there is no such thing as "absolute privacy." There is no central authority or management, and no one to install the technology or establish network-wide security and privacy policies. We are, however, reluctant to give up the advantages and the services of the Web technology. We appreciate the easy access to the Web site services when checking health information, buying the drugstore items, and many other things. The number and kinds of PCEH applications increase dramatically each year, and the impact of the Web technology is felt around the planet.

The widespread use of personally identifiable information (PII) and the complexity of Web infrastructure is a combination that makes solitude and privacy more essential to the individual. Privacy has emerged as a central policy concern as more people go online every day. Not surprisingly, a great many people are fretful about the things that could happen online and the way in which data about them might be gathered and used. A strong sense of distrust shadows individuals' view of the online world, and the uneasiness has grown. An overwhelming majority of customers are concerned about businesses or people they don't know getting personal information about themselves or their families. (Fox, Rainie, Horrigan, Lenhart, Spooner, & Carter, 2000b). Customers are afraid of Web sites selling or giving away information about them, about insurance companies learning what they have done online and making coverage decisions based on that, and about their employers learning what they have done (Fox & Rainie, 2000a).

Privacy concerns can pose a serious impediment to expanded growth of PCEH in the future. Even the most convenient PCEH services may function ineffectively, because sharing personal medical and health information requires a certain leap of faith—or at least a strong sense of privacy and trust (Fox & Fallows, 2003). Trust is a critical factor in any relationship in which the individual does not have direct control over the actions of company, the decision is important, and the environment is uncertain (Mayer, Davis, & Schoorman, 1995).

This chapter concentrates on privacy issues and problems in two main interests; namely, the online customer and the online health provider. Customers of PCEH are active and involved participants, and therefore, our target is to consider individual needs and capabilities as the primary criteria for designing PCEH services and privacy practices. In this chapter, a framework for PCEH privacy management is presented. The framework balances the rights of individuals to privacy against the possibility of companies to use this technology opportunistically. This understanding is critical, because individuals are becoming increasingly privacy aware and more interested in knowing how to protect their own privacy. At the same time, individuals desire a wide range of new PCEH services.

BACKGROUND

Perspectives on Privacy

Privacy, which is often associated with, and sometimes described in terms of liberty, autonomy, solitude, and secrecy is a concept that is not easily defined (Tavani, 1999a, pp. 137). "Unlike privacy, secrecy appears to have a tight connection to information" (Thompson, 2001, pp. 15). If something is secret, there is at least one person to whom the information is not known. "While confidentiality continues to be an important ethical problem for computer professions, and while security is an increasingly important technical issue, privacy is a red herring" (Thompson, 2001, p. 14).

The term "privacy" is sometimes used to designate a situation in which people are protected from intrusion or observation by natural or physical circumstances. Natural privacy rights are intended to protect a sphere of activity, often a physical place but sometimes an interpersonal relationship, from intrusion by government and other third parties, *the right to be let alone* (Warren & Brandeis, 1890).

Many analysts use the expression "informational privacy" or "information privacy" to refer to a distinct category of privacy concern. Informational privacy is a category of privacy with a set of issues that are distinguishable from privacy concerns related to intrusion and interference (Tavani, 1999a; Tavani, 1999b). When we consider informational privacy "one often finds oneself in a conceptual muddle", because "the issues are not trivial matters of semantics" (Moor, 1998, pp. 16). There are cases when general knowledge of private matters does not breach persons' privacy in any morally significant way. A person's health information may be widely known, but that in no way makes them less private. Having information about a person's sensitive matters may make it possible for someone to violate that person's privacy by discriminating for or against them in an inappropriate way. Such information is widely available in most societies, and "the significance of such information lies not in simple knowledge of it, but in its further use […] Medical information can be used to deny employment and other opportunities to which a person is entitled, and embarrassment is a form of emotional harm that can have extreme consequences in certain situations" (Thompson, 2001, pp.15). "Many Americans know that violation of copyright is a crime, and many believe that violation of their privacy should be a crime too. Why is distributing a corporation's software without its permission called 'piracy,' while distributing a person's information without permission is called 'sharing'?" (Fox et al., 2000b, pp. 11).

A normatively private situation is a situation protected by ethical, legal, or conventional norms. When we frame the debate simply in terms of how to balance privacy interests as an individual good against interests involving the larger social good, support for those interests believed to benefit the latter good will likely override concerns regarding individual privacy (Regan, 1995, pp. 213). There is almost a paradox about our feelings in the personal and social costs of sabotage and the concomitant personal and social benefits of tight security. For the sake of my safety, I would like all others' e-mails monitored to eliminate any possibility that they will be able to damage society. At the same time, I would prefer that my e-mails not be monitored. My wish to maintain privacy for my personal e-mails is, however, unreasonable against the generalization of everyone's wish for their safety. "In isolation my desire for privacy is reasonable; it only becomes unreasonable in the contemporary social context" (McArthur, 2001, pp. 125). If the monitoring of e-mails would add security in a community or would raise that community's standard of living, then a decision to add monitoring would likely be perceived as yielding a greater overall good than would a decision to protect the privacy of individuals. Theorists working in sociological traditions have tended to interpret the emergence of computerized information technology as something that enables an evolution in social power relations that favors governmental and commercial organizations against the interests of individual citizens (Johnson, 1994; Gotlieb, 1995). And it includes elements of the threat of overly broad normative law that contains the possibility for misinterpretations. Human nature has also shown that security fears can be used to hurt a community with big brother style invasions of privacy used to support one social group over another.

There are two main solutions to deal with the legitimate rights of informational privacy. The more common is to use the regulatory powers of the state. This practice is predominant in the EU, which uses very strict directives concerning the privacy matter1. The other solution is the voluntary basis. That practice is very predominant in the U.S., where the greatest likelihood is that industry will be left to develop voluntary guidelines2, rather than Congress imposing regulations.

There was little legal protection for health information—online or off-line—until the release of HIPAA regulation in the U.S.3 But while HIPAA regulation is an important step, its application is limited. The regulation does not cover a significant portion of the health-related activities that take place online. The HIPAA analysis of Choy et al. (2001) shows that many who engage in online health activities will fall outside the scope of the regulation. "People often believe they are invisible and anonymous online, but they are often exposing their most sensitive health information to online healthcare sites that are not required by law to protect the information or keep it confidential. The potential for abuse is enormous" (Choy et al., 2001, pp. 25).

If we put conceptions of privacy together with distinction between normative and natural privacy, we get a situation-dependent issue of privacy: "An individual or group has normative privacy in a situation with regard to others if and only if in that situation the individual or group is normatively protected from intrusion, interference, and information access by others" (Culver, Moor, Duerfeldt, Kapp, & Sullivan, 1994, pp. 6). The general term "situation" is useful because it is broad enough to cover many kinds of informational privacy: private locations such as a medicine delivery record in a database; private relationships such as an electronic prescription to one's pharmacy, and private activities such as the utilization of computerized health information. Privacy situation covers also role, time, and place-dependant issues.

If an unauthorized entry is made into a normatively private situation, "privacy has not only been lost, it has been breached or invaded" (Moor, 1997, pp. 30). If a worker uses an online system for the delivery of a medicine and processes a customer's healthcare treatment using the older information of the medicine deliveries, then the worker is not invading the individual's privacy. She is allowed in this situation and working role to investigate the customer's medicine history. However, if that same worker were to "open" that same customer's case record after hours just to browse around, then the worker would be breaching the individual's privacy although the worker may gain no new information. The worker has legitimate access in the first situation but not the in the second.

Value of Privacy

The Internet technology has created a "universal" technology platform, and to justify the importance of privacy more exactly in the global setting we can continue by asking whether informational privacy has instrumental and intrinsic value. Instrumental values are those values that are good because they lead to something else which is good. Intrinsic values are values that are good in themselves (Moor, 1997).

Privacy has instrumental value, because privacy offers us protection against harm, but "to justify the high instrumental value of privacy we need to show that not only does privacy have instrumental value but that it leads to something very, very important" (Moor, 1997, pp. 28) One of the most well-known attempts to do this has been given by James Rachels. In a 1975 article, Rachels lists several cases where "information about a person might provide someone with a reason for mistreating him in some way" (Rachels, 1975, pp. 351). Rachels suggests that such cases are misleading when they are taken to indicate why privacy is important. Privacy is valuable because it enables us to form varied relationships with other people. Privacy also enables us to form intimate bonds with other people that might otherwise be difficult to form and maintain in public. In a society where individuals have no privacy, friendships, intimacy, and trust cannot develop (Fried, 1970). If we want such relationships, we must have privacy. However, the need to relate to others differently may not ground privacy securely "because not everyone may want to form varied relationships and those who do may not need privacy to do it" (Moor, 1997, pp. 28). This view is based on the principle that some people simply do not care how others perceive them.

Some arguments tie privacy more tightly to autonomy, because privacy is understood to be not just a means of autonomy but a part of the very meaning of this term. We don't seek privacy in order to get autonomy, but "autonomy is inconceivable without privacy." (Johnson, 1994, p. 89). Autonomy is not just one among many values (i.e., autonomy is fundamental to what it means to be human and to our value as human beings). Privacy is necessary for diversity of relationships, and privacy is an essential aspect of autonomy. Assuming that autonomy is intrinsically valuable and privacy is a necessary condition for autonomy we have the strong and attractive claim that privacy is a necessary condition for an intrinsic good. But, is it true that autonomy is inconceivable without informational privacy? Suppose an online pharmacy collects information about customer purchases into database. Normally, customers recognize the collection process when they fill medicine prescriptions online. Consider the situation in which the online pharmacy does not share the information with anyone else or take advantage of customer in any way whatsoever. Customers have complete autonomy, just no privacy (Moor, 1997, pp. 28). Thus, it follows that privacy is not an essential condition for autonomy on PCEH services. It is conceivable to have autonomy without privacy.

We can continue by asking whether privacy is a core value. Core values are set of values that are shared by most, if not all, humans and are familiar to all of us. They are shared and fundamental to human evaluation, for example, life and happiness are two of the most obvious. It is possible to test for a core value by asking whether it a value that is found in all human cultures. The core values provide standards with which to evaluate the rationality of our actions and policies. They give us reasons to prefer some courses of action over others. They provide a framework of values for judging the activities of others as well (Moor, 1997; Moor, 1998).

It seems that privacy is not a core value per se, because “the concept of privacy has a distinctly cultural aspect which goes beyond the core values. Some cultures may value privacy and some may not” (Moor, 1997, pp.29). Maybe privacy is not a core value per se, but it is deeply linked to the value of security. Gotlieb (1995, pp. 168) points out that “what must be secured in every civilized and free society is, of course, security of person.” Protection from strangers who may have goals antithetical to our own is sought, and all cultures need security of some kind because without protection species and cultures don’t survive and flourish. “As societies become larger, highly interactive, but less intimate, privacy becomes a natural expression of the need for security.” (Moor, 1997, pp. 29). In particular, a highly computerized culture where lots of personally identifiable information is manipulated, stored, and transferred, it is almost inevitable that privacy will emerge as an expression of the core value, security.

In summary, the justification of privacy is firm because privacy can be grounded instrumentally and intrinsically—instrumentally, in support of the core values, and intrinsically, as an expression of security and more. Because privacy is instrumental in support of the core values, it is instrumental for important matters. Moreover, because privacy is an expression of the core value of security, it is a critical, interlocking member of our systems of values in our increasingly electronic culture. If an online company collects a lot of personally identifiable information without consent (which does not harm its customer when it collects, stores, and manipulates), it nevertheless seems to be doing something wrong intrinsically. The subjects’ security is being violated by the company even if no other harm befalls the person. The seminal article of Warren and Brandeis (1890) initiated the view that privacy is a positive good, and that individuals have an interest in maintaining a political right to privacy. Privacy is also a necessary means of support in a networked electronic healthcare, and thus, privacy is well grounded for our consideration. People have a basic right to protection, which, from the viewpoint of the patient-centered e-health, includes privacy protection.

PRIVACY FRAMEWORK

Privacy seems to be something of very great importance and something vital to defend, but also a matter of individual preference and culturally relative. The attempt to find one general measure for global privacy policy fails—there are too many situation-dependant aspects to consider. Privacy matters are deeply situation-dependent issues and cannot be found by applying a predefined list without considering the situation widely. A privacy problem may arise in a specific situation, and it may occur as the result of an unpredictable incident. Privacy constantly includes a large number of evolving situations that are difficult to conceptualize clearly, and it is hard to find justified practices. Therefore, privacy involves more than rote application of existing norms.

This section presents existing privacy theories and consider how they apply to PCEH. Finally the privacy framework is presented. It acknowledges the voluntary nature of the way in which individuals have surrendered control over personal information in exchange for the benefits that information technology brings.

Privacy Theories

Two privacy theories, which relate to personal information, are the "control" and the "limitation" theories.

According to the control theory, one has privacy if and only if one has control over information about oneself. "Privacy is not simply an absence of information about us in the minds of others, rather it is the control we have over information about ourselves" (Fried, 1984, pp. 209). The control theory correctly recognizes the aspect of choice that an individual who has privacy enjoys in being able to grant, as well as to deny, individual access to information about oneself. Control theory has some weaknesses. No one is able to have complete control over every piece of information about oneself, although Michelfelder (2001, pp. 134) states that "because the richness of the lived world is not mirrored in the online world, there are fewer relevant privacy values to be concerned about." But still the control theory has that practical problem. It is highly desirable that we are able to control information about ourselves. However, in a highly networked society it is simply impossible. We are not able to control vast amounts of electronic information about ourselves. Personally identifiable information is well greased and slides rapidly through networks around the world, around the clock.

The needed amendment to the control theory is a situation dependence, which limits the matters to consider. A theory offering assistance in this area is called the limitation theory by Tavani (1999b). The limitation theory recognizes the importance of setting up zones of privacy. Privacy consists of the condition of having access to information about oneself limited or restricted in a certain situation. One important weakness of the limitation theory is that "it tends to underestimate the role of control or choice that is also required in one's having privacy" (Tavani, 1999b, pp. 267). Some variations of the limitation theory suggest that a person's privacy correlates with the extent to which information about a person is limited. Therefore privacy according to the limitation theory would seem to be very closely related to secrecy. It seems, however, that in some cases, the word "private" is virtually synonymous with the word "secret"; or "confidential." Thompson (2001, pp. 15) points out that when we say "They want to keep some aspect of their life private in order to avoid embarrassment," or "Medical records should be kept private," we can substitute the word "confidential" for "private" without altering the meaning of the statement.

Limitation theory has many good features, but the theory ignores the fact that someone who has privacy can choose to grant, as well as to limit or deny, others access to information about oneself, thus it needs some amendments to be adequate for online practices for PCEH. Control theory has that missing feature, but because it does not include the condition of having access to information about oneself limited or restricted in certain situations, its perspective is too wide and open-ended to be practical.

Moor (1997) presents a theory, the control and restricted access theory, that covers both the preceding weaknesses. The main thesis of the theory is in order to protect ourselves we need to make sure the right people and only the right people have access to relevant information at the right time. Basically it has the advantages of the control theory for giving individuals as much control (informed consent) over personal data as realistically possible. But it also incorporates the strength of the limitation theory in maintaining that privacy needs to be understood in terms of situations where access to individuals is limited or restricted. So it recognizes the importance of setting up zones of privacy. Finally it incorporates the strength of both theories in holding that individuals affected by a certain situation need to have some control or choice in determining whether that information will be kept private or not.

In our considerations, it is important that the customers can make the most convenient choices in terms of their own needs and values from a number of alternatives, because what one customer considers a privacy invasion may be a valued feature or service to another customer. Rather than regarding privacy as an all or nothing proposition, the control and restricted access theory acknowledges the situation in which information is authorized to flow to some people some of the time. Ideally, those who need to know have access and others do not.

The control and restricted access theory also helps explain some anomalies about private situations. So far we have discussed situations in which individuals possess damaging personally identifiable information they want to keep others from knowing. Moor (1997, pp. 31) points out that "situations can be private in other circumstances." Moor presents an example that occurs in a physician's waiting room where scores of customers are waiting for their appointments. A couple begins to argue loudly and eventually shouting to each other about a problem they are having. They go into excruciating detail about various events and catastrophes. Everyone can hear them and many customers feel uncomfortable as they sit there with nothing special going on. Finally, one customer, who thinks he can help, cannot stand it anymore. He asks whether they would like his advice. The couple in unison tells him, "No, it's a private matter."

As funny as couple's comment may be in that situation, it does make sense on several levels. It is not reasonable to claim that an invasion of privacy has occurred, since the couple was the original cause of the information's becoming public. But "in private situations the access to information can be blocked in both directions" (Moor, 1997, pp. 31). The couple did not want to allow information from the customer although they themselves had been rude in revealing details to everyone.

In our considerations, it is important that the access to information is possible to be blocked in both directions by the individual. Because the Internet is an effective tool for receiving and sharing information, e-health providers can use very large pools of data from multiple sources and suggest similar advice using e-mails and much more.

Privacy Principles

McArthur (2001, pp. 124) presents two useful principles that emerge from the preceding examples:

The Mischance Principle: We cannot reasonably expect to maintain privacy over that which another person could discover, overhear, or come to know without concerted effort on his/her part to obtain this information.

Arguing loudly in the waiting room would certainly fall into this category. The mischance principle works, as McArthur (2001, pp. 124) points out, "in a range of possible instances because it is relatively easy to figure out what precautions to take to maintain privacy against casual observation." And thus, "anything put by a person in the public domain could be viewed as public information" (Fulda, 1997, pp.28).

The Voluntary Principle: If I choose to decrease the relative amount of privacy for myself and information under my control by exposing it to view, I thereby decrease the reasonableness of any expectation that this privacy will be observed.

Decreasing the relative amount of privacy is accomplished by increasing the likelihood under the circumstances that the information will come to another's attention through mischance, and therefore our examples would certainly also fall into this category. McArthur (2001, pp. 125) points out that "one of the ways in which the voluntary principle is sometimes interpreted is that the failure to attempt to maintain privacy constitutes willingness for that information to become public." By arguing loudly in the place where people are gathered, the person is positively increasing the likelihood of that information becoming known. By arguing loudly in the room where no people are gathered, the person is negatively increasing the likelihood that the matter will become known. This principle is referred to as the negative voluntary principle. The extent to which expectations of privacy are reasonable takes into account the social norms governing the particular form of information may have as well as the context. Therefore, the interpretation of whether the person is positively or negatively increasing the likelihood of that information becoming known is not always easy to make.

As DeCew (1997, pp. 7) states, we should presume in favour of privacy and then develop ways that would "allow the individual to determine for themselves how and when that presumption should be overridden." Combined with the mischance and voluntary principles, application to PCEH of Moor's (1997, pp. 32) three principles, the Publicity Principle, the Justification of Exceptions Principle, and the Adjustment Principle enables us to do as DeCew states:

- *The Publicity Principle*: Rules and conditions governing private situations should be clear and known to the persons affected by them.
- *The Justification of Exceptions Principle:* A breach of a private situation is justified if and only if there is a great likelihood that the harm caused by the disclosure will be so much less than the harm prevented that an impartial person would permit breach in this and in morally similar situations.
- *The Adjustment Principle:* If special circumstances justify a change in the parameters of a private situation, then the alteration should become an explicit and public part of the rules and conditions governing the private situations.

The strength of Moor's principles is a very practical one because customers do not need to have absolute or unlimited control in order to have privacy on PCEH. The publicity principle suggests that we can plan to protect our privacy better if we know where the zones of privacy are and under what conditions and to whom information will be given. The publicity principle encourages informed consent and rational decision making, which are important factors for expanded growth of PCEH.

Once policies are established and known, circumstances sometimes arise which invite us to breach the privacy policy. Privacy policy breaches should be avoided as much as possible because they undermine confidence in the policy. However, exceptional circumstances sometimes occur in the cases related to special health issues, which are discussed later.

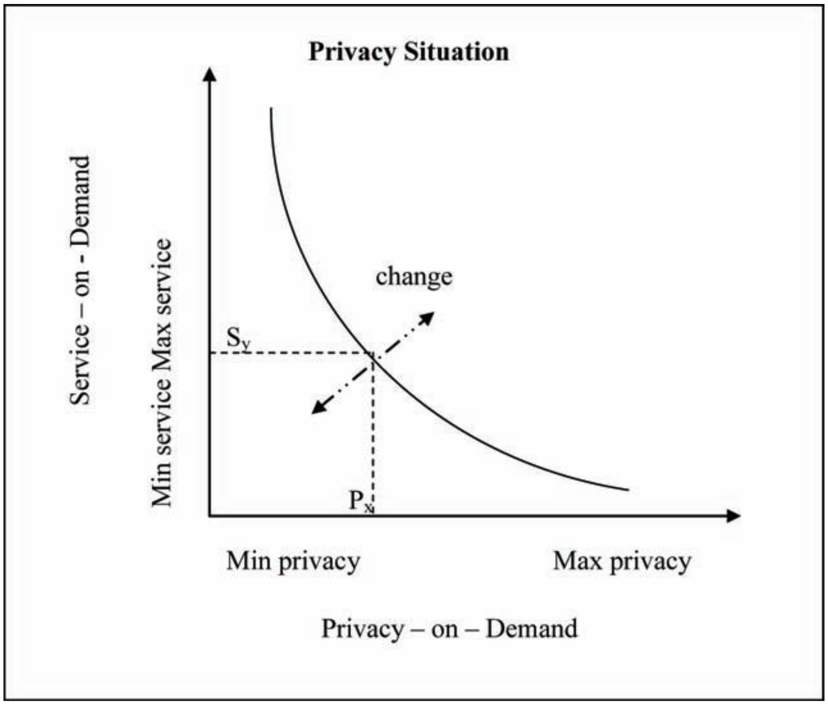
The adjustment principle normalizes the changed privacy situation. It is an important principle of PCEH where situation-dependant issues, possibilities of technological change and development of new services are pervasive.

Model of Privacy Management

The presented framework, including five principles and the control and restricted access theory, results in privacy responsibilities and advantages for both e-health customers and providers. The framework has the advantage that privacy and service functions can be fine tuned with consideration to the privacy situation.

The idea of the privacy management model of PCEH is presented in the Figure 1, where customer privacy (Privacy-on-Demand function

Figure 1. Privacy management model



P_x) is related to the service (Service-on-Demand function S_y). Employing an interactive dialog by demanding or consenting, customers are able to choose from "max service" to "min service" to be polarized into the concept of privacy (i.e., "min privacy" or "max privacy" and vice versa).

The model does not downplay the voluntary nature of the way in which customers of PCEH have surrendered control over personal information in exchange for the benefits that information technology brings. This model is consistent with exchange theory (Thibaut & Kelley, 1959). According to exchange theory, individuals form associations on the basis of trust, and try to avoid exchange relationships that are likely to bring more pain than pleasure. "Developmentally, a relationship among parties who have not had prior association is expected to emerge incrementally and to begin with small actions that initially require little reliance on trust" (Jarvenpaa, Tractinsky, & Vitale, 2000, pp. 46). If the actions are reciprocated, trust tends to spiral upward. If they are not reciprocated, trust spirals downward (Sitkin & Roth, 1993). One of the consequences of trust is that it reduces the individual's perception of risk associated with opportunistic behavior by the organization (Ganesan, 1994).

Web site interactive content can add considerable value for both the company and its customer. In the model, the customer has the opportunity to choose and "manipulate" online health service and privacy practices. Typically, more services means less privacy and more privacy means less service possibilities. The interactivity possibilities of Web applications have the means to customize privacy and service functions more exactly to the needs of PCEH customers, thus enabling them to choose privacy practices and make more informed decisions concerning to whom they entrust their personally identifiable information and what kind of service they prefer or don't prefer. Employing an interactive dialog by demanding or consenting, customers are able to change Privacy-on-Demand and Service-on-Demand functions. If the company changes privacy situations without consent or demand by the customer, it is leaning toward opportunism.

One important aspect of the model is that it proposes possibilities and advantages for both customers and companies. The model proposes flexibility for PCEH privacy policy, but also demanding rules and principles. The model normally illustrates the situation where a customer is able to give informed consent and to make rational decisions—a customer is able to opt-in to (or opt-out of) privacy and service levels (Järvinen, 2005).

Almost 90 percent of Internet users are in favor of "opt-in" privacy policies that require Internet companies to ask people for permission to use their personal information. Online applications should ask individuals for permission to use their personal information, which is the kind of system has been adopted by the EU. However, this view challenges the policy negotiated by the Federal Trade Commission and a consortium of Web advertisers, which gives users of U.S.-based Web sites the right to "opt out." An "opt-out" scheme would compel individuals to take steps to protect their privacy (Fox et al. 2000b, pp. 3).

Example of Privacy Management Model

Next the data mining of genetic information is discussed to illustrate the use of the privacy management model in practice.

Advances in data mining techniques for large databases are a technological trend that heightens ethical concerns, because they enable companies to find out a lot of detailed personal information about individuals. Data mining causes privacy concerns because individuals are often not aware of data mining practices in advance. Data for which they may have given their consent for collection and use in one context is being mined in ways they had not explicitly authorized.

Suppose a customer decides to get tested for a breast cancer gene. Breast cancer runs in her family, and she wants to know whether she is genetically disposed to have breast cancer. She goes to the laboratory for tests for the gene and the results are positive. The laboratory results are stored in her electronic medical record so that the test results are available to medical researchers and physicians to encourage aggressive testing for the disease in the future. Because the information will be computerized, it means that many health providers and researchers may have access to the information. For example, if the customer's health insurance company gets access to it, then it could mean problems to the "owner of the information." Information of this kind could be detrimental to the individual when obtaining life insurance or future health insurance. Eventually, if the medical information slides through enough networks and information systems, it could be detrimental to the individual's relatives when obtaining insurance and applying for employment, even though they have shown no signs of the disease and have never been tested (Moor, 1997).

The model suggests that Web application should set up a zone of privacy for customers (P_x) who only want predictive testing done (S_y) because there is, as Moor points out (1997, pp. 32):

> *a difference between predictive genetic testing in which the patient is tested for genetic information that may be indicative of future disease and diagnostic testing in which the patient is tested for genetic information that may confirm a diagnosis of an existing disease.*

The health provider should establish a private situation for predictive testing so that the customer's analyst results were not incorporated into the regular medical file. If we think about privacy issues from the perspective of the privacy model, these medical records would be computerized but not accessible to all of those who have access to the general medical record. This practice (S_y) allows adjustment of the access conditions to increase the level of privacy (P_x) for the customer.

According to the framework, it is clear that customers should be told what will happen to the analysis information. The customers can choose their privacy situation better if they know where the zones of privacy are and under what conditions and to whom information will be given. Rules and conditions governing private situations should be clear and known to the persons affected by them, so customers are able to determine service and privacy levels accordingly. The customers might prefer ("opt-in") to have the analysis information included in their regular medical record.

The genetic test gives us also an example that describes the nature of the justification of exceptions principle. Suppose that after some predictive genetic tests are run, new information about the consequences of the analysis results is uncovered by means of the data mining process. The customer's old health information in combination with the analysis results show that the customer surely must have transmitted a devastating disease to her offspring, but that the disease can be treated effectively if caught in time. The physician's duty to keep the customer's secrets confidential is an important protection of privacy and the values related to it, but it is by no means absolute in medical law or ethics generally (Sommerville, 1999; Mason, McCall, & Smith, 1985).

> *In the context of genetic information, the most prominent reason for breaches of confidentiality is the harm inflicted on others by their ignorance [...] But the strength of arguments like this varies from case to case, depending on the specific nature of family relationships between the individuals involved (Häyry & Takala, 2001, pp. 408).*

In such circumstances, it would seem that the health provider should notify not only the customer but also her adult offspring even though that was not part of the original privacy policy. The breach is justified because the harm caused by the disclosure will be so much less than the harm prevented. Using the justification of exception principle, a health provider may determine the change of privacy policy without the threat of opportunism. The ethical significance of beneficial outcomes should be included in discussions of privacy. We should not, however, presume that beneficial outcomes can always be used to counterbalance harmful outcomes in any straightforward manner. It should be avoided to override customers' wishes as much as possible because they undermine confidence. Using anonymity or fake names (Fox et al., 2000b; Uslaner, 2000) in the health service process is not a convenient practice because it might be even a threat to sufficient health operations.

> *To shield themselves from what they consider harmful and intrusive uses of their health information, customers have engaged in privacy-protective behaviors, such as providing incomplete information, thereby putting themselves at risk from undiagnosed, untreated conditions. The lack of complete and accurate health information on patients impacts the community as well. Healthcare information used for important research and public health initiatives downstream becomes unreliable and incomplete (Choy et al., 2001, pp. 1).*

The adjustment principle in this example states that those who continued to have predictive genetic testing would know what information would be released in stated exceptional circumstances. They would know the possible consequences of their decision to have predictive genetic testing and could plan accordingly. According to the adjustment principle, the privacy policy should indicate the new service and privacy practice.

According to the model, it is important that the customerl is given the opportunity to decide what information is to be used and whether it may be used for new purposes after changes of practices. Normally privacy policies should provide assurance that previously gathered data won't be used in any new way before consent of the customer. If the customer does not accept the change, then the customer should be able to remove all data, update it, or freeze information usage at the level of the old service and privacy practice. Concerning the change of privacy and service functions customers should have possibility to choose as follows: (a) customers do not agree with the new practices at all and demand that their personal information be deleted; (b) customers want their personal information frozen at the previous state of practice; and (c) customers agree to the new practices.

When informed about the details of new practices, some customers would perhaps be inclined to choose Option A and elect not to participate in the company's processes at all in the future. Some customers elect to have their personal information used in older ways, because they are used to getting services based on that level, provided that they can be assured that information about them would not be used in new ways. Other customers might elect Option C and consent to their information being used in new ways, probably because of certain perceived new benefits they might receive.

The important point of the model is that through explicit and open notification and the opportunity to choose different alternatives, individuals could have a greater say or choice regarding how information about them is being used. The interactivity properties of Internet technology give us an efficient manner to deal with the proposed practice of the model (see Järvinen, 2005, pp. 139–147; 201–226).

FUTURE TRENDS

Today's Web-technology enables new means to provide services for knowledge-intensive industries such as insurance, banking and healthcare. A key characteristic of the Internet is that individuals are totally in control of which sites they visit and how long they stay and perceived risk negatively influences willingness to use Web-services. Therefore, trustworthy privacy and service management are obviously imperative sources of value creation and competitiveness. In the future, companies will compete to give individuals the services and the privacy they want. In that scenario, very strict normative privacy regulations according to the privacy framework mean that individuals may not receive satisfactory services. The industry in the U.S. has vowed to self-regulate, but privacy and service management of Web-based e-health services are underdeveloped in general. In that situation, from the perspective of privacy, confidentiality and trust, individuals need more comprehensible tools to gain control over Web-organizations' privacy and service practices. From the perspective of information and communication technology, service providers need more comprehensible methods for the design of Web-based privacy and service management.

It is relatively easy to set up a Web site, but far more difficult to create a Web-based business model. The medical establishment is beginning to recognize both the potential benefits and pitfalls of using electronic communications in healthcare (Fox & Fallows, 2003). As customer demands continue to increase and the availability of informational and interactive Web site content continues to proliferate, the bar for acceptable performance by health providers will continue to rise.

CONCLUSION

It seems that privacy is a broad and, in many ways, elusive concept. Privacy is a social, cultural, and legal concept, all three aspects of which vary from country to country. However, the justification of informational privacy is firm because privacy can be grounded instrumentally and intrinsically—instrumentally, in support of the core values, and intrinsically, as an expression of security and more. Thus, there is a presumption that privacy is a positive value that is worth protecting.

Concerns about informational privacy generally relate not to the collection of information itself, which many individuals would gladly give for appropriate use in a specific situation, but to the manner in which personal information is used and then disclosed. When a business collects information without the knowledge or consent of the individual to whom the information relates, or uses that information in ways that are not known to the individual, or discloses the information without the consent of the individual, information privacy is seriously threatened.

The situations that are normatively private can vary significantly from culture to culture, situation to situation, and time to time. This does not mean that the privacy standards are arbitrary or unjustified; they are just different. A safe retreat to a realm of pure facts, without any consideration of values is never possible, and that also includes privacy and service management of patient-centered e-health.

According to the privacy framework, the attempt to find one general measure for global privacy management fails—there are too many situation-dependant aspects to consider. In general, the amount of privacy individuals have, and can reasonably expect to have, is a function of the practices and laws of society and publicity and voluntary principles. Privacy matters of healthcare are deeply situation-dependent issues and cannot be found by applying a predefined list without considering the situation thoroughly. Information practices of e-health may conflict with individuals' desires to be shielded from unauthorized use of their personal information. The framework focuses on what we should be considering when developing privacy management for protecting our privacy in that situation. It does not neglect the important distinction between the different interests affected by PCEH. The strength of the framework is its ability to distinguish between the condition of privacy and the right to privacy and between a loss of privacy and a violation of privacy.

The privacy management model acknowledges the voluntary nature of the way in which individuals have surrendered control over personal information in exchange for the benefits that information technology brings. The interactivity features of the Internet provide health providers with many opportunities for online management so that the individuals can make the most convenient choices in terms of their own needs and values from a number of alternatives. What one customer considers a privacy invasion may be a valued feature or service to another customer. Interactive Web site content can provide considerable added value for both the health provider and its customer.

Because the applications of information technology are logically malleable, there are sufficient strategic reasons to suggest that privacy management as a concept and practice will survive, and that to ignore privacy issues might be fatal for the success of PCEH. If we naively regard the issues of privacy management as routine or, even worse, as unsolvable, then individuals are in the greatest danger of being harmed by information technology, or those services will not be used at all. If privacy is understood, not merely as a value involving the good of individuals, but as one that also contributes to the broader business and organizational good, then the concern for privacy might have a greater chance of receiving the kind of consideration it deserves.

ACKNOWLEDGMENT

The Foundation for Economic Education is acknowledged for their support. This support has been very important and it has enabled fluent progress of the privacy management project. Some anonymous reviewers of the manuscript have also contributed through constructive comments.

REFERENCES

Choy, A., Hudson, Z., Pritts, J., & Goldman, J. (2001). Exposed online: Why the new federal health privacy regulation doesn't offer much protection to Internet users. *Pew Internet & American Life Project*. Retrieved May 24, 2008, from http://www.pewInternet.org/pdfs/PIP_HPP_HealthPriv_report.pdf

Culver, C., Moor, J., Duerfeldt, W., Kapp, M., & Sullivan, M. (1994). Privacy. *Professional Ethics (Gainesville, Fla.)*, *3*(3-4), 3–25.

DeCew, J. W. (1997). *In pursuit privacy: Law, ethics, and the rise of technology.* Ithica, NY: Cornell University Press.

Federal Trade Commission. (1998). *Privacy online: A report to congress.* Federal Trade Commission. Retrieved May 24, 2008, from http//www.ftc.gov/reports/privacy3/

Federal Trade Commission. (2000). *Privacy online: Fair information practices in the electronic marketplace.* A report to congress. Federal Trade Commission. Retrieved May 24, 2008, from http://www.ftc.gov/reports/privacy2000/privacy2000.pdf

Federal Trade Commission (FTC). (1973). *The code of fair information practices.* U.S. Department of Health, Education and Welfare, Secretary's Advisory Committee on Automated Personal Data Systems, Records, Computers, and the Rights of Citizens, viii. Retrieved May 24, 2008, from http://www.epic.org/privacy/consumer

Fox, S., & Fallows, D. (2003). Internet health resources. *Pew Internet & American Life Project*. Retrieved May 24, 2008, from http://www.pewInternet.org/pdfs/PIP_Health_Report_July_2003.pdf

Fox, S., & Rainie, L. (2000a). The online healthcare revolution: How the Web helps Americans take better care of themselves. *Pew Internet & American Life Project*. Retrieved May 24, 2008, from http://www.pewInternet.org/reports/toc.asp?Report=26

Fox, S., Rainie, L., Horrigan, J., Lenhart, A., Spooner, T., & Carter, C. (2000b). Trust and privacy online: Why Americans want to rewrite the rules. *Pew Internet & American Life Project*. Retrieved May 24, 2008, from http://www.pewInternet.org/reports/toc.asp?Report=19

Fried, C. (1970). Privacy: A rational context. Chap. IX in anatomy of values. New York: Cambridge University Press. (Reprinted from *Computers, Ethics, and* Society, pp. 51-63, M.D. Ermann, M.B. Williams, & C. Gutierrez, Eds., 1990, New York: Oxford University Press.

Fried, C. (1984). Privacy. In F.D. Schoeman (Ed.), *Philosophical dimensions of privacy: An anthology* (pp. 203-222). New York: Cambridge University Press.

Fulda, J. (1997). From data to knowledge: Implications of data mining. *Computers & Society*, *27*(4), 28. doi:10.1145/270913.270928

Ganesan, S. (1994). Determinants of long-term orientation in buyer-seller relationships. *Journal of Marketing*, *58*(2), 1–19. doi:10.2307/1252265

Gotlieb, C. C. (1995). Privacy: A concept whose time has come and gone. In D. Lyon & E. Zureik (Eds.), *Surveillance, Computers and Privacy* (pp. 156-171). Minneapolis: University of Minnesota Press.

Häyry, M., & Takala, T. (2001). Genetic information, rights, and autonomy. *Theoretical Medicine*, *22*, 403–414. doi:10.1023/A:1013097617552

Jarvenpaa, S. L., Tractinsky, N., & Vitale, M. (2000). Consumer trust in an Internet store. *Information Technology and Management*, *1*, 45–71. doi:10.1023/A:1019104520776

Järvinen, O. P. (2005). *Privacy management of e-health. Content analysis of 39 U.S. health provid-*

ers' privacy policies. PhD Thesis. Turku School of Economics, Turku, Finland. Retrieved May 24, 2008, from http://www.tukkk.fi/tutkimus/Vaitokset/default.asp

Johnson, D. G. (1994). *Computer ethics (second edition).* Englewood Cliffs, NJ: Prentice Hall.

Mason, J. K. McCall, & Smith, R.A. (1999). *Law and medical ethics (fifth edition).* London, England: Butterworths.

Mayer, R. J., Davis, J. H., & Schoorman, F. D. (1995). An integrative model of organizational trust. *Academy of Management Review*, *20*, 709–734. doi:10.2307/258792

McArthur, R. L. (2001). Reasonable expectation of privacy. *Ethics and Information Technology*, *3*, 123–128. doi:10.1023/A:1011898010298

Michelfelder, D. P. (2001). The moral value of informational privacy in cyberspace. *Ethics and Information Technology*, *3*, 129–135. doi:10.1023/A:1011802227136

Moor, J. H. (1997). Towards a theory of privacy in the information age. *Computers & Society*, *27*(3), 27–32. doi:10.1145/270858.270866

Moor, J. H. (1998). Reason, relativity, and responsibility in computer ethics. *Computers & Society*, *28*(1), 14–21. doi:10.1145/277351.277355

Rachels, J. (1975). Why is privacy important? Philosophy and public affairs, *12*(4). (Reprinted from *Computers, Ethics, & Social Values*, pp. 351-357, D.G. Johnson & H. Nissenbaum, Eds., 1995, Englewood Cliffs, NJ: Prentice Hall.

Regan, P. (1995). *Legislating privacy: Technology, social values, and public policy.* Chapel Hill, NC: University of North Carolina Press.

Sitkin, S., & Roth, N. L. (1993). Explaining the limited effectiveness of legalistic remedies for trust/distrust. *Organization Science*, *4*(3), 367–392. doi:10.1287/orsc.4.3.367

Sommerville, A. (1999). English V. Genetic privacy: Orthodoxy or oxymoron? *Journal of Medical Ethics*, *25*, 144–150. doi:10.1136/jme.25.2.144

Tavani, H. T. (1999a). Informational privacy, data mining, and the Internet. *Ethics and Information Technology*, *1*, 137–145. doi:10.1023/A:1010063528863

Tavani, H. T. (1999b). KDD, Data mining, and the challenge for normative privacy. *Ethics and Information Technology*, *1*, 265–273. doi:10.1023/A:1010051717305

Thibaut, J. W., & Kelley, H. H. (1959). *The social psychology of groups*. New York: Wiley.

Thompson, P. B. (2001). Privacy, secrecy and security. *Ethics and Information Technology*, *3*, 13–19. doi:10.1023/A:1011423705643

Uslaner, E. M. (2000). *Trust, civic engagement, and the Internet.* European Consortium for Political Research. University of Grenoble, April 6-11. Retrieved May 24, 2008, from http://www.bsos.umd.edu/gvpt/uslaner/Internettrust.pdf

Warren, S., & Brandeis, L. D. (1890). The right to privacy. *Harvard Law Review*, *4*, 193–220. doi:10.2307/1321160

ENDNOTES

[1] See for example Council of Europe: Convention For the Protection of Individuals with Regard to Automatic Processing of Personal Data. Council of Europe, European Treaty Series No. 108. Signed January 28, 1981 entered in force October 1, 1985; DIRECTIVE 95/46/EC Of the European Parliament and of the Council of 24 October 1995 on the protection of individuals with regard to the processing of personal data and on the free movement of such data; DIRECTIVE 97/66/EC of the European Parliament and of the

Council of 15 December 1997 concerning the processing of personal data and the protection of privacy the telecommunications sector

[2] See for example the Fair Information Practices of The Federal Trade Commission (FTC, 1973; FTC, 1998; FTC, 2000), TRUSTe (http://www.truste.com), BBBOnLine (http://www.bbbonline.com), and HONcode (http://www.hon.ch).

[3] Health Insurance Portability and Accountability Act of 1996, 42 U.S.C.A. 1320d to d-8 (West Supp.1998). The Department of Health and Human Services finally issued administrative provisions for this bill in late December 2000. Available at: http://aspe.hhs.gov/admnsimp/index.htm or Federal Register, December 28, 2000, for the implementation details (which go into full effect in 2003).

This work was previously published in Patient-Centered E-Health, edited by E. Wilson, pp. 81-97, copyright 2009 by Medical Information Science Reference (an imprint of IGI Global).

Chapter 7.5

Healthcare Ethics in the Information Age

Keith Bauer
Marquette University, USA

ABSTRACT

This chapter reviews key debates about the meaning of telehealth and also considers how new and emerging systems in telehealth work to protect patient confidentiality, improve healthcare relationships, and diminish instances of compromised access and equity in the healthcare system. This chapter also looks at how these same telehealth systems could undermine those goals, making it important to assess the way in which these emerging technologies are implemented. Various technologies are examined to show how their implementation can ensure that their benefits outweigh their risks.

INTRODUCTION

The growing use of information and communication technology (ICT) is producing widespread changes in society. One area in particular that is quickly being transformed by ICT is the field of healthcare. This is evident in the relatively new field of telehealth, which utilizes the Internet, electronic patient records systems, hand-held computers, among other types of ICT. Telehealth has great potential to improve the quality and provision of healthcare services, but there are a number of subtle ethical issues that should be considered as society moves forward with its use. The aim of this chapter is, therefore, to provide an ethical assessment of telehealth. The specific questions this chapter addresses are as follows:

1. What are the distributive justice implications of telehealth? Will medically underserved populations gain greater access to healthcare services? If so, what sorts of tradeoffs, if any, between access and quality will be required?
2. What are the implications of telehealth for provider-patient relationships? For example, will an increase in the quantity of provider-patient interactions lead to a corresponding increase or reduction in the quality of those interactions?
3. What are the implications of telehealth for medical privacy and patient confidentiality?
4. What are the future trends in telehealth and how will they affect patient care and the healthcare system in general?

BACKGROUND

In order to understand what telehealth is, it is necessary to understand its history and its meanings. The literal meaning of the word *telehealth* is *health from a distance*. Combining the word *health* with the Greek prefix *tele*, which means end, far off, or distance, produces this definition. We see similar combinations in the words *telephone*, which literally means, *sound from a distance*, and *telegraph*, which literally means *writing from a distance*.

Various definitions of telehealth are currently in circulation within the healthcare community. One common view of telehealth makes it synonymous with two-way audio-video systems that allow for interactive consults between patients and healthcare professionals. However, other definitions are equally common and may include the use of ICTs (e.g., computers) that capture, store, manipulate, and display medical data but not include the use of interactive communications between patients and healthcare providers. Consequently, a fax machine used to transmit patient medical information or the telemonitoring of a cardiac patient would not count as telehealth under the first definition but would under the second definition (Denton, 1993; Preston, 1994).

Although no universally accepted definition of telehealth exists, there is agreement that any definition of it must include at least three elements: (1) the use of ICT, (2) geographic distance between the participants, and (3) health or medical uses. On the basis of these three characteristics, the Institute of Medicine (IOM) defines telehealth/telemedicine in the following manner:

> *Telemedicine [telehealth] is the use of telecommunications and information technologies to share and to maintain patient health information and to provide clinical care and health education to patients and professionals when distance separates the participants. (Field, 1996, p. 27)*

The IOM's definition can be made more specific, depending on whether (a) emphasis is given to a particular technology (e.g., video conferencing or Internet) (b) a distinction is made between clinical and non-clinical applications, and (c) whether telehealth is conceived of as an integrated system of healthcare delivery rather than a mere collection of electronic tools.

Non-clinical applications of telehealth typically include professional education, healthcare administrative duties, management meetings, research, and the aggregation of health data, but usually exclude medical treatments and decisions for specific patients. Clinical applications of telehealth involve patient care and include medical decisions, diagnostics, and treatments for particular patients. This distinction, however, can be difficult to maintain because some ICT allow for the convergence of non-clinical and clinical activities, for example, when e-mail communications between patients and providers are automatically stored in a computerized record system.

In addition, there are a number of ways in which clinical telehealth can be subdivided. One way is to classify clinical applications by the point of service or the patient's location, for example, rural, correctional, and home. Another classificatory scheme common to clinical telehealth is to organize services by specialization, for example, telepsychiatry and telepathology (Peredina & Allen, 1995; Peredina & Brown, 1995). A third approach is simply to categorize telehealth services in terms of present and future healthcare reimbursement policies, for example, emergency care, follow-up care, consultation, and the transmission of diagnostic images (Grigsby & Kaehny, 1993).

The IOM's tripartite definition of telehealth--geography, ICT, and medicine—can be expanded upon when it is conceived as a system of healthcare rather than as the use of a particular ICT in a healthcare setting. According to one view, a *telehealth or telemedicine system* can be defined as follows:

> *A telemedicine system is an integrated, typically regional, health care network offering comprehensive health service to a defined population through the use of telecommunications and computer technology. (Bashshur & Sanders, 1997, p. 9)*

When telehealth is defined as a system of healthcare, the distributive and integrative strengths of ICT to form a seamless healthcare network are highlighted. This definition, because it highlights the systemic nature of telehealth, also helps to illuminate many of its social and ethical aspects not readily visible in other definitions.

KEY ETHICAL ISSUES

Most evaluations of telehealth have not centered on its ethical dimensions. In what follows, I explore three key ethical concerns surrounding the growth of telehealth. I begin with an examination of the potential distributive justice ramifications of telehealth.

Distributive Justice

Much of the debate over healthcare justice in the United States remains focused on the lack of access to healthcare services and inadequate health insurance coverage. The reason for this is that there are approximately 42 million persons who lack health insurance coverage (Schroeder, 2001). At this time, there are about 700,000 physicians practicing in the United States, which means there are approximately 275 physicians for every 100,000 persons. However, even with this doctor-to-patient ratio, many citizens still lack access to adequate healthcare services (Marwick, 2000). From a public health perspective, this is a serious problem. For, as numerous empirical studies have demonstrated, there is a strong correlation between positive health outcomes and access to healthcare services (Davis, 1991). But the problem is even more serious for health profession shortage areas, as they tend to have higher percentages of poverty, elderly people, people lacking health insurance coverage, and people with chronic diseases. From a distributive justice perspective, this means that one of the least fortunate and medically needy populations in the United States faces the greatest burdens in gaining access to healthcare services. As a way of ameliorating these healthcare disparities, telemedical initiatives are being devised to meet the healthcare needs of underserved populations. The good news is that telehealth services have the potential to produce a more equitable or fair distribution of healthcare resources. The bad news is that the Internet and other telecommunication technologies are not yet universally available, which in turn raises an entirely different but related set of distributive justice concerns about the digital divide—the equitable distribution of ICT.

However, before looking at the distributive justice pros and cons of telehealth, it will be useful to be more precise about what *distributive justice* in healthcare means. The general answer is that it pertains to questions about access and the fair allocation of healthcare benefits and burdens among populations. More specifically, distributive justice in healthcare requires the application of *fair standards* that make *quality* healthcare *available* and *accessibl*e to persons in an *efficient* manner (President's Commission, 1982). It is these five elements—fairness, quality, availability, accessibility, and efficiency—that are typically involved when distributive justice in healthcare is at stake. But what do these elements of distributive justice mean and how should we understand them in the context of telehealth?

A healthcare system is typically considered *fair* when (1) persons are not denied healthcare services on the basis of *prima facie* morally irrelevant criteria, such as class, race, and gender; and when (2) persons can secure an adequate level of care without excessive burdens (IOM, 2001). Because geography can create burdens for medically needy populations, geographic location, the place where one is born and lives, should not be used as a criterion for deciding who gets healthcare services. Rather, medical need should be the decisive factor.

Next, *quality* in the distribution of healthcare means not only that services are delivered with an eye towards avoiding errors, but should also be provided in a competent, compassionate, and respectful manner (IOM, 2001). The problem for many telehealth services at this time is that it is not fully known under what clinical conditions ICT should be employed and when, if at all, they should supplement or replace face-to-face interactions between patients and providers, for example, online psychiatry with severely depressed or suicidal patients. Consequently, standards of care and questions of whether telehealth improves or decreases the quality of healthcare have to be better understood.

The importance of *availability* and *accessibility* for distributive justice is that persons should receive services when they need it without *undue* burden. In some cases, services may be available within a geographical region but remain inaccessible because of inadequate transportation. The Internet along with advances in digital technology, for example, now make it possible to deliver some healthcare services to persons in underserved areas who would otherwise need to travel long distances. Telehealth technology, especially when located in the home, can make it easier to provide healthcare information and services over long distances and minimize the physical and financial burdens and lost time of patients who must travel long distances to meet with healthcare providers (Ostbye & Hurlen, 1997; Bauer, 2001).

Finally, *efficiency* is also an important variable in the distributive justice equation for telehealth. Because of limited healthcare resources and the high demand for them, the healthcare system should minimize inefficiencies such as duplicated services and errors to the greatest extent possible. For example, rather than replicating expensive services and technologies at different sites, a telehealth network could electronically link multiple sites to a centralized healthcare center where patients' records are stored.

Thus, efficiency, along with fairness, quality, accessibility, and availability, are the core elements of a general conception of distributive justice in healthcare and important to an ethical assessment of telehealth. If healthcare justice is to be a reality, no one of the aforementioned elements should be pursed to the exclusion of the other. A problem with this goal is that the five elements of distributive justice frequently come into conflict with each other. For example, improvements in the quality of some services may require placing limitations on the availability of other services because they lead to an unacceptable increase in the aggregate cost of healthcare and produce an unfair allocation of limited healthcare dollars. Also, ICT is likely to increase access to medical services, but the quality and confidentiality of those same services might not meet current standards of care established for traditional face-to-face medical encounters. Nevertheless, given the option of no healthcare services, telehealth, even if of lower quality, may be preferable.

As more healthcare information goes online and as more telemedical services are made available to the public, the digital divide (i.e., the unavailability or inaccessibility to ICT) should also be viewed as a healthcare justice problem. The digital divide is relevant because persons who lack access to information technology or the skills needed to operate the same technology may have greater burdens obtaining telemedical services compared to persons who have training and access to the Internet and computers (AMIA, 1997). Therefore, those who are the least well off and have the greatest medical needs—disabled elderly persons who live in health profession shortage areas—will have greater burdens in obtaining online health information and telehealth services that rely on the Internet. Until this gap in digital services is filled, telehealth services will remain limited for this medically needy population (Borberg, 1995).

But digital inclusion may not be the panacea that it appears to be for telehealth initiatives. If, as discussed above, digital inclusion becomes a reality in the near future for health profession shortage areas, there is the possibility that electronically mediated healthcare services will be of a lower quality compared to face-to-face healthcare services. If so, we will need to answer some important questions: When, if at all, should telehealth services either replace or supplement in-person services? What sorts of tradeoffs between access and quality are ethically acceptable and who gets to decide? Or, on the other hand, instead of pushing for digital inclusion and the establishment of telehealth systems, maybe a just healthcare system should require more effort and financial resources be devoted to enticing physicians and other healthcare professionals to practice in medically underserved regions.

Provider-Patient Relationships

Before looking at how telehealth is reshaping the provider-patient relationship, it is important to first identify the core goals and values that should be used to evaluate this relationship. For the purpose of this chapter, there are at least three major and overlapping healthcare goals and values that are central to an ethical evaluation of provider-patient relationships. These are (1) to achieve the best quality of patient care, (2) to balance the art of healthcare with the science of healthcare, and (3) to balance patient autonomy with professional autonomy (Hanson & Callahan, 1999; Kaplan, 2000). As will be discussed subsequently, various telehealth services may advance or retard any one of the three aforementioned healthcare goals and values.

First, *quality of patient care* refers to the ability of a new medical technology to improve patient care and health outcomes. Sometimes, however, acceptance of a new medical technology by providers has more to do with their belief in it than whether it can be demonstrated to improve the quality of patient care. For some, telehealth is a threat to the provider-patient relationship; to others, it is no threat at all. The reality is that until telehealth services have been adequately evaluated, we are left with competing speculations. Nevertheless, the belief that a new medical technology either harms or benefits the quality of patient care and the provider-patient relationship will play a large role in whether telehealth is accepted.

Second, *healthcare as both an art and science* has an extensive history and is closely connected to the quality of patient care. *The science of healthcare* refers to standardized clinical practice guidelines, automated procedures, scientific evidence, and the employment of medical technology. As is the case with science generally, the science of healthcare is always changing as new discoveries are made and better techniques emerge. *The art of healthcare* refers to the individual clinical judgements and intuitions of healthcare providers. The art of healthcare also refers to the emotional dimension of the provider-patient relationship. When the art of healthcare is practiced well, providers are able to genuinely feel and express empathy and compassion for their sick and vulnerable patients. Unlike the science of healthcare, the art of healthcare encompasses what is likely a universal and unchanging aspect of the human condition—the experience of being ill, being vulnerable, being dependent, and being healed. The art of healthcare requires a deep moral sensitivity to the experience of illness. Concerning this experience, Edmund Pellegrino states the following:

> *It [illness] is only in part defined medically as a concrete organic or psychological aberration. It is the perception of the change in existential states that forms the central experience of illness---the perception of impairment and the need to be made whole again---to be cured, healed, or cared for. (Pellegrino, 1981, p. 71).*

If Pellegrino is correct, then both the art and science of healthcare are desirable and necessary for the provision of technically sound and ethically appropriate healthcare services. Since Hippocrates' day, however, there have been tensions between the science and art of healthcare. According to Pellegrino and Thomasma, modern medicine is characterized by an imbalance in which technology and the science of healthcare dominate the provider-patient relationship:

> *The temptation to employ technology rather than to give oneself as a person in the process of healing is a "technological fix." The technological fix is much easier to conceptualize and to implement than the more difficult process of a truly human engagement. The training and the skills of modern health professionals overwhelmingly foster the use of technological fixes. (Pellegrino & Thomasma, 1993, p. 124).*

At this time, some applications of telehealth have proven to be easier and cheaper. Although the verdict is out on whether telehealth is simply an instance of modern man's proclivity for easy technical solutions to complex human problems, Pellegrino and Thomasma think, I believe correctly, that an overemphasis on technology and technical competence at the expense of compassion in medical education gives us good reasons to be concerned.

Autonomy is the final healthcare value basic to the acceptance of new medical technology and the provider-patient relationship. Modern healthcare, with its use of ICT, clinical practice guidelines, and research protocols, tends to give more weight to the science of healthcare and less weight to the expertise and judgments of individual providers. This is already the case in most healthcare settings where teams of providers, rather than individual providers, are more likely to care for a single patient. As such, the professional autonomy of individual providers is diluted because unilateral decision-making has given way to consensus building and shared decision-making. The rise of telehealth has intensified this trend. According to Douglas Walton:

> *The Hippocratic treatises are quite right to cite excellence of craftsmanship as a central ethic of competence for medical treatment. But in modern terms this competence must be understood to entail a sharing of scientific knowledge. Hence a corporate and institutional notion of technology as the coordination of a team effort is necessary. It is futile to try to go back altogether to the model of the caring family doctor as the bringer of treatment. (Walton, 1985, p.60).*

Moreover, as telehealth evolves, it is likely that patients will take on more responsibilities for administering and regulating their own healthcare, thereby, further limiting the role providers have in direct patient care. As more patients self care with the aid of telehealth technology, providers will not only work in teams, they will work in virtual teams that are geographically and temporally decentralized, lacking, in many instances, any face-to-face interactions with their patients and colleagues. Consequently, more effort at coordinating patient care will need to be made. This, in turn, is likely to increase the responsibilities and autonomy of patients, but place new restrictions on the professional autonomy of providers.

Changes in the provider-patient relationship are not new. A myriad of social, economic, and technological forces have continuously reshaped the provider-patient relationship since the dawn of medicine. Until relatively recently in medicine's history, the provider-patient relationship has been characterized by a substantial imbalance of power between patients and healthcare providers. Within the traditional provider-patient relationship, providers, especially doctors, have had more control and authority than their patients have. In simple terms, providers have had a dominant and active role while patients have had a subordinate and passive role in healthcare decision-making.

This unequal distribution of power is predominately a consequence of the medical expertise that providers have but patients lack but need in order to get well. Of course, imbalances in medical knowledge and power still exist within contemporary provider-patient relationships, but they are considerably less pronounced as they once were due to ICT.

For some theorists, the gradual realignment of power within the traditional paternal provider-patient relationship is, and continues to be, the result of *modernity*, which consists of convergent social, economic, and technological forces associated with the process of industrialization. Cockerham has the following to say:

> *Modernity promotes social relations that span the globe, moves social life away from traditional practices, and features the progressive use of knowledge to organize and transform society. In this context, medical science becomes increasingly accessible to laypersons. This situation, along with the desire of modern individuals to be in control of their lives, points towards a modification in the physician-patient [provider-patient] relationship in the direction of greater equality between the two parties. (Cockerham, 1993, p. 48).*

Cockerham does not explicitly mention telehealth, but the expanded use of ITC in healthcare can also be seen as an elaboration of modernism.

Telehealth, as a manifestation of modernism, raises a variety of ethical concerns. However, concerns about medical technology are not new. In fact, alarm over the increasing use of technology within patient-provider interactions also has a long history that includes the introduction of low-tech medical instruments such as the now commonly used stethoscope. When introduced, many physicians considered this device controversial because they believed it dehumanized the provider-patient relationship by putting physical distance between providers and patients. On this point, Evans has this to say:

> *Many chroniclers claim that high-tech medicine has evolved at the expense of the doctor-patient relationship, that machines have created a cold and impersonal chasm between the healer and the patient. In their minds the doctor has become a mere technician, a "body mechanic," who can treat disease but not the person. (Evans, 1993, p. 82).*

"High-tech" healthcare, however, does not have to be synonymous with an impersonal provider-patient relationship; it can also be associated with a personal and "high-touch" provider-patient relationship. This is possible because we need not accept, on the one hand, the view that medical technology is singularly responsible (i.e., technological fix) for the changes, good or bad, which have occurred within the provider-patient relationship. Nor need we accept that view, on the other hand, that the consequences of medical technology for the provider-patient relationship are tantamount to an endless stream of interpretations and rootless meanings. Rather, it is possible to adopt a middle course in which the meanings assigned to a new medical technology are as important as the technology itself in altering the provider-patient relationship. From this standpoint, technology, culture, institutional contexts, and the values and goals held by providers and patients all play a significant role in either the adoption or rejection of a new medical device. This was the case in the changed attitudes toward the stethoscope, which is now taken for granted as a basic and reliable medical tool. Thus, it would be premature to conclude that the high-tech of telehealth is inherently incompatible with a compassionate or high-touch provider-patient relationship (Turkle, 1984; Schement & Curtis, 1995).

Although modernism and the introduction of new medical technologies have had the overall effect of reducing the authority of providers, it has also given them greater power in the relationship in other respects. First, unlike the vast majority of their patients, providers understand how sophisticated medical tools function. Second, many medical devices have modified provider-patient interactions by facilitating the creation of an objective scientific nosology (i.e., classificatory scheme) that allows providers to diagnose a patient's disease independent of the patient's subjective reports. Third, because of an objective nosology and the relatively simple and universal manner in which medical devices are used, doctors are now able to delegate time-consuming activities to nurses and support staff, making doctors less directly involved in basic patient care. According to Evans:

> *With medical instruments, doctors [healthcare providers] could subject patients and their symptoms to objective scrutiny. As doctors gained more data from instruments, the quality of the information related by the patient seemed less important. Doctor and patient shared less knowledge; there was less common ground between them. A medical instrument acted as a lens through which the doctor could see the disease unfiltered by the patient's interpretations. Instruments thus altered the doctor-patient relationship, making the patient's experience of illness less important. (Evan, 1993, p. 90).*

Concerns about the impact of ICT on provider-patient relationships also have a long history. As early as the 1880s some physicians were lamenting the use of the telephone as a means of communicating with their patients. They were concerned that geographical distance and the lack of a hands-on approach with patients would undermine their ability to care for their patients. Before the telephone, the telegraph was subjected to similar criticism. Now, with the advent of modern-day telehealth the same worries have emerged. Like their ancestors, some contemporary healthcare providers and patients are apprehensive about the possible consequences ITC will have on the balance between the art and science of healthcare, professional autonomy, and the quality of patient care (Sanders & Bashsur, 1995; Wooton & Darkins, 1997).

First, some speculate that as telehealth services become more commonplace, providers will be less adept at understanding their patients' experiences of living with and dying from disease. One particular concern is that physical separation and electronically mediated communication may make the establishment of emotional connections between patients and healthcare providers more difficult. On the patient side, confidence, trust and dependence on providers may be diminished as patients increasingly obtain their medical information from websites, receive emotional support from on on-line support groups, and electronically communicate with their providers by means of e-mail and interactive video (Bero & Jadad, 1997; Eng & Gustafson, 1999). If this happens, there is concern that telehealth may deleteriously affect the quality of patient care. In support of these worries, a number of studies using randomized controlled trials have demonstrated that the quality of clinical communication is related to positive health outcomes. In other words, the more cumbersome and awkward provider-patient communication, the more likely patients will not get well (Kaplan & Greenfield, 1989).

Second, although some telehealth applications have the capacity to enhance patient autonomy and well-being, they also have the capacity to undermine patient autonomy and well-being especially when, for example, telemedical tools are limited to automated telemetry-capable medical devices and computerized patient records (Beasly & Graber, 1984; Howe, 2001). The reason for this is that providers will have little or no physical contact with their patients, interacting only with abstract patient data sets that have been transmitted through electronic networks and stored as computerized patient records. On this point, George Marckmann argues that under these conditions healthcare providers may (1) fail to include patients in decision-making about the patient's care and (2) inadvertently dehumanize their patients. He writes the following:

> *Without the physical presence of the patient there will be an increasing probability of unilateral decisions by physicians, thus conflicting with the ideal of a shared decision-making between physician and patient. (Marckmann, 1999, p. 60).*

And later:

> *If the personal consultation of specialists is replaced by teleconsultations, there will be an increasing risk that not the individual patient but just the digital data set-the gnostic analogue of the patient---becomes the object of diagnosis and treatment. Electronic patient records must be considered as a highly abstract, possible erroneous "artifact" which should not get a life of its own: not the data set but the patient needs treatment. (Marckmann, 1999, p. 60).*

If Marckmann is correct, then telehealth may modify the level of *interconnectedness* that exists between patients and providers and, thereby, detrimentally transform the provider-patient relationship. In brief, the concept of *interconnectedness* refers to the effects of ICT on social relationships. Interconnectedness at the individual level has particular relevance to provider-patient relationships that take place within telehealth:

> *At the micro level, individuals experience interconnectedness as a change in the nature of their social relationships. For most people, this means an increase in the number of relationships, but a decrease in their depth. That is, we are in regular-if not frequent contact with more people, but we don't know many of them very well. (Schement & Curtis, 1995, p. 47).*

Similar notions about the quality of social relationships are expressed in the *theory of social presence*. According to this theory, *social presence* is the feeling one has that other persons are involved in a communication exchange. The degree of social presence in an interaction is hypothesized to be determined by the communication medium: the fewer channels or codes available within a medium, the less attention that will be given by the user to the presence of other social participants. As social presence declines, messages become more impersonal and task oriented (Walther, 1995).

Assuming that the concept of interconnectedness and the theory of social presence are accurate, the primary goal of many electronically mediated relationships may turn out to be neither the person nor the relationship, but the information. Of course, the accurate and timely exchange of information between patients and providers has great benefits in the diagnosing and treatment of patients and in the cost-effective management of healthcare organizations. Moreover, easy access to health information and healthcare workers via telehealth technology may enhance the autonomy of patients, reduce their anxiety, and provide for an overall better quality of life for them. However, an effective and ethically appropriate provider-patient relationship will most likely require more than the efficient accumulation of patient data; it will also require a patient-centered relationship infused with empathetic communication and an awareness of the patient's existential state in the midst of illness.

Privacy and Confidentiality

Defining *privacy* and privacy-related concepts such as *confidentiality* is not a simple task, as there is no universally accepted definition, theory, or justification for privacy within the philosophical, legal, and public policy literature. Because of this lack of agreement on the scope of privacy, identification and analysis of important privacy issues within telehealth can be difficult, if not entirely overlooked. It what follows distinctions among physical privacy, informational privacy, and confidentiality will be made and their relevance to telehealth discussed.

Physical privacy generally refers to the restricted access that others have to our bodies, relationships, and living spaces. Physical privacy is ethically significant because it allows for intimacy, solitude, personal control, and peace of mind (Allen, 1995). Telehealth, especially when used in the homes of patients, is significant because it has the potential to reduce the number of unwanted in-person intrusions by healthcare workers. As teleconsultation and telemonitoring increasingly substitute for in-home visits, it may be possible for patients to gain more control over their homes, personal relationships, and daily schedules. On the other hand, these same patients may want to have more in-person visits than televisits, willingly sacrificing a measure of physical privacy for greater in-person social interaction. Whatever patients decide, the point is that telehealth services will give them options that don't widely exist today.

Informational privacy refers to the *confidentiality* and *security* of identifiable patient health information and clinical data found in patient records and in communications among healthcare professionals and patients (Allen, 1995). *Confidentiality* is the protection of private information, once it has been disclosed by a patient to a healthcare professional (e.g., during a medical examination or taking of a medical history). In short, confidentiality requires patients to give up their informational privacy. Once the patient discloses medical information, it becomes confidential and is no longer private. Although there are exceptions to the maintenance of confidentiality, providers are legally and ethically prohibited from sharing patient information with others who are not directly involved in the patient's care.

Telehealth's use of computerized patient records, electronic mail, medical websites, online support groups, and video conferencing tools create new threats and opportunities for the physical and informational privacy of patients. On one hand, patients can gain greater physical privacy, but, on the other hand, patients' informational privacy may be a greater risk, especially when the security of socially stigmatizing health information is breached by hacking or the accidental transmission of patient information to unintended recipients. In such scenarios, patients may not only lose their informational privacy, they also may be subject to social ostracism, job discrimination, loss of insurance, and social control in the form of blackmail (Shea, 1994).

Total informational and physical privacy is not realistic in telehealth and healthcare generally. First, other goods like medical research and public health require that limits be placed on the privacy of health information. Second, in order to treat and cure their patients, healthcare professionals must sometimes compromise the informational and physical privacy of their patients. Healthcare professionals must be able to touch their patients and obtain information about the intimate details of their patients' lifestyles and personal habits. Hence, patients must give up some informational and physical privacy to achieve the benefits of medical expertise. Depending on the site or point of care (e.g., hospitals, ambulatory clinics, and patients' homes), patients will have more or less informational and physical privacy.

Unfortunately, much of the telehealth literature on privacy simply fails to distinguish between informational and physical privacy. Furthermore, even when distinctions among physical and informational privacy are acknowledged in the telehealth literature, the focus is more often than not on informational privacy and the confidentiality of identifiable health information (Field, 1996). When these distinctions are not recognized, many of the privacy issues of telehealth that should be considered will be overlooked. For example, electronic mail and video conferencing can enhance the physical privacy of patients by reducing the number of in-person visits from healthcare professionals. Yet, these same patients may increase their risks to their informational privacy as their physiological data and electronic communications stream through standard phone lines and over wireless networks. In short, if the distinctions between physical and informational privacy are minimized, then ethically significant conflicts between these kinds of privacy and the need for possible compromises will be missed and remain unarticulated in policies, laws, and procedures affecting telehealth services.

FUTURE TRENDS

Before concluding, I want to discuss two future trends in the evolution of telehealth, which include the creation and use of smart homes and implantable biosensor technology.

Smart homes refer to the use of ITC to augment the range of services that homes and other buildings can provide for their occupants, for example, using computers to turn lights on and off without human assistance (Bauer, 2007). More advanced forms of ambient intelligence and ubiquitous computing technology can even monitor the time, frequency, and variety of a person's activities, including, for example, how often a person is waking up and walking, using the toilet, or opening his medicine cabinet to take medication. Moreover, software is presently being tested that analyzes the various activities detected by sensors embedded in patients' homes. This information is then used to assist either the inhabitants of the house directly or passed on to others, for example relatives and healthcare providers. The benefit of smart home technology is that it gives patients greater physical privacy and simultaneously allows providers to obtain real-time and comprehensive information about their patients' activities and living environments without being physical present, and to do so in a non-intrusive manner. Moreover, even though smart home technology is ubiquitous in most cases, it is invisible by being architecturally integrated into patients' homes.

One type of smart home technology gaining use with dementia patients is object recognition systems that track certain objects when they're put down. The system works by taking a picture of any object. Then, with cameras placed throughout the house, it goes and looks for the object. A patient uses the system by asking the computer where a specific object is located, for example, a pair of reading glasses, and the computer tells them where the requested object is located in the home. Another smart home technology being developed is the health detector. Like the recognition system above, this system is also made up of multiple cameras. These cameras, however, regularly take pictures of the patient's face and body and compare those pictures to others taken previously. The aim of the health detector is to identify any changes in physical appearance that may indicate a decline in function or, for example, the presence of skin cancer or the loss of weight. As this system is part of a larger telehealth network, the collected data can be simultaneously transmitted to the patient's healthcare providers to be analyzed (Coye, 2007).

Although in limited use at this time, *implantable biosensors* are now increasingly being used (Bauer, 2007; Viseu, 2003). Unlike smart home ICT, these sensors go one step farther by embedding ICT directly into the patient's body. In conjunction with smart homes, implantable biosensors are likely to facilitate independent living and continuum of care. Second, increased use of implantable biosensors is likely to make healthcare more proactive and preventative rather than reactive and episodic. These trends in telehealth are likely to help move healthcare delivery from institutional settings to non-institutional settings such as the home, giving patients more autonomy and a greater role in managing their own healthcare.

Two specific uses of implantable biosensors that are on the rise in telehealth are prosthetic and monitoring functions. First, neurotrophic brain implants are now being tested as mental prostheses to compensate for a loss of normal function in persons unable to speak, for example, because of stroke, spinal cord injuries, or ALS (McGee, 1999; Kennedy & Bakay, 1998). As recently as 2004, the Food and Drug Administration gave approval to begin systematic clinical trials to implant microchips in the brains of paralyzed patients (CNN.com, 2004). A neurotrophic brain implant works by implanting an electrode into the motor cortex of the patient's brain. Neurons in the brain then transmit electrical signals to the electrode, which, in turn, transmits the same signals to a receiver placed on the patient's scalp. These recorded signals are connected to a computer and are used as a substitute cursor or mouse. As patients learn to control the strength and pattern of electrical impulses being produced in their brain, they are able to direct the cursor to a specific point on the computer as they wish. In doing so, patients are able to communicate and can even send email.

Second, implantable biosensors are being used to monitor patients. For example, implantable cardiac biosensors that use wireless technology are being linked to sophisticated Internet-based monitoring networks that allow patients to transmit device and physiologic data to their providers without leaving their homes. Providers can remotely monitor the condition of their patients by logging into a secure website. Patients may also have access to the same website where they can obtain health-related information and personalized device data. In some locations, providers can access patient data by means of a handheld computer or personal digital assistant (PDA) (DeVille, 2003).

What makes smart homes as well as prosthetic and monitoring bioimplants revolutionary is that they have the potential to create a continuum of care that is seamless and more proactive. How will these future trends in telehealth achieve this goal? The general answer is that these technologies will better enable the integration of the patient's body with its immediate environment and the larger healthcare community. Since smart homes and implantable biosensors, like many other kinds of ICT, are interactive, they can help facilitate damaged or less than optimal person-environment interactions that are due to illness or environmental barriers (e.g., lack of transportation). The traditional view in medicine has been to view the purpose of technology as a way to fix persons, not environments. The problem with this view is that it construes persons as being distinct from their environments and overlooks the essential reality of person-environment interaction. As implants, smart homes, and other telehealth services become more commonplace in the provision of healthcare, this traditional view will and should dissipate.

Second, as smart homes and implantable biosensors more fully integrate patient bodies with their environments, patient care is likely to become mobile and migrate from institutional to non-institutional settings such as the home (Medical News, 2005). Home sensors in concert with implantable biosensors will likely exhibit a collective, synergistic intelligence that not only monitors, stores, and transmits biometric data to healthcare providers, but also allows patients to more easily regulate their home environments and to travel anywhere at anytime with the peace of mind that they are under continuous medical supervision. By giving patients more control over their environments and lifestyles, implantable biosensors and smart homes have the capacity to enhance the autonomy and well being of patients.

Third, much of the healthcare system today can be characterized as reactive and episodic, rather than proactive and preventative. As such, it is expensive and does a poor job of detecting medical conditions and preventing and responding to medical emergencies. Consequently, the present model of healthcare is less likely to maximize both the quality of patient care and patient health outcomes. In conjunction with external ICT, how might smart homes and implantable biosensors help us transition from a reactive to a preventative healthcare system? In answering this question, take, for example, the cardiac biosensors discussed earlier. These biosensors, which allow for the continuous real-time monitoring and transmission of a patient's cardiac functions, can be coupled with desktop telehealth units and the Internet, which, in turn, can automatically alert an emergency call center in case of a cardiac event.

Unlike a reactive and episodic approach that responds after a cardiac event is in progress, an automated telehealth system that incorporates implants and smart home technology is preventative because it can detect and report a cardiac event even before the patient knows what is happening. In doing so, not only are opportunities to prevent serious patient harms or death increased, the costs of treating and managing cardiac patients is likely to decrease. In concrete terms, a proactive healthcare system that can prevent emergencies is a healthcare system that is more likely to be more efficient and lead to better health outcomes for patients.

CONCLUSION

Telehealth has its risks, but this author believes that the overall impact of telehealth is likely to be positive for patients and healthcare providers alike. In closing, this chapter has explored how telehealth is substantially transforming our healthcare system, arguing that three key ethical issues should be examined as telehealth services are implemented: 1) distributive justice, 2) provider-patient relationships, and 3) privacy. This chapter also identified two overlapping and developing trends in telehealth—smart homes and implantable biosensors—that are likely to improve the continuum of patient care, facilitate independent living, and make the healthcare systems less reactive and more proactive in the future.

REFERENCES

Allen, A. (1995). Privacy in healthcare. *Encyclopedia of Bioethics* (pp. 2064-2073). New York, NY: Simon & Schuster Macmillan.

AMIA. (1997). A proposal to improve quality, increase efficiency, and expand access in the U.S. healthcare system. *Journal of the American Medical Informatics Association*, *4*, 340–341.

Bashshur, R., & Sanders, J. (Eds.). (1997). *Telemedicine: Theory and practice*. Springfield, IL: Charles C. Thomas Publisher, LTD.

Bauer, K. (2001). Home-based telemedicine: A survey of ethical issues. *Cambridge Quarterly of Healthcare Ethics*, *10*(2), 137–146. doi:10.1017/S0963180101002043

Bauer, K. (2007). Wired patients: Implantable microchips and biosensors in patient care. *Cambridge Quarterly of Healthcare Ethics*, *16*(3), 281–290. doi:10.1017/S0963180107070314

Beasly, A., & Graber, G. (1984). The range of autonomy: Informed consent in medicine. *Theoretical Medicine*, *5*, 31–41. doi:10.1007/BF00489244

Bero, L., & Jadad, A. (1997). How consumers and policy makers can use systematic reviews for decision making. *Annals of Internal Medicine*, *127*, 37–42.

Borberg, E. (1995). Development, acceptance, and use patterns of computer-based education and support systems for people living with AIDS/HIV infection. *Computers in Human Behavior*, *11*(2), 289–311. doi:10.1016/0747-5632(94)00037-I

CNN.com. (2004). *Brain implant devices approved for trials.* Retrieved July 2, 2007, from http://www.webmd.com/stroke/news/20040415/Brain-Implants

Cockerham, W. (1993). The changing pattern of physician-patient interaction. In M. Clair & R. Allman (Eds.), *Sociomedical perspectives on patient care* (pp. 47-57). Lexington, KY: University Press of Kentucky.

Coye, M. (2007) *Jogging into the sunset*. Retrieved July 2, 2007, from http://www.healthtechcenter.org/Common_site/news/docs/Molly_MostWired112906.pdf

Davis, K. (1991). Inequality and access to health care. *The Milbank Quarterly*, *69*(2), 253–273. doi:10.2307/3350204

Denton, I. (1993). Telemedicine: A new paradigm. *Healthcare Informatics*, *10*(11), 44–46, 48, 50.

DeVille, K. (2003). The ethical implications of handheld medical computers in medicine. *Ethics & Health Care*, *6*(1), 1–4.

Eng, T., & Gustafson, D. (1999). *Wired for health and well-being: The emergence of interactive health communication*. Washington, DC: Science Panel on Interactive Communication, U.S. Department of Health and Human Services.

Evans, H. (1993). High tech vs. high touch: The impact of technology on patient care. In M. Clair & R. Allman (Eds.), *Sociomedical perspectives on patient care* (pp. 82-95). Lexington, KY: University Press of Kentucky.

Field, M. (Ed.). (1996). *Telemedicine: A guide to assessing telecommunications in health care*. Washington, DC: National Academy Press.

Grigsby, J., & Kaehny, M. (1993). *Analysis of expansion of access through use of telemedicine and mobile health services.* Denver, CO: University of Colorado Health Science Center.

Hanson, M., & Callahan, D. (Eds.). (1999). The *goals of medicine: The forgotten issue in healthcare reform*. Washington, DC: Georgetown University Press.

Howe, E. (2001). Should ethics consultants use telemedicine? A comment on Pronovost and Williams. *The Journal of Clinical Ethics*, *12*(1), 73–79.

IOM. (2001). *Crossing the quality chasm: A new health system for the 21st century.* Washington, DC: National Academy Press.

Kaplan, B. (2000). Culture counts: How institutional values affect computer use. *M.D. Computing*, *17*(1), 23–26.

Kaplan, S., & Greenfield, S. (1989). Assessing the effects of physician-patient interactions on the outcomes of chronic disease. *Medical Care*, *27*, S100–S127.

Kennedy, P., & Bakay, R. (1998). Restoration of neural output from a paralyzed patient by direct brain connection. *Neuroreport*, *9*(8), 1707–1711. doi:10.1097/00001756-199806010-00007

Marckmann, G. (1999). Telemedicine and ethics. *Biomedical Ethics: Newsletter for the European Network for Biomedical Ethics*, *4*(2), 59–62.

Marwick, C. (2000). National health service corps faces reauthorization during risky time. *Journal of the American Medical Association*, *283*(20), 2641–2642. doi:10.1001/jama.283.20.2641

McGee, E. (1999). Implantable brain chips? Time for debate. *The Hastings Center Report*, *29*(1), 7–13. doi:10.2307/3528533

Medical News Today. (2005). Smart fabric to keep patients healthy. *Medical News Today.* Retrieved July 1, 2007, from http://www.medicalnewstoday.com/medicalnews.php?newsid=21338

Ostbye, T., & Hurlen, P. (1997). The electronic house call: Consequences of telemedicine consultation for physicians, patients, and society. *Archives of Family Medicine*, *6*(3), 266–271. doi:10.1001/archfami.6.3.266

Pellegrino, E. (1981). Being ill and being healed: Some reflections on the grounding of medical morality. *Bulletin of the New York Academy of Medicine*, *57*(1), 70–79.

Pellegrino, E., & Thomasma, D. (1993). *The virtues in medical practice*. New York: Oxford University Press.

Peredina, D., & Allen, A. (1995). Telemedicine technology and clinical applications. *Journal of the American Medical Association*, *273*(6), 483–488. doi:10.1001/jama.273.6.483

Peredina, D., & Brown, N. (1995). Teledermatology: One application of telemedicine. *Bulletin of the Medical Library Association*, *83*(1), 42–47.

President's commission for the study of ethical problems in medicine and biomedical and behavior research. (1982). *Making health care decisions: A report on the ethical and legal implications of informed consent in the patient-practitioner relationship*. Washington, DC: U.S. Government Printing Office.

Preston, J. (1994). *The telemedical handbook: Improving care with interactive video*. Austin TX: Telemedical Interactive Services, Inc.

Schement, J., & Curtis, T. (1995). *Tendencies and tensions of the information age: The production and distribution of information in the United States*. New Jersey: Transaction Publishers.

Schroeder, S. (2001). Prospects for expanding health insurance coverage. *The New England Journal of Medicine*, *344*(11), 847–852. doi:10.1056/NEJM200103153441113

Shea, S. (1994). Security versus access: Trade-offs are only part of the story. *Journal of the American Medical Informatics Association*, *1*(4), 314–315.

Turkle, S. (1984). *The second self: Computers and the human spirit*. New York: Simon & Schuster, Inc.

Viseu, A. (2003). Simulation and augmentation: Issues of wearable computers. *Ethics and Information Technology*, *5*, 17–26. doi:10.1023/A:1024928320234

Walther, J. (1995). Relational aspects of computer-mediated communication: Experimental observations over time. *Organization Science*, *6*(2), 186–203. doi:10.1287/orsc.6.2.186

Walton, D. (1985*). Physician-patient decision-making: A study in medical ethics*. Westport, Connecticut: Greenwood Press.

Wooton, R., & Darkins, A. (1997). Telemedicine and the doctor-patient relationship. *Journal of the Royal College of Physicians*, *31*(6), 598–599.

KEY TERMS

Art of Healthcare: Individual clinical judgements and intuitions of healthcare providers.

Confidentiality: The protection of private information, once it has been disclosed by a patient to a healthcare professional (e.g., during a medical examination or taking of a medical history). Confidentiality requires patients to give up their informational privacy.

Distributive Justice: A sub-field of ethics that deals with questions about access and the fair allocation of healthcare benefits and burdens among populations. More specifically, distributive justice in healthcare requires the application of *fair standards* that make *quality* healthcare *available* and *accessibl*e to persons in an *efficient* manner.

Ethics: The descriptive and prescriptive study of what is right, wrong, good, and bad, of what ought and out not be done.

Implantable Biosensors: Sensors that are directly embedding into the human body to monitor vital signs and to provide prosthetic functions, often in concert with smart home technology and larger telehealth networks.

Informational Privacy: Refers to the security of identifiable patient health information and clinical data found in patient records and in communications among healthcare professionals and patients.

Interconnectedness and Social Presence: The quality and feeling of communication exchange with other persons, with or without ITC.

Modernity: The social, economic, and technological forces that have shaped the contemporary provider-patient relationship.

Physical Privacy: Refers to the restricted access that others have to our bodies, relationships, and living spaces.

Science of Healthcare: Standardized clinical practice guidelines, automated procedures, scientific evidence, and the employment of medical technology.

Smart Homes: The use of ITC to augment the range of services that homes can provide for their occupants without human assistance, for example, monitoring the time, frequency, and variety of a person's activities, including how often a person is waking up and walking, using the toilet, or opening his medicine cabinet to take medication.

Telehealth/Telemedicine: The use of ICT to share and to maintain patient health information and to provide clinical care and health education to patients and professionals when distance separates the participants.

Technological Fix: The temptation to employ technology as a panacea rather than to give oneself as a person in the process of healing patients.

This work was previously published in Handbook of Research on Technoethics, edited by R. Luppicini and R. Adell, pp. 170-185, copyright 2009 by Information Science Reference (an imprint of IGI Global).

Chapter 7.6

Quality and Reliability Aspects in Telehealth Systems

Anastasia Kastania
Athens University of Economics and Business, Greece

Stelios Zimeras
University of the Aegean, Greece

ABSTRACT

In this chapter the authors investigate telehealth quality and reliability assurance. Various models and standards can be applied to assess software quality and reliability in telehealth platforms and there are also general principles for total quality management which can be adopted. There are also models to assess the quality of the system and the quality of care which are also presented. The approach based on user satisfaction, considers the expectation measurement as information which is not inextricably linked to quality. A different approach is the one based on expectations as well as on disconfirmation of user expectations. The underlying structural model is based on a modified SERVQUAL approach that consists of five dimensions (Tangibles, Reliability, Responsiveness, Assurance and Empathy) which have been consistently ranked by customers to be most important for service quality across all industries. The model can thus be used for evaluation of healthcare services and for planning improvements on services. All these aspects for telehealth systems design are discussed to formulate epistemic criteria for evaluation purposes.

INTRODUCTION

In this chapter the authors investigate measures and models for telehealth quality and reliability assurance. Telehealth is defined as “the exchange of health information and the provision of health care services through electronic information and communications technology, where participants are separated by geographic, time, social and cultural barriers” (Hebert, M., 2001). There are two basic components to quality: quality assurance and quality control (Whitney, C.W., Lind, B.K. and Wahl, P.W., 1998). The following quality evaluation issues should be considered in telehealth design and evaluation: system, software, care, patient satisfaction and management.

Very different measures are necessary for measuring the effectiveness of an information system.

Related to the information systems effectiveness the dimensions of information systems success have been defined (DeLone, W. H. and McLean E. R., 2002). Other researchers (Cameron, K.S. and Whetten, D.A., 1983) have proposed a useful framework for selecting appropriate measures for future information systems research focused on organizational performance. In the scientific literature it is also proposed (Seddon, P.B., Staples, S., Patnayakuni, R. and Bowtell, M., 1999) that the diversity of information systems effectiveness measures is to be encouraged. Guidelines for standardisation of quality assurance in clinical trials are also described (Knatterud, G.L., Rockhold, F.W., George, S.L., Barton, F.B., Davis, C.E., Fairweather, W.R., Honohan, T., Mowery, R. and O'Neil, R., 1998).

The transcedental aspect of product quality (Ward, W.A. and Venkataraman, B., 1999) is identified with the sense of perfection that each person has. Because of this subjectivity, the methods and the models for the improvement of quality are necessary. With regard to the user view, a product is of quality if it satisfies the user. From the product view quality depends from its acquired characteristics and can be appraised from the presence or absence of certain attributes/characteristics. The manufacturer view is focused to the fulfillment of the required specifications and determines quality as a function. The value based view determines the quality as the means that offer the required services in financially accessible and acceptable cost. Empiric methods are also described to model the factors of software quality (Thomas, W. and Cerino, D. A., 1995). These are separated in functional characteristics (reliability), in programming characteristics (development cost and duration) and in maintenance characteristics. The method they propose (Thomas, W. and Cerino, D. A., 1995) is set from qualitative indicators for the evaluation of quality from the first stages.

Quality of care is a fundamental issue worldwide. There are many different approaches to monitoring the quality of services provided by an individual telehealthcare system, but one of the most valuable is obtaining feedback and opinions from users of the services. One of the main methodological problems in modern literature deals with the interpretation and the comprehension of the role of "expectation" in systems. "Expectation" represents a complex and dynamic concept (Harvey, J., 1998), defined within the framework of two prevailing trends. The approach based on user satisfaction, considers the expectation measurement as information which is not directly linked to quality. With respect to this there are a variety of tools for assessing the quality of a service but one of the most popular is SERVQUAL, an instrument designed by Parasuraman, and colleagues (Parasuraman, A., Berry, L.L., Zeithaml, V.A., 1988). This consists of a set of five dimensions which have been consistently ranked by customers to be most important for service quality, regardless of service industry. According to the general definition, expectations relate to the user's "predictions" for the services, whereas, on the basis of the second, expectations refer to the user's evaluation regarding the level of the services the provider needs to offer. The user's expectations of the quality of the healthcare services provided derive from a combination of characteristics and factors (Lewis, B.R and Mitchell, V.W., 1990) (Liljander, V. and Strandvik, T., 1994) (Rose, R., Uli, J., Abdul, M. and Ng, K., 2004) which are summarized as follows: (i) previous experiences the user has gathered from the service. (ii) third party suggestions (physicians, relatives, friends and other involved parties). (iii) factors relating to communication (direct & indirect) between the user and the service. (iv) factors relating to the Public or non -Public status of services: (iv.a) personal needs within the framework of the user value system, demographic – social- economic characteristics of the users etc. (iv.b) users perceive the healthcare system mainly through the institutional role of competent public services and the local administration. Lastly, measurement of the levels of user expectations allows the investigation of causes for quality problems in the organization.

ISO and standards facilitate the development of a quality management system, which serves as a basis for continuous process improvement and ensures consistency in processes (Hysell, D., 1999).

Worldwide, systems to measure service quality have been developed which have subsequently been modified according to the particular case and adopted by major organizations. With reference to the nature and structure of the service provided, the public sector is conducting user-satisfaction measurement research in competitive environments in order to develop prior principal and support services with the aim of improving the relationship between the providers and the user. User satisfaction and/or service quality (SERVQUAL) constitute essential components of healthcare (Donabedian, A., 1988). Users determine the strategy for quality management in healthcare services (Hasin, M.A.A., Seeluangsawat, R., Shareef, M.A., 2001). Methodological issues concerning service quality measurements have been discussed in the international literature (Lin, B. and Kelly, E., 1995) for many years and have been the subject of topical studies throughout the world (Ovretveit, J., 2000). Significant efforts have been made to develop user satisfaction models (Grigoroudis, E. and Siskos, Y., 2002) (Athanasopoulos, A., Gounaris, Sp. and Stathakopoulos, Vl., 2001) as well as to assess user satisfaction in healthcare services (Angelopoulou, P., Kangis, P., Babis, G., 1998) (Merkouris, A., Yfantopoulos, J., Lanara, V., Lemonidou, C., 1999) (Moumtzoglou, A., Dafogianni, C., Karra, V., Michailidou, D., Lazarou, P. and Bartsocas, C., 2000). The fact is that "user satisfaction" and/or "service quality" are complex phenomena involving intricate operations such as the measurement of quality in healthcare services, currently under examination, their perceived "value", and the social image of the organization.

DEFINITION OF QUALITY IN HEALTHCARE

Satisfaction with service quality depends on a large number of dimensions - both tangible and intangible attributes of the product-service offer. It is necessary to explain the importance of adopting common semantics when developing health geo-information services that span administrative boundaries and carry geographical information for the evaluation of the healthcare sectors. With reference to the nature and structure of the service provided, the public sector is conducting user-satisfaction measurement research in competitive environments in order to develop prior principal and support services with the aim of improving the relationship between the provider and the user. The final objective lies in increasing the market share of the organization. This observation also refers to the close relation between quality management and the marketing policy. With regard to healthcare services, a range of actions within the framework of a "special Marketing" can be introduced, which apart from taking into account the user satisfaction measurement will also aim at meeting user expectations. Quality measurement objectives in the Public Sector differ from the ones in the Private Sector as illustrated by the following statements (Robinson, St., 1999) (Teas, R.K., 1993): (i) Questions regarding service pricing rarely arise, whereas data concerning the user's perceived "value" of the service provided are taken into consideration. (ii) Often questions asked refer to the Public dimension of the Healthcare System, which must function in keeping with the concept of public interest, safeguarding its basic principles such as equal treatment, protection and safety, totality as well as accessibility to health services. (iii) The "user expectations" parameter assumes major importance for user "acceptance" of the services provided and also for the final "value" (Parasuraman, A., Berry, L.L. and Zeithaml, V.A., 1991) attributed to the public system of healthcare services. The trilogy for quality management (Juran, J.M., 1988), is consisting of Quality Planning, Quality Control and Quality Improvement. Quality planning involves identification of customers and their needs, and development of products to satisfy customer needs, and processes to produce those product attributes. Quality control involves evaluation of the gap between actual and targeted quality performances and the actions to fill the gap. Quality improvement deals with development of infrastructure, identification of improvement goals, establishment of project teams and allocation of resources to implement quality improvement projects.

The approach based on user satisfaction, considers the expectation measurement as information which is not inextricably linked to quality. Satisfaction is a cognitive state *(it follows the implementation of the service)* and derives from service quality. Moreover, it offers additional information such as meeting the needs *(expressed and implied),* perceived performance, perceived value of services and assessment of the benefit deriving from services. Therefore, according to this approach, quality determines the level of user satisfaction following a comprehensive assessment of the service provided. Similar approaches are the "service performance" (SERVPERF) which defines quality as equal to the user's performance perception of the service (*Service Quality = perceived performance*) and the approach of Teas (Teas, R.K., 1993), which presents a weighted SERVPERF model: *Service Quality = perceived importance × perceived performance.* A different approach is the one based on expectations as well as on disconfirmation of user expectations. In this case, the established model is the SERVQUAL "Service Quality" model (Parasuraman, A., Zeithaml, V., Berry, L.L., 1985). Moreover, within this approach Service Quality (SQ) is measured by comparing Perceptions "P" with Expectations "E" and is defined as the difference between perceptions and expectations (SQ=P - E). Regardless of the numerous distinct views voiced within the framework of this specific approach, (Liljander, V. and Strandvik, T., 1997) it is agreed that the user perceives "high" quality when perceived performance exceeds his or her expectations. Another broadly known methodology relating to the expectation disconfirmation approach lies in the expectation disconfirmation model (Oliver, R.L., 1996). The expectation concept is gradually incorporated into scientific approaches to Total Quality Management (Perkins, W.St., 1993) (Donaldson, W.G., 1995).

SERVICE QUALITY IN HEALTHCARE

Service quality is relating to meets customers satisfaction needs, leading to the investigation of preserved service quality in order to understand customers. Preserved quality is the difference between customers' expectation and their perceptions of the actual service received. Customer satisfaction is an individual emotional response to the evaluation of an object (or a service) (Parasuraman, A., Zeithaml, V., Berry, L.L., 1985).

It is difficult to measure service quality due to fewer tangible cues available when customers purchase services (Parasuraman, A., Zeithaml, V., Berry, L.L., 1985), fewer search properties but higher in experience and credence properties (Parasuraman, A., Zeithaml, V., Berry, L.L., 1985), as compared to services. There are a number of different definitions as to what is meant by service quality. One that is commonly used defines service quality as the extent to which a service meets customers' needs or expectations. Service quality can thus be defined as the difference between customer expectations of service and perceived service. If expectations are greater than performance, then perceived quality is less than satisfactory and hence customer dissatisfaction occurs.

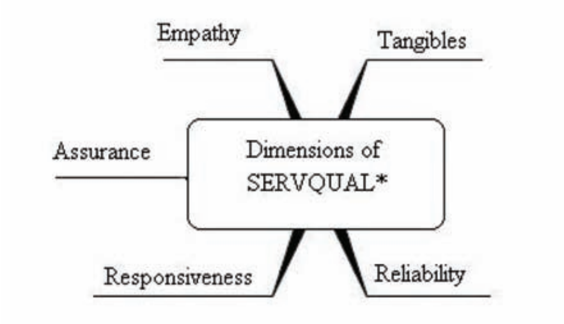
Although the SERVQUAL model has raised debates about dimensionality, the need to measure expectations, the reliability and validity of difference-score formulation, and the interpretation of expectations, it have been the predominant method used to measure consumers' perceptions of service quality. It represents a multiitem scale that can be used for measuring expectations and perceptions of service quality- as perceived among consumers. The SERVQUAL model, a 22-item scale has five generic dimensions or factors and is stated as follows: (1) Tangibles, (2) Reliability, (3) Responsiveness, (4) Assurance, (5) Empathy (Figure 1). When referring to surveys related to healthcare institutions the dimensions of service quality can be adjusted as follows:

1. **Reliability:** Ability to perform the service dependably and accurately
2. **Tangibles:** Appearance of physical facilities and provision of appropriate equipment
3. **Responsiveness**: Willingness to help customers
4. **Assurance:** The knowledge of employees and their ability to inspire trust and confidence.
5. **Empathy:** The caring individualized attention the firm provides to its customers.

It is important to note that without adequate information on both the quality of services expected and perceptions of services received then feedback from customer surveys can be highly misleading from both a policy and an operational perspective. To improve quality services to these customers we must first of all understand their needs. In order to understand their needs, we must in turn understand the quality attributes embraced by the customers. People perceive quality differently.

When analyzing the data gathered most of the surveys are based on the '**gap theory**', that is, the difference between clients' expectations about performance of a service and their assessment of the actual performance of service. For example 'gap theory' in healthcare context has been used to develop a number of questions in order to compare what customers 'look for' (expect) and what they 'experience' from doctors, equipments, healthcare services e.t.c.

Figure 1. SERVQUAL's five dimensions



It is important to note, that the SERVQUAL is designed to investigate the aforementioned gap; nevertheless it is important to recognize the existence of four other gaps:

- **The understanding gap:** The difference between what consumers expect of a service and what management perceives consumers to expect.
- **The design gap:** The difference between the management perceives and consumers expect and the quality specifications set for service delivery.
- **The delivery gap:** The difference between the quality specifications set for service delivery and the actual quality of that service delivery.
- **The communications gap:** The difference between the actual quality of service delivery and the quality of that service delivery as described in the 'firm's' external communications.

When gathering the data from the questionnaires, in the case study of the survey, there may be a 'mismatch' between customer's expectations and their perceived quality. The analysis of the gathered data may be descriptive as well as inferential. A researcher assessed the scale's reliability by calculating the *Cronbach alpha*; for analyzing the service quality, the mean and the standard deviation scores for each of the items were calculated for the perception level (P) and the expectation levels (E). The mean perception scores were compared to the mean expectation scores for the various customer requirements and the design characteristics, so as to identify the Gap scores (P-E=Gap). The underlying dimensionality was tested through an exploratory factor analysis conducted on each of the correlation matrices of the perception, expectation, and Gap scores. The QDF matrix was framed with rows representing 'customer requirements'-'what'- and the columns representing the 'design characteristics'-'how'. Customers were asked the level of importance they assigned to the different customer requirements. They were also asked to give their perception of the relationship between items of each row and the items of each column. Thereafter the *QDF* matrix was used, wherein the respondent was required to specify the relationship between the customer requirements and design characteristics. Finally, the quality function deployment technique along with correlation analysis was used to identify the minimum set of design elements (synonymous to the quality components) able to cover the customer requirements.

Current literature on SERVQUAL applications in healthcare services describes variations of the initial model according to the following: (Robledo, M.A., 2001)

- The first category of the SERVQUAL model variations deals with the definition of different dimensions and/or service characteristics in order to measure quality (Brady, M.K., Cronin, J.J., Brand, R.R., 2002) (Conway, T., Willcocks, St., 1997) (Hwang, Li-Jen J., Eves, A., Desombre, T., 2003). In this specific field, it is hard to be original and consequently, similar characteristics are presented in dissimilar forms.
- The second category of SERVQUAL refers to the introduction or the non-introduction of different weight in the dimensions and/or characteristics. This way, models with similar or different weights are produced. The Overall Service Quality (OSQ) is estimated by the main value of the five dimensions. The weights employed in SERVQUAL models arise either by introducing a third section of questions for the estimation of weight by the users themselves or by the personnel in the organization through preliminary empirical studies *(structured survey or interview)* or through a combination of the aforementioned.
- The last category of the SERVQUAL model variations relates to the measurement scales employed. The Likert measurement scales may be identical or distinct per measurement section (perceptions, expectations and/or importance). The choice of scale is made on the basis of the respondents' understanding, the required level of sensitivity and the impact on the internal reliability of the questionnaire. The latest approaches to service quality (Rose, R. Ch., Uli, J., Abdul, M., Ng, K.L., 2004) (Butler, T., Kendra, J., Grimley, R., Taylor, B., 1996) (Kandampully, J., 1997) (Sohail, M.S., 2003) (Zimeras S., Lambrinoudakis C., Fournaridis G., Fournaridis I, 2005) involve a uniform high sensitivity Likert scale.

In the SERVQUAL model gaps between user service perceptions and expectations are known as GAP 5. Gaps arise either when the service falls short of the user's expectations or when the service fails to meet the user's needs. Numerous surveys conducted in health services have provided information about GAP 5 (Butler, T., Kendra, J., Grimley, R., Taylor, B., 1996) (Kandampully, J., 1997) (Sohail, M.S., 2003). The *"Gap Zone"* is divided into positive (expectations exceed to a great extent user perceptions), intermediate (discrepancy observed between expectations and perceptions is not striking) and negative (expectations fall short of user perceptions). The extent of each of these zones allows the categorization of the GAP 5 SERVQUAL score gaps. The intermediate zone is of utmost importance because it relates to healthcare services that are generally considered tolerable (neither satisfying nor dissatisfying) by users and this is called Zone of Tolerance.

DATA ANALYSIS PROCEDURES

Some researchers, in order to test whether the initial conceptual framework was optimal, they use two types of factor analyses, namely exploratory factor analysis (EFA) and confirmatory factor analysis (CFA), followed by reliability analysis and qualitative analysis. Confirmatory factor analysis is first performed to evaluate the validity of the original SERVQUAL conceptual framework. Exploratory factor analysis is then performed for determining the number and structure of the dimensions that are underlying the data. Then the resulted dimensions from the exploratory factor analysis are then confirmed again by using the confirmatory factor analysis and reliability analysis. The derived dimensions and items are then compared with the findings of qualitative analysis for its validity and usefulness.

The use of statistical methodologies comprising multivariate analysis techniques (Mardia, K.V., Kent, J.I., Bibby, M., 1979) may elucidate the variables of overriding importance for the complex problems under investigation and depict correlations. Multivariate statistics provide the ability to analyze complex sets of data. Multivariate statistics are provided for analysis where there are many independent and possible dependent variables, which are correlated to each other to varying degrees. The method of principal components allows the replacement of the plethora of interrelated variables by groups of factors (hypothetical sections) exhibiting similar behavior to the major statistical variables. Principal components analysis (PCA) was applied to a single set of variables to discover which sets of variables form coherent subsets that are relatively independent of one another (Zimeras, S., Kostagiolas P. and Lambrinoudakis C., 2007).

Also cluster analysis could be considered in cases we investigate the effectiveness of the characteristics into spatial regions. Using this technique, we could justify which regions are important so we could direct our analysis to these areas. Cluster analysis is a technique used to classify objects into relatively homogeneous groups called clusters. Objects in each cluster tend to be similar to each other and dissimilar with objects in the other clusters (Malhotra N.K. and Birks H. 2003). A very useful graph in displaying clustering results is the dendrogram. The dendrogram is read from left to right. It shows where the clusters are joined together as well as the distance at which the clusters are jointed. It is very useful to decide the appropriate number of clusters.

In recent years, there has been an unprecedented demand for measures of quality in the healthcare industry. It is therefore crucial to develop effective tools for monitoring the quality of the medical services offered. Furthermore, in order to ensure the reliability of the results it is necessary to have a large number of patients, and in some cases medical personnel, participating in the evaluation process. With respect to healthcare, information services and the internet provides a unique platform that enables the creation of important information systems that can be accessed from anywhere and any time. The goal is to establish a consistent level of e-support to healthcare professional learners of Total Quality Management concepts, quality methods and tools.

Brainstorming, fishbone diagram, flowchart, run sheet, Pareto analysis, control chart and histogram are some of the tools that can help to zero in on quality problems. Quality function deployment helps to concentrate on customer needs while developing new services. For example *brainstorming* is a systematic approach to generate ideas from a group. A brainstorming group consists of individuals who can help to develop ideas relevant to a problem to be solved. Each individual suggests ideas (or directions) without regard to their validity. After all ideas are collected, they are critically reviewed. Brainstorming is a method to identify problems, develop ideas and improve creativity. Also *fishbone diagram* is a graphical approach to represent "cause and effect". The effect is desired outcome and causes are the spines. In practice most applications will have more branches where there will be a single outcome that we wish to improve or eliminate. A well drawn fishbone diagram can help to detect effects of quality quickly so that an alternative action can be taken. An alternative would be a tree diagram, which is much easier to follow. Finally a *control chart* essentially presents the expected range of variations in a stable process. A process is stable when all the data points fall within the prescribed control limits. Control chart is an excellent technique to monitor a process which is subject to variations. The control chart is a graphical representation of hypothesis testing. All these tools could be used for different purposes, considering the needs of the individual groups (doctors, technicians, administrative department, etc.) (Figure 2)

CONSIDERATIONS FOR THE STRATEGIC EVALUATION OF TELEHEALTH SYSTEMS

The following aspects should be studied, criticized and adopted or adapted (Figure 3).

The Hebert Quality of Care Framework In Telehealth Applications

The Hebert Quality of Care framework (Hebert, M., 2001) contains inquiring questions related with the Quality of Care. For patients, providers and organizations the structure, the process and the outcomes are studied.

With regard to the *structure*, the individuals that participate in studies for the evaluation of quality of Information Systems in Health usually are individuals that have the study problem and after they are informed on this, they accept or not to participate. During the selection of these individuals we want not to be connected as relatives, to belong in a wide age-related spectrum, be from different regions and suffer from the same illness. Each one of them can participate for various personal reasons. Nevertheless they exist probably also other reasons. Somebody with a chronic/serious disease needs intensive medical follow-up and probably the intervention of an expert. Persons that live in borders and inaccessible areas are those with the bigger need and who will profit more from the program. Usually these patients have minimal alternative solutions for provision of care. The health care providers are selected on the basis of criteria that are determined by each research framework. They should be the more suitable and most capable for the particular place. They participate in the studies in order to contribute in the growth of their company, for projection, research and mainly in order to provide the better possible services of health in the patients. Alternative solutions for the providers exist but usually they choose the most

Figure 2. Likert scale

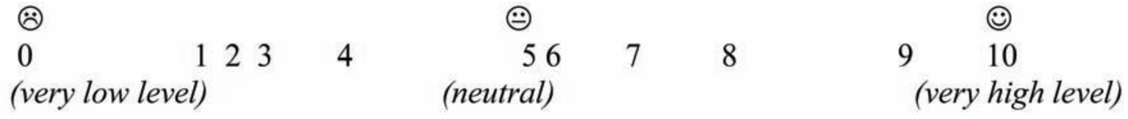
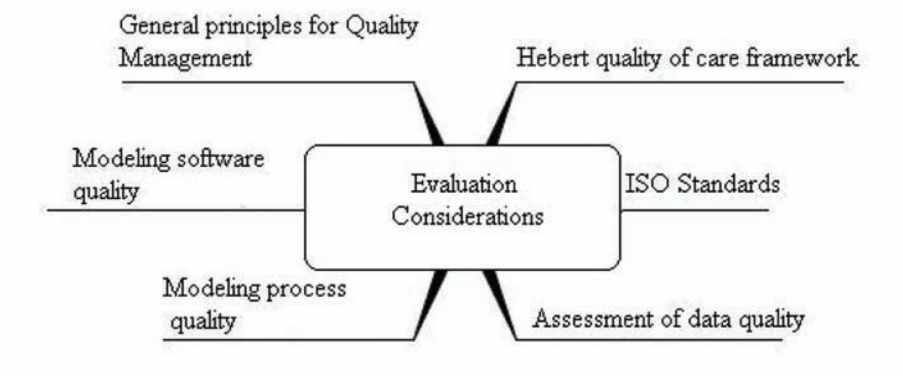


Figure 3. Telehealth evaluation aspects



lucrative for the interest of the company. Good provision of services ensures satisfied customers and consequently good quality. To provide services using a Health Information System their training is necessary. The organizations that use these technologies can be public or private health care providers. Various types of technology have been adopted. Computational systems, medical instruments, robotics, high performance computing and communications, videoconferencing contribute in the implementation of Telemedicine services.

With regard to the *process* the relation patient-doctor using telehealth is not anymore direct but indirect. The patient may not have personal contact with his doctor but he is provided the same medical care from distance. To achieve this a medical patient record should exist. Health care providers feel “comfortably” offering care with the use of electronic means, because they can offer more, time is saved from them and better service of patients exists. Nevertheless they are certain questions which influence the benefit of care with the use of telemedicine/telehealth technologies. Specialized personnel is needed and specialized patients to have knowledge of computers and be capable to handle the new technology. Via this technology the organizations want to achieve prevention, clinical care, even social support.

As far as the *outcomes* are concerned patient satisfaction is one of the desirable results. It becomes perceptible from the comments of patient on the program of care, but also from the perceptible improvement of his/her health. The outcomes that are important from the patient side are mainly the patient requirements satisfaction from the program. If the patient is satisfied and the program is characterized by ease of use then its success is ensured. The customer indications give useful information, empiric elements and indications for the needs, expectations and wishes, essential elements for the determination of objectives for customer satisfaction. From the health information systems and the interventions related to telehealth all patients can benefit from but mainly these with chronic diseases, these in some critical stage of health, and those that live far from health care centers. The organizations apply/adapt the technology depending on their needs and with that they want to use. The organizations change the initial way of technology use after certain comments from the patients, the providers or other colleagues in the organization. Success for a program is to achieve its initial aim, while at the same time increases its quality. The recording of these incidents becomes with many different ways. Usually via evaluation questionnaires or a Process Failure Mode Effects Analysis.

ISO Standards

According to the International Standards Organization, the ISO standards define the requirements for products of advanced technology, services, mechanisms, materials and systems, for evaluations of good conformity and for administrative and organizational applications. The most known existing models for quality certification are the Maturity Model in USA and the ISO standards that are recognized on International level (Saiedian, H. and McClanahan, L., 1995). A product to be imported in the European Union should be ISO-compatible. (Rada, R., 1996)

- **ISO 9000:** The International Standards Organization has developed a series of ISO standards for quality certification. Up to the 70's existed various models for the determination of quality. In November 1992, the countries of the European Union agreed to use ISO 9000 as the national model of quality (Dadoun, G., 1992)

ISO 9000 refers to quality management. This means that "an organization is supposed to satisfy the requirements of the customer for quality and the applicable regulating requirements, while at the same time it aims at continuous improvement of efforts".

ISO is divided in the parts 9001, 9002 and 9003. ISO 9001 refers in activities as planning, growth, production, installation and maintenance, ISO 9002 is applied in the production and installation and ISO 9003 covers the final control and trial (Dadoun, G., 1992). In the year 2000, the series 9001, 9002 and 9003 were included in ISO 9001:2000. This is the only standard in the ISO 9000 family that is certified by an external agency.

- ISO 9004: 2000: It extends the advantages of ISO 9001:2000 in all the interested teams (e.g. employees, employers, owners, providers and society). The 8 principles for quality management that are formulated in ISO 9000:2000 & ISO 9004:2000 are:
  - **Principle 1:** Focus in the customer
  - **Principle 2:** Leadership
  - **Principle 3:** Collaboration of individuals
  - **Principle 4:** Process based approach
  - **Principle 5:** Systemic approach in the Administration
  - **Principle 6:** Continuous improvement
  - **Principle 7:** Realistic approach in decision-making
  - **Principle 8:** Mutually beneficial relations of suppliers

These principles form the basis for requirements for ISO 9004:2000.

ISO 9000:2000 and ISO 9004:2000 have been designed as a single pair of standards, for easier use and flexibility. Starting from 9001:2000 a first level of performance can be reached. Applying then ISO 9004:2000 a more efficient system of quality management can be achieved.

ISO 9004-4 refers to the Administration of Quality and in the elements of Quality Systems. The 4th part provides governing directives for the Administration, so that Continuous Quality Improvement is applied in an organization.

- **ISO 15504 or SPICE:** Additional to ISO 9001. It offers confidence in the quality management of the suppliers and a framework that determines if the candidate suppliers are suitable. It also helps the evaluation process.
- **ISO 9126:** It is a extensive model for the sector of Medical Informatics. ISO 9126 provides a framework for the estimation of software quality. According to this the six characteristics of software quality are: Functionality, Reliability, Usability, Performance, Maintainability, and Portability.

- **ISO 15504 in comparison with ISO 9001:** ISO standards ensure the continuous improvement of quality; the user knows that he has to deal with regularly qualitatively products and services (Hysell, D., 1999). They provide better perception of quality, better recording of processes and control of operations. Due to the permanently increasing need for qualitative products and services, more companies record the processes, their tactics of operation and their organizational duties (Schuler, K., 1996).

The need for certifications of safety or interoperability helped in the growth of Information Technology Standards of safety (Ferris, J.M., 1994). These are developed under accreditations of the International Standards Organization and depending on the specifications that follow they can be characterized as international, national or even local.

ISO 9000 was developed for industrial operations (Averill, E., 1994). For software operations it was needed an extension that was given with the creation ISO 9000-3. ISO 9000 is important because (Rada, R., 1996) it provides directives with regard to the way that an enterprise will improve the quality and promotion of her products. The conformity of an organization with the ISO 9000 can be checked from the organization, or from the one in which are addressed the products or the services provided by this organization, or from a third independent organization that is specialized clearly in such certifications. For an organization to be certified, both its documentation and its human potential should follow the specifications of quality. Despite the fact that ISO 9000 began for constructional companies and organizations, it is also extended also in the health sector, where the certification of quality is very important. The certificates provided by certain third persons, are more prone in errors due to the involvement of the human factor (Ungureanu, V., 2001).

Assessment of Data Quality

A model has been proposed for data quality measurement from the user viewpoint. (Cappiello, C., Francalanci, C., Pernici, B., 2004). According to this, the users are separated in age-groups, where each age-group is constituted by users with common characteristics. The age-group of user selector determines which dimensions of data quality will be delivered with the information that the user has asked. The service sends the demand in the selector and depending on the characteristics of age-group of user, the department of evaluation sends in the end the data in the user with the results from quality evaluation. If the information is of low quality, that is to say if the requirements of user are not satisfied, an alert message is presented.

MedCritic system and the QUIL (Quality Indicator Language) are another way of quality evaluation (Advani, A., Shahar, Y., Musen, M. A., 2002). QUIL allows the determination quality indicators and the modeling of the medical directives so that the determination of quality from the side of patient is easier.

Another way of quality measurement from the user viewpoint is the protection of his/her personal data. A model exists (Kam, L.E. and Chismar, W.G., 2003) which combines the discretion in the collection of data from the patients, with the sensitivity of content and the qualitative feedback. A secure platform has been proposed (Taylor, K.L., O'Keefe, C.M., Colton, J., Baxter, R., Sparks, R., Srinivasan, U., Cameron, M.A., and Lefort, L. A., 2004), for personal data named Health Research Data Network (HRDN).

The collection of medical histories should have evident definitions of data, settled guidelines and specialized personnel for this purpose (Arts, D. G. T., de Keizer, N. and Scheffer, G. J., 2002). The guarantee of data quality depends from the prevention, the localization and the actions that will follow (Knatterud, G.L., Rockhold, F.W., George, S.L., Barton, F.B., Davis, C.E., Fairweather, W.R., Honohan, T., Mowery, R. and O'Neil, R., 1998)

.

Modelling Process Quality

A quality model for information technology systems has been proposed (Marchetti, C., Pernici, B., and Plebani, P.A., 2004) that separates evidently the planning of services, from the network and the devices. The quality as conceived by the user in such a system mainly depends from the quality of the media that are used for the provision of services (network, devices) and less from the quality the services it provides. The supplier of services and the user of services sign a contract agreement for the quality of services. This contract describes the offered quality level with regard to the quality of data, the safety and the availability. It is supported (Nejmeh, B. A., 1995) that the best methods of evaluation of progress of processes are: SEI (Software Engineering Institute) CMM (Capability Maturity Model), ISO9000, Tick-IT, SPICE (Software Process Improvement and Capability dEtermination) and the Malcolm Baldrige National Quality Award.

Modelling Software Quality

- McCall's Quality Model (McCall, J., Richards, P., and Walters, G., 1977): It describes the quality as relation between the factors, the criteria and metrics of quality (Ward, W.A. and Venkataraman, B., 1999).

Quality measurement is performed in the following steps:

1. Identification of all factors that can influence software quality
2. Recognition of criteria for each factor.
3. Definition of metrics for each criterion and determination of relation between metric and all the criteria that are reported in each factor
4. Assessment of metrics
5. Correlation of metrics with a line of directives that should follows each team of software development
6. Development of recommendations for metrics collection

ISO 9126 (see aforementioned description)

Dromey model (Dromey, R. G., 1995) is based on the following steps for the development of software quality models. In the first step, we define the attributes of high quality. Then we determine analytically the various parts of a product, and for each part we categorize the most important properties of quality. Afterwards we propose connections between the quality-carrying properties and the quality attributes. We repeat the aforementioned steps using a process of assessment and perfection.

General Principles for Quality Management

The fact that a lot of models exist for the improvement of quality can mean two things: either it is very difficult to model right the quality or it is impossible (Saturno P.J., 1999). The right collection, verification and interpretation of data is one of the most usual problems for the cost of data quality (Keogh W., Atkins M.H., Dalrymple J.F., 2000). Further research is needed in order to clarify the long-lasting dimensions of telemedicine and the derived results in the expenses of health (Roine, R., Ohinmaa, A., Hailey, D., 2001).

According to the Centre for Human services, any measure that improves the quality can be considered as Quality Assurance (QA). Usually it is constituted from a QA tool, a QA approach and a QA program. Teams from a variety of health care organizations have reported the successful usage of methods like team work, flow charts, data collection and graphic analysis of data (Plsek P.E., 1999).

Statistical Process Control (SPC) and various other examples of practical applications of control charts have been used in health care (Benneyan J.C., Lloyd R. C., Plsek P. E., 2003). Almost all these models have the same steps: "planning-monitoring –improvement".

To achieve quality at low cost is essential the adoption and use of methods as the Continuous Quality Improvement (CQI) or the Total Quality Management (TQM) (Shortell, S.M., Bennett, C. L., and Buck, G. R., 1998). CQI it is the continuous improvement of processes performed to offer a service that corresponds in the needs and expectations of customers.

There are quality concepts and criteria to record quality. The engineers and managers are responsible for the quality during the process of the construction of a product. Quality metrics check how much the product corresponds in the requirements of the customer. ISO and other standards have as basic condition the installation, maintenance and control of recorded remaining processes.

The challenge is in the planning of models that keep pace with good medical practice (Abston, C. K., Pryor, A.T., Haug, P.J., Anderson J.L., 1997). The implementation guidelines should include rules for when we begin and / or we avoid interventions in health care.

There are also data mining challenges (Kastania, A.N., 2004) in the design of telehealth platforms that should be taken into account during the telehealth quality and reliability evaluation process. Especially those related with intelligent decision systems participation in the evaluation process of telemedicine models for primary care (Kastania, A.N., 2004).

CONCLUSION

Herein, we have investigated aspects related to quality and reliability assurance in telehealth. We have defined quality and service quality in healthcare combined with data analysis strategies based on SERVQUAL as a tool for reliability assurance. Finally we have presented a set of considerations for the strategic evaluation of quality in telehealth systems.

REFERENCES

Abston, C. K., Pryor, A. T., Haug, P. J., & Anderson, J. L. (1997). Introducing practice guidelines from a hospital database. Presented at the *Proc/ AMIA Annu Fall Symp (1997)*, (pp. 168–172).

Advani, A., Shahar, Y., & Musen, M. A., Medical Quality Assessment by Scoring Adherence to Guideline Intentions (2002). *Journal of the American Medical Informatics Association*,*9*(6), S92-S97. doi:10.1197/jamia.M1236

Angelopoulou, P., Kangis, P., & Babis, G. (1998). Private and public medicine: A comparison of quality perceptions. *International Journal of Health Care Quality Assurance*, *11*(1), 14–20. doi:10.1108/09526869810199601

Arts, D. G. T., de Keizer, N., & Scheffer, G. J. (2002). Defining and improving data quality in medical registries: A literature review, case study, and generic framework. *Journal of the American Medical Informatics Association*, *9*(6), 600–611. doi:10.1197/jamia.M1087

Athanasopoulos, A., Gounaris, Sp., Stathakopoulos, V. (2001). Behavioural responses to customer satisfaction: An empirical Study. *European Journal of Marketing*, *35*(5/6), 687–707. doi:10.1108/03090560110388169

Averill, E. (1994). Reference models and standards. *StandardView*, *2*(2), 96–109. doi:10.1145/202949.202959

Benneyan, J. C., Lloyd, R. C., & Plsek, P. E. (2003). Statistical process control as a tool for research and healthcare improvement . *Quality & Safety in Health Care*, *12*, 458–464. doi:10.1136/qhc.12.6.458

Brady, M. K., Cronin, J. J., & Brand, R. R. (2002). Performance-only measurement of service quality: A replication and extension. *Journal of Business Research*, *55*, 17–31. doi:10.1016/S0148-2963(00)00171-5

Butler, T., Kendra, J., Grimley, R., & Taylor, B. (1996). Can we measure the effectiveness of our organizations. *International Journal of Health Care Quality Assurance*, *9*(5), 37–38. doi:10.1108/09526869610125028

Cameron, K. S., & Whetten, D. A. (1983). Some Conclusions about Organisational Effectiveness. In K.S. Cameron and D.A. Whetten, (Eds.). *Organisational Effectiveness: A Comparison of Multiple Models*. New York: Academic Press, (pp. 261-277).

Cappiello, C., Francalanci, C., & Pernici, B. (2004). Data quality assessment from the user's perspective, Information Quality in Informational Systems. In *Proceedings of the 2004 international workshop on Information quality in information systems*. Paris, France, (pp.68 – 73), ISBN:1-58113-902-0.

Conway, T., & Willcocks, S. (1997). The role of expectations in the perception of health care quality: developing a conceptual model. *International Journal of Health Care Quality Assurance*, *10*(3), 131–140. doi:10.1108/09526869710167058

Dadoun, G. (1992). ISO 9000 a requirement for doing business. IBM Centre for Advanced Studies Conference. In *Proceedings of the 1992 conference of the Centre for Advanced Studies on Collaborative research*. Toronto, Ontario, Canada, SESSION: Software engineering environment, vol.1, (pp. 433-437).

DeLone, W. H., & McLean, E. R. (2002). Information success revisited. *Presented at Hawaii International Conference on System Sciences*. Big Island, Hawaii.

Donabedian, A. (1988). Quality assessment and assurance: unity of purpose, diversity of means . *Inquiry*, *25*, 173–192.

Donaldson, W. G. (1995). Manufacturers need to show greater commitment to customer-service. *Industrial Marketing Management*, *24*, 421–430. doi:10.1016/0019-8501(95)00032-6

Dromey, R. G. (1995). A model for software product quality. *IEEE Transactions on Software Engineering*, *21*(2), 146–162. doi:10.1109/32.345830

Ferris, J. M. (1994). Using standards as a security policy tool. *StandardView*, *2*(2), 72–77. doi:10.1145/202949.202953

Grigoroudis, E., & Siskos, Y. (2002). Preference disaggregation for measuring and analysing customer satisfaction: The MUSA method . *European Journal of Operational Research*, *143*, 148–170. doi:10.1016/S0377-2217(01)00332-0

Harvey, J. (1998). Service Quality: A tutorial. *Journal of Operations Management*, *16*, 583–597. doi:10.1016/S0272-6963(97)00026-0

Hasin, M. A. A., Seeluangsawat, R., & Shareef, M. A. (2001). Statistical measures of customer satisfaction for hospital health-care quality assurance: a case study. *International Journal of Health Care Quality Assurance*, *14*(1), 6–14. doi:10.1108/09526860110366214

Hebert, M. (2001). Telehealth success: Evaluation framework development. *Presented at Medinfo*, *10*(Pt 2), 1145–1149.

Hwang, Li-Jen J., Eves, A., Desombre, T. (2003). Gap analysis of patient meal service perceptions. *International Journal of Health Care Quality Assurance*, *16*(3), 143–153. doi:10.1108/09526860310470874

Hysell, D. (1999). ISO 9001: Traditions before and after. ACM Special Interest Group for Design of Communication. *Presented at the proceedings of the 17th annual international conference on Computer Documentation*. New Orleans, Louisiana, United States, (pp. 99-104), ISBN: 1-58113-072-4.

Juran, J. M. (1988). Juran's Quality Control Handbook. In J.M. Juran, (Ed.) *Fourth edition*, New York: McGraw-Hill Book Company.

Kam, L. E., & Chismar, W. G. (2003), A self-disclosure model for personal health information. HICSS. In *Proceedings of the 36th Annual Hawaii International Conference on System Sciences (HICSS'03) - Track 6 - Volume 6*, (pp.161.2), ISBN: 0-7695-1874-5.

Kandampully, J. (1997). Firms should give loyalty before they can expect it from customers. *Managing Service Quality*, *7*(2), 92–94. doi:10.1108/09604529710161478

Kastania, A. N. (2004). Telemedicine models for primary care. In R. Latifi (Ed), *Establishing telemedicine in developing Countries: from inception to implementation*. Amsterdam: IOS Press.

Kastania, A. N. (2004). Data mining challenges in the design of Telemedicine platforms. In R. Latifi, (Ed.), *Establishing telemedicine in developing countries: from inception to implementation*. Amsterdam: IOS Press.

Keogh, W., Atkins, M. H., & Dalrymple, J. F. (2000). Data collection and the economics of quality: Identifying problems. In *Proceedings of the 4th International and 7th National Research Conference on Quality Management*. Sydney. Retrieved 24 December 2007 from http://mams.rmit.edu.au/kh85606qs2qn.pdf

Knatterud, G. L., Rockhold, F. W., George, S. L., Barton, F. B., Davis, C. E., & Fairweather, W. R. (1998). Guideliness for quality assurance in multicenter trials: A position paper. *Controlled Clinical Trials*, *19*, 477–493. doi:10.1016/S0197-2456(98)00033-6

Lewis, B. R., & Mitchell, V. W. (1990). Defining and measuring the quality of customer service. *Marketing Intelligence & Planning*, *8*, 11–17. doi:10.1108/EUM0000000001086

Liljander, V., & Strandvik, T. (1994). Estimating zones of tolerance in perceived service quality and perceived service value. *International Journal of Service Industry Management*, *2*, 6–28.

Liljander, V., & Strandvik, T. (1997). Emotions in service satisfaction. *International Journal of Service Industry Management*, *8*(2), 148–169. doi:10.1108/09564239710166272

Lin, B., & Kelly, E. (1995). Methodological issues in patient satisfaction surveys. *International Journal of Health Care Quality Assurance*, *8*(6), 32–37. doi:10.1108/09526869510098840

Malhotra, N. K., & Birks, H. (2003). *Marketing research, an applied approach*. Harlow: Prentice Hall.

Marchetti, C., Pernici, B., & Plebani, P. A. (2004). Quality model for multichannel adaptive information systems. In *Proceedings of the 13th international World Wide Web conference on Alternate track papers & posters*. New York, Quality of service, (pp.48 – 54). ISBN: 1-58113-912-8.

Mardia, K. V., Kent, J. I., & Bibby, M. (1979). *Multivariate analysis, 1st ed*. Academic Press.

McCall, J., Richards, P., & Walters, G. (1977), *Factors in software quality*. RADC-TR-77-369, US Department of Commerce.

Merkouris, A., Yfantopoulos, J., Lanara, V., & Lemonidou, C. (1999). Developing an instrument to measure patient satisfaction with nursing care in Greece. *Journal of Nursing Management*, *7*, 91–100. doi:10.1046/j.1365-2834.1999.00104.x

Moumtzoglou, A., Dafogianni, C., Karra, V., Michailidou, D., Lazarou, P., & Bartsocas, C. (2000). Development and application of a questionnaire for assessing parent satisfaction with care. *International Journal for Quality in Health Care*, *12*(4), 331–337. doi:10.1093/intqhc/12.4.331

Nejmeh, B. A. (1995). Process cost and value analysis. *Communications of the ACM*, *38*(6), 19–24. doi:10.1145/203241.203246

Oliver, R. L. (1996). *Satisfaction: A behavioral perspective on the consumer*. McGraw-Hill Education

Ovretveit, J. (2000). The economics of quality. *International Journal of Health Care Quality Assurance*, *13*(5), 200–207. doi:10.1108/09526860010372803

Parasuraman, A., Berry, L. L., & Zeithaml, V. A. (1988). SERVQUAL: A multiple-item scale for measuring customer perceptions of service quality. *Journal of Retailing*, *64*, 12–40.

Parasuraman, A., Berry, L. L., & Zeithaml, V. A. (1991). Understanding customer expectations of service. *Sloan Management Review*, 39–48.

Parasuraman, A., Zeithaml, V., & Berry, L. L. (1985). A conceptual model of service quality and its implications for future research. *Journal of Marketing*, *49*, 41–50. doi:10.2307/1251430

Plsek, P. E. (1999). Quality improvement methods in clinical medicine. *Pediatrics*, *103*(1), 203–214.

Rada, R. (1996). ISO 9000 reflects the best in standards. *Communications of the ACM*, *39*(3), 17–20. doi:10.1145/227234.227236

Robinson, St. (1999). Measuring service quality: current thinking and future requirements. *Marketing Intelligence & Planning*, *17*(1), 21–32. doi:10.1108/02634509910253777

Robledo, M. A. (2001). Measuring and managing service quality: Integrating customer expectations. *Managing Service Quality*, *11*(1), 22–31. doi:10.1108/09604520110379472

Roine, R., Ohinmaa, A., & Hailey, D. (2001). Assessing telemedicine: A systematic review of the literature. *Canadian Medical Association Journal*, *165*(6), 765–771.

Rose, R., Uli, J., Abdul, M., & Ng, K. (2004). Hospital service quality: a managerial challenge. *International Journal of Health Care Quality Assurance*, *17*, 146–159. doi:10.1108/09526860410532784

Saiedian, H., & McClanahan, L. (1995). A study of two frameworks for quality software process, presented at the Symposium on Applied Computing. In *Proceedings of the 1995 ACM symposium on Applied computing, Nashville*. Tennessee, United States, (pp.434-439). ISBN:0-89791-658-1.

Saturno, P. J. (1999). Quality in Health Care: models, labels and terminology. *International Journal for Quality in Health Care*, *11*(5), 373–374. doi:10.1093/intqhc/11.5.373

Schuler, K. (1996). Preparing for ISO 9000 registration: the role of the technical communicator, ACM Special Interest Group for Design of Communication. In *Proceedings of the 13th annual international conference on Systems documentation: emerging from chaos: Solutions for the growing complexity of our jobs*. Savannah, Georgia, United States, (pp.148-154). ISBN:0-89791-713-8.

Seddon, P. B., Staples, S., Patnayakuni, R., & Bowtell, M. (1999). Dimensions of information systems success. *Communications of the Association for Information Systems*, *2*(20).

Shortell, S. M., Bennett, C. L., & Buck, G. R. (1998). Assessing the impact of continuous quality improvement on clinical practice: What it will take to accelerate progress. *The Milbank Quarterly*, *76*(4), 593–624. doi:10.1111/1468-0009.00107

Sohail, M. S. (2003). Service quality in hospitals: More favourable than you might think. *Managing Service Quality*, *13*(9), 197–206. doi:10.1108/09604520310476463

St. Perkins, W. (1993). Measuring customer satisfaction. *Industrial Marketing Management*, *22*, 247–254. doi:10.1016/0019-8501(93)90012-V

Taylor, K. L., O'Keefe, C. M., Colton, J., Baxter, R., Sparks, R., Srinivasan, U., et al. (2004). Service oriented architecture for a health research data network. In *Proceedings of the 16th International Conference on Scientific and Statistical Database Management*, (pp.443- 444).

Teas, R. K. (1993). Expectations, performance evaluation and consumers' perceptions of quality. *Journal of Marketing*, *57*, 18–34. doi:10.2307/1252216

Thomas, W., & Cerino, D. A. (1995). Predicting software quality for reuse certification, presented at the Annual International Conference on Ada. In *Proceedings of the conference on TRI-Ada '95: Ada's role in global markets: solutions for a changing complex world*. Anaheim, California, United States, (pp.367-377). ISBN: 0-89791-705-7.

Ungureanu, V. (2001), A regulated approach to certificate management, ACSAC. In *Proceedings of the 17th Annual Computer Security Applications Conference*, (pp 377). ISBN: 0-7695-1405-7.

Ward, W. A., & Venkataraman, B. (1999). Some observations on Software Quality. In *Proceedings of the 37th annual Southeast regional conference.* (CD-ROM), Article No. 2. ISBN:1-58113-128-3.

Whitney, C. W., Lind, B. K., & Wahl, P. W. (1998). Quality Assurance and Quality Control in Longitudinal Studies. *Epidemiologic Reviews*, *20*(1), 71–80.

Zimeras, S., Kostagiolas, P., & Lambrinoudakis, C. (2007). Quality evaluation in healthcare based on the assessment of services expectation using a web-based questionnaire system and adaptive sampling techniques. *The Journal on Information Technology in Healthcare*, *5*(1), 50–58.

Zimeras, S., Lambrinoudakis, C., Fournaridis, G., & Fournaridis, I. (2005). An IT-based questionnaire system for the evaluation of healthcare services using electronic sampling techniques. *The Journal on Information Technology in Healthcare*, *3*, 239–247.

KEY TERMS

Telehealth Quality: The quality measurement of telehealth services should be based on product characteristics that contribute to user satisfaction and on product attributes that can be present or absent. In order to measure quality, the user view, the developer view, the product view and the value-based view should be considered.

Telehealth Reliability: Reliability is the probability that software will not cause the failure of the system for a specified time under specified conditions. For the reliability assessment, models exist that present graphically the number of failures of system operation in the time. When users think for software quality they usually mean the reliability on the basis of the existing reliability model: IEEE/

ANSI standard 982.2. The code should be reliable according to the deviating views of individuals that develop software, check software or are users of software. A developer-based view focuses on software faults; if the developer has grounds for believing that the system is relatively fault-free then the system is assumed to be reliable. On the other hand a user-based view emphasizes the functions of the system and how often they fail.

This work was previously published in Handbook of Research on Distributed Medical Informatics and E-Health, edited by A. Lazakidou and K. Siassiakos, pp. 425-442, copyright 2009 by Medical Information Science Reference (an imprint of IGI Global).

Chapter 7.7

Electronic Medical Records, HIPAA, and Patient Privacy

Jingquan Li
Texas A&M University-Kingsville, USA

Michael J. Shaw
University of Illinois at Urbana-Champaign, USA

ABSTRACT

The continued growth of healthcare information systems (HCIS) promises to improve quality of care, lower costs, and streamline the entire healthcare system. But the resulting dependence on electronic medical records (EMRs) has also kindled patient concern about who has access to sensitive medical records. Healthcare organizations are obliged to protect patient records under HIPAA. The purpose of this study is to develop a formal privacy policy to protect the privacy and security of EMRs. This article describes the impact of EMRs and HIPAA on patient privacy in healthcare. It proposes access control and audit log policies to safeguard patient privacy. To illustrate the best practices in the healthcare industry, this article presents the case of the University of Texas M. D. Anderson Cancer Center. The case demonstrates that it is critical for a healthcare organization to have a privacy policy.

INTRODUCTION

The strategic utilization of information systems/information technologies (IS/IT) has played a central role in enabling organizations across many industry segments to address many business challenges and achieve a level of sustainable competitive advantage (Croasdell, 2001; Hammond, 2001; Holt, Love, & Li, 2000). Healthcare is noted for embracing new scientific discoveries and using leading edge technologies to enable better cures for diseases and better means to enable early detection of most life threatening diseases. Ironically, the healthcare industry in the United States, which has a greater need for more accurate and timely information, has experienced less development of IS/IT than other industries such as banks or airlines. The Health Insurance Portability and Accountability Act (HIPAA) of 1996 is the largest governmental law in healthcare since Medicare. HIPAA mandates new federal standards for electronic transactions, such as payment processing, patient's medical information privacy, and security procedures that secure the privacy protections. Currently healthcare organizations are contending with relentless pressures not only to implement IS/IT technologies but also to become compliant with HIPAA.

The growing use of healthcare information systems (HCIS) has provided healthcare organizations with tremendous benefits, including significantly reduced costs, reduced harmful medical errors, and improved quality of care. But the resulting dependence on electronic medical records (EMRs) has also kindled patient concern about patient data privacy and security. EMRs often contain some of the most sensitive information about who and what we are, such as mental and physical illness. Perhaps more than any other type of data, the confidentiality of EMRs is absolutely essential. When doctors' file cabinets held the bulk of medical records, the employees working in those practices had access to them. As hospitals and clinics switch to electronic record keeping, however, many more people might have access to private medical records. Under HIPAA, new healthcare privacy provisions designed to protect data transmitted and stored electronically went into effect April 14, 2003. The requirements of HIPAA and compliance issues are getting the attention of top executives in the healthcare industry.

Having a formal privacy policy is a key step in implementing any HIPAA compliance program. It should expressly cover how a health organization is protecting EMRs; the rules and limits on who can access and use EMRs; and the capability to track who has disclosed sensitive data and the circumstances of disclosure. A positive, formal, and continually practiced privacy policy by all employees can establish rules and limits on who can access and disclose EMRs and thus minimize the possibilities of privacy breaches. On the other hand, a poorly defined and improperly implemented and managed privacy policy can make EMRs ripe for privacy abuse. The HIPAA privacy rule puts an emphasis on access control and audit trails to protect patient data. This study investigates the use of access control and audit log policies to safeguard patient privacy.

The objective of this study is to develop formal access control and audit policies to protect the privacy of EMRs. The development of HIPAA compliance program and security policies has been addressed by several studies (Kieke, 2003; Messmer, 2003; DeMuro & Grant, 2001; Li & Shaw, 2004; Patient privacy, 2001). There are also several papers addressing the issue of protection of EMRs (Ateniese & Medeiros, 2002; Swartz, 2004). The closely related works to this study include the following. Zunkel (2005) studied how to use biometric technology to protect personal information and found that biometric technology does not endanger personal information; it protects it. Borrowing the principles of reporting and auditing from the accounting sector, Stevens (2002) found that through comprehensive reports of network activity logs and regular auditing of security measures and devices, healthcare organizations can generate the proof of HIPAA compliance. While these studies are devoted to technical aspects and particular access control and audit log technologies, this study takes a management-oriented approach to develop access control and audit log policies to protect EMRs strategically.

The rest of the article is organized as follows. In the second section, we discuss the issue of patient privacy in healthcare. In the third section, we describe the HIPAA privacy rule and its privacy implications. In the fourth section, we investigate access control and audit log policies to protect patient privacy. To illustrate the impact of EMRs on patient privacy and the importance of having a privacy policy in the healthcare system, we present a case example of the University of Texas M. D. Anderson Cancer Center in the fifth section. We conclude with a summary in the final section.

Patient Privacy in Healthcare

Traditionally, our medical records were kept in paper documents in different doctor's offices. Cumbersome paper records not only contain too many errors and inefficiencies but also hinder communication between healthcare providers. According to the *Journal of the American Medical Association*, each year, as many as 98,000 patients die in U.S. hospitals from preventable medical errors, such as receiving the wrong medication. Nearly half of all patients do not get all the treatments or tests that they should have received. These problems persist because of industrywide failures connected to the lack of accurate and reliable health data.

As many hospitals and health systems begin to implement healthcare information systems, electronic medical records have become the primary means for storing health data, and electronic communications have been the preferred way of doing business. Storing and sharing patient health records electronically benefits both patients and doctors by speeding up access to patient information and ensuring that information is accurately and reliably available in the right place at the right time. HCIS enable doctors, nurses, and lab technicians to access medical records from a computer, instead of having to track down paper files. HCIS can also use networked computer databases to inform doctors about best practices for treating patients. With HCIS, for instance, a click of a mouse pulls up a patient's full medical record. The computerized system can alert doctors to everything from a patient's current medications to drug allergies. According to research firm Harris Interactive (Taylor & Leitman, 2001), the major causes of medical errors include multiple physicians treating the same patient without all having access to all the patient's medical records and with each storing different, incomplete medical records in different places. There is near consensus among healthcare industry experts that the widespread use of EMRs, accessible to all those seeing and treating a patient as well as to the patient, would substantially improve the coordination and quality of health care, in addition, electronic prescribing would further reduce errors that result from handwritten, hard to decipher prescriptions. Converting paper files into EMRs can significantly improve quality of care, reduce harmful medical errors, lower costs, and streamline the entire healthcare system. As a consequence, many healthcare organizations are now fully dependent upon their EMRs and HCIS.

The implementation of networked healthcare information systems has provided healthcare organizations with tremendous opportunities to improve quality of care. But the resulting dependence on EMRs and electronic communications also creates significant potential problems that can result in major harm to healthcare organizations. One of the problems will be the invasion of patient privacy. EMRs contain some of the most sensitive information about who and what we are, such as mental illness, sexual behaviors, HIV/AIDS, communicable diseases, cancer, and other stigmatized conditions. Perhaps more than any other type of data, it is important for healthcare organizations to keep medical records confidential and ensure that only personnel authorized to see the data get to view it.

When a patient's health records were kept in paper files in doctor's offices, these records were protected through the doctor–patient code of confidentiality, and third-party access to records was at the doctor's discretion. As hospitals and clinics switch to electronic record keeping, however, EMRs now can be transmitted with the click of a computer mouse. The Internet age, with free and easy exchange of data over open networks, exacerbates the situation. It is realized that the code of confidentiality is inadequate to protect the patient's interests because too many people will see your medical records. Through networked electronic medical records systems, doctors today interact with other health practitioners, diagnostic services, and hospitals, all of whom contribute to the medical records. Others who have access to patient data are: support staff, receptionists, clerks, administrators, transcriptionists, laboratory technicians, insurers, and healthcare providers. Once your medical records are exposed intentionally or accidentally, they will live forever on the Internet. But what happens to healthcare when the privacy of patient data is not protected and insurers and employers have access to an unprecedented amount of information? There will be (and there has been) potential for real harm to patients. For instance, some patients are likely to withhold health data from their physicians or reluctant to seek care if they do not trust that their personal data will be kept confidential. For that reason, implementing HCIS systems that protect patient privacy, yet are able to communicate needed information, is the key to whether healthcare information systems move forward or back. Furthermore, patient privacy and security concerns are driven by HIPAA.

HIPAA Privacy Rule

Healthcare organizations have long been under scrutiny when it comes to implementing patient privacy policies and procedures, but the Health Insurance Portability and Accountability Act of 1996, passed by the U.S. Congress and signed into law in 2000, has elevated its importance and placed comprehensive new privacy requirements on the U.S. healthcare industry. HIPAA calls for standardization of electronic patient health, administrative, and financial data, and unique health identifiers for individuals, employees, health plans, and healthcare providers. The greatest challenges among these standards for health organizations will be those regarding patient privacy (Li & Shaw, 2004). HIPAA mandates that healthcare organizations follow certain guidelines of privacy protection and that patients are given some specific control over how personal medical information is used and transmitted electronically. The U.S. Department of Health and Human Services (HHS) issued those patient-data privacy guidelines, as ordered under the HIPAA regulations. Subject to interpretation, the HIPAA privacy rule demands that any organization providing healthcare services—and any of its business associates handling protected patient data—apply "administrative, physical and technical safeguards" to ensure confidentiality.

HIPAA defines three main groups as "covered entities": healthcare providers, health plans, and healthcare clearinghouses (DeMuro & Grant, 2001). "Healthcare providers" refer to organizations that provide medical or health services and transmit any health data in electronic form. "Health plan" is defined broadly to include any individual or group plan that provides or pays the cost of medical care. HMOs, health insurers, and group health plans, including employee benefit plans, are considered to be health plans. "Healthcare clearinghouse" is defined as a public or private entity that processes or facilitates the processing of nonstandard data elements of health information into standard data elements. Billing companies are considered to be healthcare clearinghouses. Working closely with these groups are "business associates." Business associates are defined by HIPAA as persons who perform functions or activities involving the use or disclosure of protected health information (PHI) on behalf of "covered entities." This includes claims processing or administration, data analysis, utilization review, quality assurance, billing, benefit management, practice management, legal, actuarial, management, accreditation, or financial services.

Under the HIPAA privacy rule, healthcare organizations are obliged to protect patient records. A central feature of the HIPAA privacy rule is a set of limitations on the use and disclosure of protected health information. According to the regulation, PHI is individually identifiable health information that is a subset of health information, including demographic information collected from an individual, medical data related to the past, present, or future physical or mental health or condition of an individual, and financial information related to the past, present, or future payment for the provision of healthcare to an individual. Examples of PHI include personal information such as name, address, phone, social security number, credit card number, e-mail, identities of doctor and patient, and so forth. Since PHI includes the most sensitive information in medical records, the HIPAA regulation prohibits PHI from being released to third parties, or used by the healthcare industry, except as directly by the patient in signed consent or authorization forms.

The HIPAA privacy rule outlines severe penalties to individuals or organizations misusing patient information, intentionally or otherwise. Compliance is required by April 14, 2003; non-compliance will carry stiff civil and criminal penalties, including fines up to $25,000 for multiple violations of the same standard in a calendar year and fines up to $250,000 and/or imprisonment up to 10 years for knowing misuse. Because of HIPAA, healthcare organizations are now open to a range of potentially damaging consequences, including fines, liability claims, criminal charges, and even prison terms. Healthcare organizations should become knowledgeable about HIPAA and consider the requirements of HIPAA in their planning, management, and implementation efforts. A formal privacy policy must be in place to protect patient privacy.

The Importance of Privacy Policies and Procedures

Under HIPAA, healthcare organizations must not only ensure the privacy of PHI, but also ensure that business associates with which they do business maintain the privacy. Today as medical databases become networked in more complex healthcare information systems, healthcare organizations are facing a rising number of privacy attacks. In fact, many healthcare organizations are unprepared to safeguard the confidentiality of patient medical records as the healthcare industry prepares to move from archaic paper files to EMRs. Loss or compromise of sensitive EMRs can occur from hackers and identity thieves, or even from internal sources in the form of disgruntled employees or corrupt executives. It is fundamental for any healthcare organization to formulate a formal privacy policy because technical mechanisms must be accompanied by formal organizational policies for controlling the access to EMRs. Without privacy policies and procedures in place to protect EMRs, patients' right to privacy is at risk. This is the reason why it is so important to take the strategic, management-oriented approach starting with privacy management policies and procedures.

Privacy policies are the management directives that give guidance to personnel on how their organization will handle EMRs and patients' right to privacy. These policies identify classification of medical data based on their sensitivity. The policies include requirements to implement appropriate policies and procedures to prevent intentional and accidental disclosures of protected information; establish training programs for all employees of the covered entity who may have access to protected information; designate a privacy officer with primary responsibility for ensuring compliance with the regulations; establish a system for receiving and responding to complaints regarding the covered entity; and implement appropriate sanctions for violations of the privacy guidelines (DeMuro & Grant, 2001). Some weak and ignored policies include: (1) access controls are not being applied; (2) inadequate monitoring and auditing of information systems; and (3) lack of a security incident and disaster recovery plan (Schneier, 2000). The HIPAA privacy rule puts an emphasis on access control and audit logs policies to protect EMRs. This study investigates the importance of access control and audit log policies around patient privacy.

Access Control

If access is more limited and tightly controlled, EMRs are more privacy sensitive than paper files. Two most common access control approaches are credentialed data access and authentication. In the credentialed data access, access control policies should grant access to patient data on a need-to-know basis only, and they should be the driving force in the implementation of healthcare information systems. An organization should identify the persons or classes of persons, as appropriate, in its workforce who need access to the sensitive data to carry out its duties. For each such person or class of persons, the organization should identify the category(s) of potential sensitive data to which access is needed and any conditions appropriate to such access. The organization should make best efforts to limit the access of such persons or classes of persons identified above to the types and amount of sensitive data required to do their jobs. Access to confidential data is limited to persons with a legitimate "need to know" to perform their jobs within the organization. The credentialed data access thereby reduces the exposure of sensitive data within the organization.

Another approach is authentication. Authentication usually involves a user name and a password, but more companies are implementing multifactor authentication that includes other methods of demonstrating identity, such as access cards, hardware tokens, fingerprints, or voice recognition. The acceptable forms by which humans can authenticate themselves are something the person is which can be biometrically identified such as voice or retinal patterns, fingerprint, vein, iris, hand geometry, face, and signature; something the person has such as an access card or hardware token; and something the person knows such as a password or personal identification number.

Information systems managers have devised clever and complex password systems requiring frequent changes, rules for alphanumeric and symbolic characters, and prohibitions against repetition of character strings. Password management and allocation often becomes so complex that a user resorts to typing the password into a text file and leaving it on his or her electronic desktop, or worse, writing it in a post-it note and sticking it to the monitor. When IT managers also require a "what you have" factor—such as an access card that transmits the password to the terminal—it may end up in a desk drawer or hanging on a cord suspended from a push-pin, readily accessible to others.

The use of biometrics provides a means by which healthcare records can be kept confidential (Zunkel, 2005). Biometric technology provides a "who you are" solution to these issues, ensuring the person gaining access to data is, in fact, the person authorized. As with any credential-based access system, the biometric technology employed must be reliable, user friendly, and, most of all, manageable, and technology developers have pushed to meet those requirements.

Audit Logs

While many healthcare organizations have wisely deployed technical safeguards, such as firewalls and encryption technologies, to keep patients' data confidential, proving that those safeguards are successful is harder. Audit logs provide the capability to track all accesses to EMRs and audit tools that allow more frequent examination of audit logs to detect inappropriate accesses to EMRs. In the field of databases, database engine records every transaction in a transaction log to maintain database consistency and to aid in recovery. The log is a storage area that automatically tracks changes to a database. If the system fails, the automatic recovery process uses the transaction log to roll forward all committed transactions and roll back any incomplete transactions. The concept of transaction log in database systems can be extended to protection of EMRs in medical databases. Every time someone accesses the patient record, information systems have got to know what she or he has accessed, when it was accessed, and what they did.

Audit logs provide several benefits. First, through comprehensive reports of database activity logs, healthcare organizations can generate the proof of compliance that HIPAA demands. In the case of litigation, it is interesting to note that in general, courts have been lenient when dealing with organizations that have privacy policies and procedures in place, even if these policies are not perfect. They are generally less lenient with organizations that can demonstrate nothing in regards to managing patient privacy. In this sense, through comprehensive reports of database activity logs and regular auditing of established privacy policies and safeguards, healthcare organizations can generate the proof of HIPAA compliance, which is extremely important.

Second, audit logs help track criminals when a privacy breach occurs. For those companies that suffered privacy breaches, they found that it was difficult to figure out where the data was initially compromised and to find the trail back to where that the data was compromised. Therefore, it is very important for organizations to know exactly where the data lies and to be able to provide an auditable trail of their activities.

Finally, audit logs demonstrates a commitment to the highest level of legal and ethical conduct in the manner in which an organization gathers, stores, uses, and protects patient medical records. Knowing that the organization takes seriously its obligation to follow the HIPAA privacy rule makes patients and their loved ones feel safer that their personal details are not floating around in the public domain. Privacy management is a continuous process. The organization needs to continue to reassess and change its technical safeguards over time, as business environment is dynamic. Therefore, it is very important to collect and analyze information from the audit logs to make improvements.

The M. D. Anderson Case: Overview and Findings

To illustrate the impact of EMRs on patient privacy and the importance of having a privacy policy in the healthcare industry, we now consider the case of the University of Texas M. D. Anderson Cancer Center. EMRs promise to promote better medical outcomes, lower costs, and streamline the entire healthcare system. The development of the electronic medical records system with a major focus on the integration of research and clinical data has been identified as a key strategic initiative at M. D. Anderson. Meanwhile, M. D. Anderson is strongly committed to maintaining the security and privacy of patient medical records under HIPAA. To this end, M. D. Anderson has developed data access and audit trail policies to protect the privacy and confidentiality of medical data. In this section, we illustrate how a best practices standard, such as the EMRs initiative, would work in conjunction with the enhanced formal privacy policy that M. D. Anderson proposes. We focus on how M. D. Anderson applies data access management and audit trails to ensure the privacy and security of EMRs.

M. D. Anderson Cancer Center in Houston is a premier cancer hospital in the United States. With more than 16,000 faculty and staff and 1,600 volunteers working in more than 25 buildings around Houston and in central Texas, M. D. Anderson is one of the largest cancer centers in the world. The center, which treats more than 70,000 patients a year, includes an in-patient pavilion with 512 beds, an out-patient clinic, two research buildings, a faculty building, and a patient-family hotel. M. D. Anderson is also a top research center; the center invests more than $400 million on cancer research each year; about 11,000 patients participated in therapeutic clinical trials last year. M. D. Anderson has identified improvement in electronic processing and communications of medical records as a key to enhance the safety and efficiency of its patient care. The center has developed an electronic medical records system that would integrate patient records with clinical research data. In a healthcare institution like M. D. Anderson, everyone wants to keep all the medical data forever and has it accessed immediately. The electronic medical records system has now between 600 and 800 terabytes of data that is in a high-availability environment. Probably the best example of that is the center's imaging environment. Technologies such as computed tomography (CT) and magnetic resonance imaging (MRI) has been an integral part of clinical cancer care and imaging techniques are continually improving and finding more and more applications in clinical and research situations. The center has more than 200 million images online available for our clinicians. That environment is completely replicated, so the center actually have 400 million images online—a copy of each one—and the center has a third backup maintained off-site that is an extract of the images. The creation of the electronic medical records system improves quality of care by speeding up access to cancer patient information and ensuring that information is more complete and readily available for diagnosis, treatment, and claims-payment purposes. The new system also promises to improve medical research and innovative treatment at the center by integrating clinical trials data with clinical data. The increased availability of electronic medical records carries significant benefits for M. D. Anderson. But this has put increasing demands on the underlying privacy protection mechanisms. Like other medical providers, M. D. Anderson is bound by the HIPAA privacy rule to provide adequate protection for the personal medical data.

M. D. Anderson has always been a leader in standing up for patients' rights since it was established in the 1940s. The center is committed to safeguard patient confidences and privacy with the constraints of HIPAA requirements. It has developed formal policies that explicitly articulates how EMRs to be protected. The center believes that patients "own" the data about themselves (as defined by HIPAA's PHI definition) and they only allow its use by others under certain circumstances. Since access is one of the areas most vulnerable to privacy breaches, the center needs ability to authorize access to EMRs and keep audit logs over complex heterogeneous information systems and networks. The truth is that the more access and availability there is, the more risk there is.

The center stresses formal role-based data access policies and procedures that clearly define who in the organization have privilege and need to access to particular data, the rules determining a person's right of access, the reasons for denying access to individuals, including how access is granted, modified, and denied. If you are a physician, you can only see certain things; if you are a nurse, you can only see certain things; if you are a pharmacist, you can only see certain things; If you are a cancer researcher, you can only see certain things; if you are an administrator in the Department of Cancer Medicine, you can only see certain things. For example, clinical EMRs may be used and/or disclosed for certain research purposes. All research projects at the center are subject to review and approval by an Institutional Review Board (IRB). An IRB committee responsible for protecting individual research subjects and insuring that research is conducted ethically. You will not be enrolled in a research project that is not reviewed and approved by an IRB. The goal is to restrict the access and/or release of protected health information to authorized individuals and prevent unreasonable possibility of unnecessary, inadvertent, wrongful, or malicious access to protected information.

M. D. Anderson has established the formal auditing policy based on HIPAA regulatory requirements and security best practices. The center has a substantial department of information security that watches over access to the electronic medical records system very carefully. The system maintains records of all access to EMRs. A required accounting must include: (1) the date of the disclosure; (2) the name and address of the entity or person who received the medical information; (3) a brief description of the medical information disclosed; and (4) a brief statement of the purpose of the disclosure. Audit logs for systems containing EMRs should be retained and reviewed regularly according to the M. D. Anderson privacy policy. No security information system is foolproof. The center has audit trail tools that allow more frequent examination of audit logs to detect inappropriate accesses to EMRs. Once a privacy breach happens to data, IT professional will be indispensable in locking down the systems, then determining the extent of the breach, data compromised, and source of attack.

The case of M. D. Anderson demonstrates that it is critical for a healthcare organization to have a formal privacy policy. Electronic record keeping presents a massive threat to patient privacy—PHI in particular. Keeping patient records private and secure is a huge concern for any healthcare organization. By establishing privacy policies and implementing them with state-of-the-art security technologies, a healthcare organization can actually turn the privacy issue into a benefit when it uses EMRs. Paper medical records are not immune to privacy risks. There is no way to restrict who sees them, or to detect inappropriate accesses to them. In contrast, EMRs provide the potential for greater protections with access controls and audit trails. The access control policy expressly defines who in the organization have privilege and need to access to particular data and ensures that they access only a small part of the database to carry out their job duties. The formal auditing policy maintains audit logs of all access to clinical information (EMRs) and allows frequent examination of audit logs to detect privacy breaches.

CONCLUSION

Patient privacy is a major concern for most healthcare organizations today due to the continued growth of healthcare information systems and the resulting dependence on EMRs and electronic communications. Healthcare organizations in the United States face governmental and regulatory pressures to become compliant with the HIPAA privacy rule. In this article, we described the importance of patient privacy in the context of EMRs and HIPAA compliance. We found that it is crucial for a healthcare organization to have a formal privacy policy. We developed and analyzed access control and audit log policies to protect the privacy of EMRs. More importantly, to illustrate the best practices in the healthcare industry, we presented the case of the University of Texas M. D. Anderson Cancer Center and developed insights into the impact of EMRs on patient privacy and the importance of having a privacy policy. Further research about privacy protection in healthcare should try on a systematic view of security and privacy of EMRs. We also notice that the explosive progress of IS/IT, including Web-based systems and mobile computing devices, causes healthcare information systems more porous. In this case, new privacy management practices need to be developed to safeguard patient privacy.

REFERENCES

Ateniese, G., & Medeiros, B. (2002). Anonymous e-prescriptions. In *Proceedings of WPES'02*, Washington, DC (pp. 19–28).

Croasdell, D. C. (2001). IT's role in organizational memory and learning. *Information Systems Management, 18*(1), 8–11.

DeMuro, P. R., & Grant, A.H., III (2001). Health privacy standards raise complex implementation issues. *Healthcare Financial Management, 55*(1), 42–47.

Hammond, C. (2001). The intelligent enterprise. *InfoWorld, 23*(6), 45–46.

Holt, G. D., Love, P. E. D., & Li, H. (2000). The learning organization: Toward a paradigm for mutually beneficial strategic construction alliances. *International Journal of Project Management, 18*(6), 415–421.

How M. D. Anderson takes care of data. (2007). *Baseline, 1*(68), 1.

Kieke, R. L. (2003). What's next, now that the April deadline has passed? *Journal of Health Care Compliance, 5*(4), 41–43.

Li, J., & Shaw, J. (2004). Protection of health information in data mining. *International Journal of Healthcare Technology and Management, 6*(2), 210–222.

Matt, S. (2002). Auditing and reporting for HIPAA compliance. *Health Management Technology, 23*(12), 12–13.

Messmer, E. (2003). HIPAA deadline ups healthcare anxiety. *Network World, 20*(10), 30.

Patient privacy in an information age. (2001). *Direct Marketing, 64*(3), 32–36.

Schneier, B. (2000). *Secrets & lies: Digital security in a networked world*. New York: John Wiley & Sons, Inc.

Swartz, N. (2004). A prescription for electronic health records. *Information Management Journal, 38*(4), 20–26.

Taylor, H., & Leitman, R. (2001). U.S. trails other English speaking countries in use of electronic medical records and electronic prescribing. *Harris Interactive, 1*(28), 1–3.

Zunkel, D. (2005). The other side of privacy: Protecting information with biometircs. *Security Technology & Design, 15*(6), 46–53.

This work was previously published in International Journal of Information Security and Privacy, Vol. 2, Issue 3, edited by H. Nemati, pp. 45-54, copyright 2008 by IGI Publishing (an imprint of IGI Global).

Chapter 7.8

A Quality Assurance Approach to Healthcare:

Implications for Information Systems

Mark C. Shaw
De Montfort University, UK

Bernd Carsten Stahl
De Montfort University, UK

ABSTRACT

Despite decades of research, healthcare information systems have been characterised by cost over-runs, poor specifications and lack of user uptake. A new approach is required which provides organisations with a reason to invest in this type of software. W Edwards Deming argues that quality is not an entity but derives from using feedback, iteratively to seek improvement to processes, in order to increase productivity and to make better use of resources. The authors propose that supporting this form of quality assurance (QA) using information systems (IS) has the potential to deliver a return on investment. An object-oriented analysis, where healthcare is viewed as the delivery of interdependent processes to which Deming's form of QA is applied, results in a class model of data types that has some useful characteristics. It is able to store data about medical and non-medical events; to save descriptions of procedures and to represent the QA process itself. With software based on the model, organisations will have a memory of previous attempts at making improvements as well as data about feedback from patients and staff to drive future change. A critical research in information systems (CRIS) analysis of this model proposes a number of criticisms deriving from theories about rationality; concepts of technology; politics and hidden agendas, as well as the social consequences of technology. The view that QA is a standardised, ongoing conversation about the important characteristics of a process pre-empts many of these counter arguments. The CRIS critique also highlights the need to ensure that development is in harmony with the needs of the many stakeholders in healthcare IS. These concepts lead to new directions in healthcare IS research. The class model needs to be tested against clinical and non-clinical use-cases for its viability not only as support for QA but also as an electronic patient

record. A standard terminology is required for processes and for how objects from the model should be used to represent them. The model predicts that user interfaces will have to collect more detailed data than hitherto. Also use of the software should be tested in controlled trials to demonstrate whether the required improvements in quality not only benefit the patient but also the organisations managing their care.

INTRODUCTION

The primary aim of W. Edwards Deming's approach to QA is to improve productivity by avoiding re-work, thereby making better use of man-hours and machine-time (Deming, 1990e). The effect is a reduction in the costs of manufacture of good product. The method requires an organisation continuously to seek improvement to processes as a result of systematically obtaining feedback. We propose that the delivery of health care can be modelled as a set of interdependent procedures and that there is every reason to apply Deming's ideas, even though they were developed for manufacturing industries.

What are the implications for healthcare information systems and their fundamental data structure - the electronic patient record - of being designed to support Deming's form of QA? By drawing on the theories that underpin his approach, the meaning of QA in the context of healthcare is examined and a generic class model that supports the process is developed, using object-oriented analysis.

If an information system is created using our set of classes, what factors will influence its success? A step back is taken and a judgmental eye cast on the model from the perspective of CRIS. We argue that even when a completely different interpretation of the nature and purpose of QA and healthcare IS is adopted, there remain good arguments to support our approach. Having outlined our concepts, we conclude by proposing new directions for research.

BACKGROUND

Why Invest in Health Information Systems?

Reviews of individual health information systems for the management of patients with chronic diseases are positive (Dorr et al., 2007) as are those of computer based nurse documentation (Ammenwerth et al., 2001). There is agreement that the overall costs and benefits have rarely been fully assessed (Herbst, Littlejohns, Rawlinson, Collinson, & Wyatt, 1999; Shekelle, Morton, & Keeler, 2006) but none-the-less Shekelle (2006) states that:

"Despite the heterogeneity in the analytic methods used, all cost-benefit analyses predicted substantial savings from [Electronic Health Record implementation.] The quantifiable benefits are projected to outweigh the investment costs. However, the predicted time needed to break even varied from three to as many as 13 years."

This conclusion is open to question because an understanding is required of how different research methods influence results (Moehr, Anglin, Schaafsma, Pantazi, & Grimm, 2006; Wyatt & Wyatt, 2003; van't Riet, Berg, Hiddema, & Sol, 2001). Consequently some authors have suggested the need for a broadly accepted, standard evaluation framework (Rahimi & Vimarlund, 2007; Ammenwerth, Graber, Herrmann, Burkle, & Konig, 2003; Ammenwerth et al., 2004).

An overview of academic medical informatics (Jaspers, Knaup, & Schmidt, 2006) suggested that:

"The computerised patient record ... is playing a growing part in medical informatics research and

evaluation studies, but the goal of establishing a comprehensive lifelong electronic health record ... is still a long way off."

Why should healthcare organisations invest in information systems that are yet to provide an electronic health record and which offer, at best, a modest economic benefit? We propose that they are most likely to gain if they establish a QA process and use software to support it.

What is Quality?

The concept of 'quality' has been criticised because the meaning is elusive. A narrow definition focussed mainly on customer satisfaction, has been used to legitimate increasing managerial control over healthcare professionals (Palfrey, Thomas, & Phillips, 2004b). On the other hand, making 'quality' synonymous with high professional standards is seen as forcing staff to adhere to yardsticks imposed by senior management (Palfrey, Thomas, & Phillips, 2004a).

Additional barriers to the success of QA in the British National Health Service (NHS) have been: lack of resources; lack of expertise or advice on project design and analysis; lack of an overall plan for audit; organisational impediments and problems between groups and group members (Johnston, Crombie, Alder, Davies, & Millard, 2000). It is no surprise that the effects of quality improvement projects are variable, depending on the context in which they are used and the way they are implemented (Walshe & Freeman, 2002).

Quality Assurance

We avoid arguments over the meaning of the word: 'quality' by proposing that healthcare can be modelled as a set of interdependent processes. Viewed this way, we can apply Deming's ideas about: 'seeking continuously and forever, iteratively to improve process and product' (Deming, 1990d).

Deming suggested that each process should be described in terms of a specific test of its action and a pass/fail criterion (Deming, 1990b). When tracked over time, the proportion of failures to meet these 'operational definitions' will fluctuate and statistical boundaries can be set for the extent of the variation.

When the proportion of failures lies outside pre-defined, statistical limits: 'special causes' are said to be present. These require to be investigated and to be remedied on a case by case basis as soon as possible after they are detected. Often they represent rare or exceptional circumstances, such as equipment failure.

When the proportion of failures lies within pre-defined statistical limits, a process is said to be in statistical control and variation is due to: 'systematic causes', which require management to improve the method of working.

As part of an agenda to avoid developing better systems, management may argue that each patient is 'one-of-a-kind' due to biological variation. This logic is faulty because it is likely that patients can be classified into one of a set of variants and care tailored accordingly.

A consequence of defining healthcare as a sequence of interdependent processes is that errors in preceding activities, if left unaddressed, will accumulate and affect the correct performance of their dependants. This is another reason for management not to avoid its responsibilities.

For manufactured goods, quality may be defined in terms of improvements in three areas: the product; the customer's use of the product and the requirements for maintenance of the product. In contrast, we propose that the quality of a service may be defined in terms of improvements to the design of its constituent processes. Enhancements should be sought in the actions undertaken and the operational definitions needed, using feedback from patients about the process and its effects and from staff about the resources needed to keep consistently delivering without fault.

Meaningful feedback needs to be obtained in a systematic way. The plan, implement, observe and review approach suggested by Shewhart and popularised by Deming (1990c) offers a useful methodology. Planning defines the process and desirable changes. Implementation executes the alteration on as small a scale as can be demonstrated to provide meaningful results. Observation gathers data about the effects of the modification. Review examines what was learnt and what can be predicted regarding future operations. This should be an iterative process which acts as a permanent driver for improvement.

Continuous Quality Improvement

Continuous quality improvement (CQI) is the application of Deming's form of QA to healthcare. It has been used to improve cardiac care in a hospital, over a 10 year period (Brush et al., 2006), as well as in an emergency department to reduce complaints and increase patient satisfaction (Welch & Allen, 2006). Without a control group however, it is difficult to ascertain whether these reported changes follow from the QA process or other factors such as better technology.

Data collected before and after the CQI implementation of a number of care pathways, showed that most lead to better treatment (Panella, Marchisio, & Di Stanislao, 2003). The investigators reported difficulty obtaining results from existing information systems and pathway failures were attributed to the inability to engage clinicians in the process of quality improvement because of a lack of timely statistics about changes to care.

A randomised controlled trial demonstrated that CQI had no effect on the care delivered to patients with asthma in two geographic areas of the United States. There were methodological problems with the assessment of effect and external factors such as financial stringency and organisational change confounded the results (Homer et al., 2005). In contrast a second trial examining the effect of CQI on the management of depressed patients, demonstrated modest improvements in the process and outcome of care: more completed the required programme and more functioned better socially (Rubenstein et al., 2006).

Deming (Deming, 1990a) suggested that initial change will be dramatic as special causes are removed. What is left thereafter is the need to change the methods of work, which is altogether a more difficult and longer-term undertaking. The results reported in the research on CQI are to be expected because the investigators have yet to take full account of this possibility.

IMPLICATIONS FOR INFORMATION SYSTEMS

Object-Oriented Analysis

In order to examine the effects on information systems design, we performed an object-oriented analysis (Booch, 1994) of Deming's form of QA as applied to healthcare.

When dealing with health, it is useful to be able to follow the patient for long periods of time. We argue that this can only be achieved only if there is knowledge of data type and location. These pre-requisites ensure that the correct comparison procedure can be applied.

In quantitative research, classification of data into groups, using the appropriate comparison operation, leads to the ability to count them and thereby to the performance of statistical analyses. In qualitative research, comparison permits identification of terms used to describe themes of interest.

In our analysis, we have attempted to apply these principles to arrive at a description of QA that avoids the need for free-text, wherein the location and the type of the data are unknown (at least until there is reliable, automated natural-language comprehension).

Class Model

In the following section, the classes of information employed in the model are written in capital letters, when they are first mentioned.

Processes may be represented as combinations of ACTIONs, performed by ACTORs.

The test component of an operational definition may be represented as an action from which an OBSERVATION may result.

The 'pass/fail criterion' of an operational definition requires classifying observations according to some standard. We propose that an ANALYSIS type of action should be used to represent this and other methods of summarising and interpreting data.

Groups of analyses may be recognised as forming a set. The resulting HYPOTHESIS about the cause of a problem may lead to the PLANNING of remedial TASKS. Each task will require a set of CAPABILITIES, such as a person's SKILLs or a machine's FUNCTION, for its successful conclusion. Part of planning will be to choose appropriate actors to fulfill the requested capabilities.

An advantage of real time data gathering is that it is possible to provide people with an opportunity to record why they succeeded or failed to perform a task (Buetow, 2005). The INDICATION class handles both these scenarios, providing the capability to determine whether a hypothesis was "in favour" or "against" a task.

Machines may perform actions on behalf of people, such as monitoring blood pressure. LOCATIONS describe where an event took place in space and may be composed of sub-locations. Arguably, locations may perform actions on behalf of people and so we propose that an actor could be a PERSON, a piece of EQUIPMENT or a LOCATION.

No individual acts in isolation; each lives in a physical and social environment and inherits a genetic legacy. A person has a RELATIONSHIP with other people. This might be genetic, marriage or friendship. Also an actor may have a ROLE within an ORGANISATION. Examples are employment or membership of a sports club. Organisations may themselves be composed of a number of sub-organisations and may have a location in space.

For QA, actors must have the ability to remember PLANs about what tasks to undertake when a particular hypothesis pertains. Plans need to be made sensitive to circumstances by being able to represent decisions. Since tasks can lead to actions which result in observations that are analysed: it can be argued that one or more hypotheses may pertain following a task. Plans may be created to define what to do for each of these expected hypotheses.

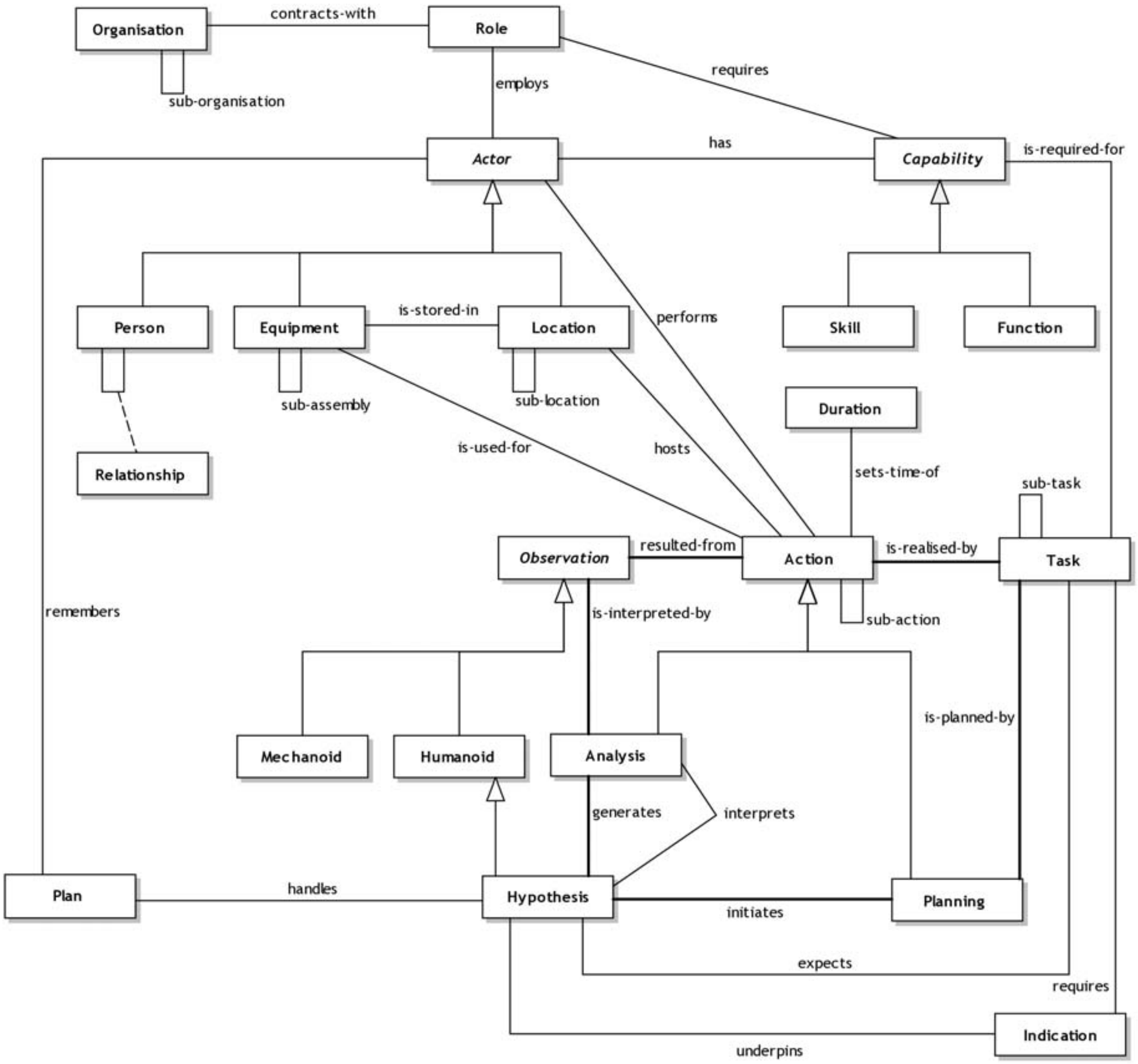
Figure 1 shows the class diagram that was created following the above analysis. Links are to be read from left-to-right and from top-to-bottom. The QA feedback loop is characterised by the following relationships:

An OBSERVATION "resulted-from" an ACTION, which a PERSON "performs".
An OBSERVATION "is-interpreted-by" an ANALYSIS, which a PERSON "performs".
A PERSON "performs" an ANALYSIS, which "generates" a HYPOTHESIS.
A HYPOTHESIS "initiates" PLANNING, which a PERSON "performs".
A TASK "is-planned-by" PLANNING.
A PERSON "performs" an ACTION, which "is-realised-by" a TASK.

More About Observations

Deming suggested that operational definitions should be couched in terms of objective tests such as the red, green and blue settings needed to achieve a particular colour. We note that whilst such observations are common in medicine there

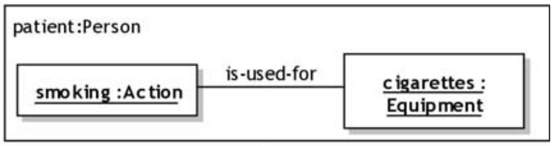
Figure 1. Class model, showing the QA loop



are many, such as symptoms and signs, which involve a degree of subjectivity on the part of the observer. We propose the use of 'mechanoid' and 'humanoid' observations to distinguish the two.

A mechanoid observation is defined as one where a machine makes a record of a measurement directly from sensor data and provides the same report of previous measurements to multiple independent observers. In contrast, a humanoid observation is one where no data about what the sensor detected are available; only a person's interpretation of what was present. Both types of observation may involve data loss. In the case of mechanoid observations, the nature of the loss and the processing that generated it is, in principle, explicit and available for all to examine and verify. In the case of the humanoid observation, there are no such guarantees.

Figure 2. Representation of a person smoking



Modelling Health Care

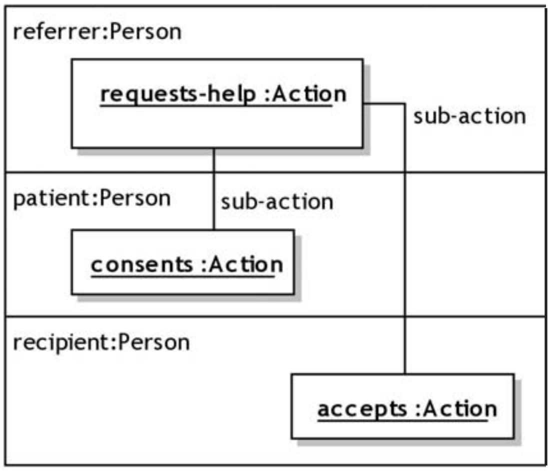
In the following sections, we demonstrate that useful concepts regarding the management of patients in a healthcare setting can be modelled using the classes and relationships in figure 1. This is not intended as proof of validity but rather as an illustration of potential utility in representing medical and administrative processes.

Risk Factor

A 'risk factor' increases the chances that a person may contract a disease.

In Figure 2, the box surrounding 'smoking:Action' and 'cigarettes:Equipment' is a swim lane. In the diagrams in this section and those which follow, swim lanes are used to show an actor performing an action.

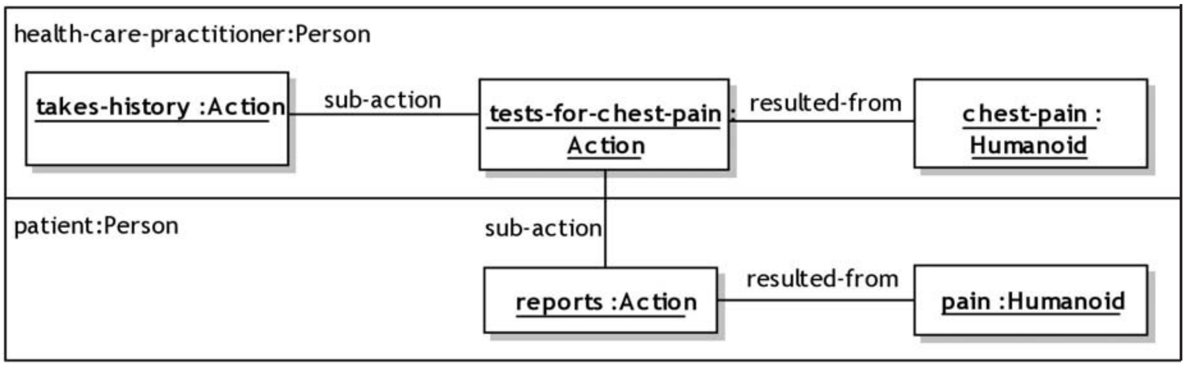
Figure 3. Representation of a referral



Referral

A referral is a request for help made to a health care professional either by a patient or a colleague. One approach to modelling this is to use the idea that a patient consents to the action and that a recipient accepts the request. (see Figure 3)

Figure 4. Representation of a symptom



Assessment

Assessment is the process of gathering observations about the patient by listening to a description of the problem (taking a history), by conducting a physical examination and by organising investigations, such as sampling blood, taking x-rays or ultrasound images, measuring physiological parameters or examining tissue samples taken during operative procedures.

While taking the history, the clinician interprets what has been said and applies labels mapping the description to accepted medical terminology for symptoms. During physical examination, the professional's senses (vision, touch, hearing and smell) are used to look for manifestations of disease (Nardonne, 1990). Humanoid observations should be used for symptoms, signs and those physiological measurements where no independent record is taken. The use of mechanoid observations should be reserved for investigations where a record of the sensor's output is kept.

In Figure 4, a health care practitioner takes a history, during which the patient is asked about chest pain. Pain is reported, leading to a positive test, represented by the existence of the chest-pain humanoid observation.

In Figure 5, the patient is examined for an irregular pulse. If the humanoid observation were missing, it would be reasonable for an analyst to deduce that the clinician examined the forearm and found nothing. If the examines-for-irregular-pulse action were absent, no such inference could be made. This demonstrates how the class model

Figure 5. Representation of a sign

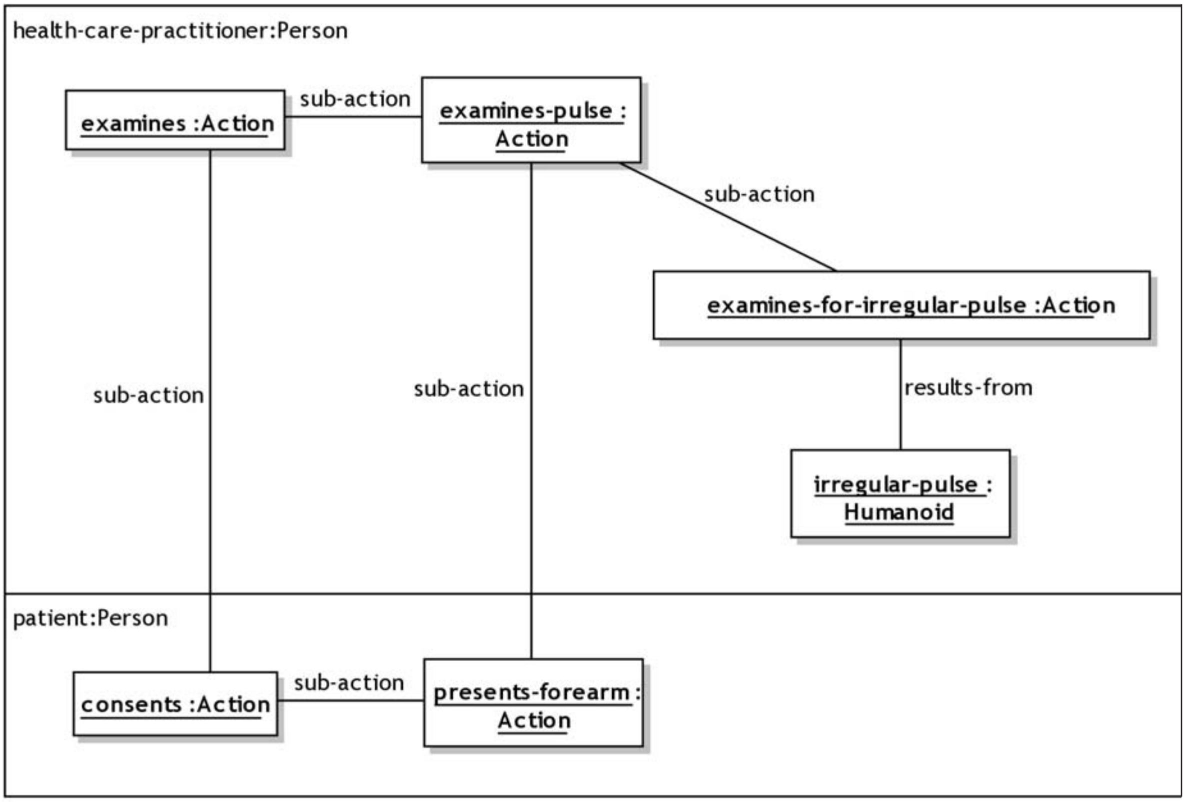
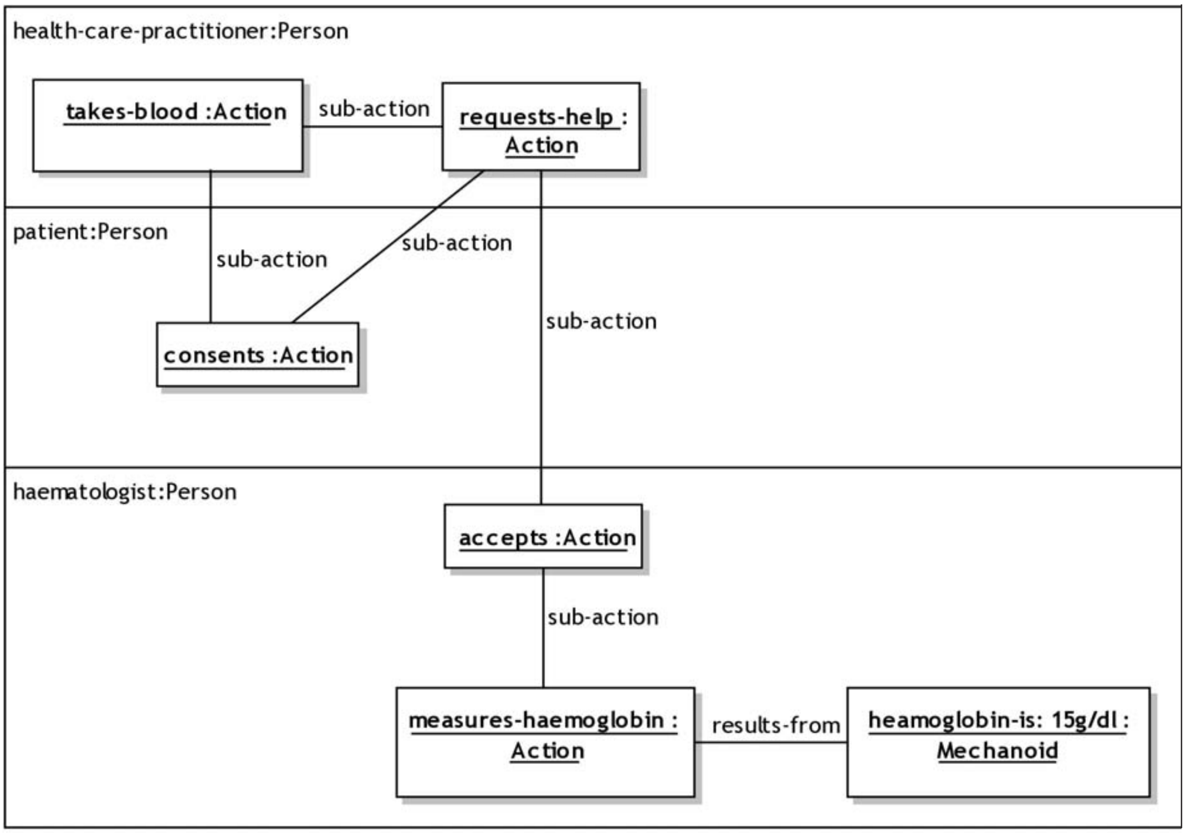


Figure 6. Representation of an investigation



could handle an important concept in medical diagnosis: the contrary finding (see *Diagnosis*).

Figure 6 presents a simplified view of the analysis of a blood sample. Many details such as the method of taking blood, the administrative procedures, the equipment used and the process of transporting the blood sample, are not shown.

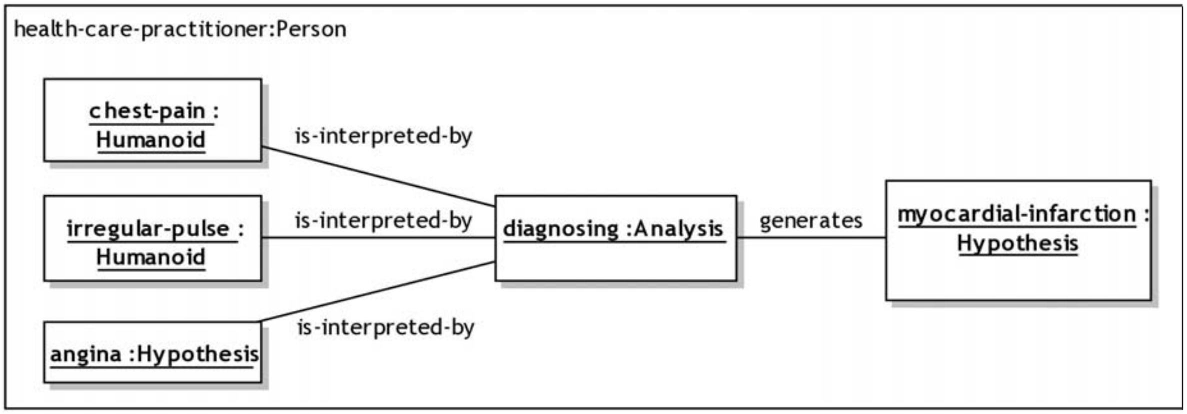
Diagnosis

Diagnosis is the process of labelling clusters of observations; the clinician selects which ones form a set, based on recognised patterns or the characteristics of disease processes (Nardonne, 1990). The technique for synthesising observations into a diagnosis has been described as one of hypothesis generation followed either by refinement or by elimination, as a result of a contrary finding (Nardonne, 1990) making the ability to store the latter important to an electronic patient record. (see Figure 7)

Management

Management is the selection, planning, execution and monitoring of tasks appropriate to the

Figure 7. Representation of a diagnosis



handling of a patient's problems. Usually the diagnosis forms the basis upon which treatment is selected but the clinician may also choose to use symptoms or signs, either because of the distress they are causing or because an urgent intervention is required (Nardonne, 1990).

While planning a task, decisions are made about who will perform the procedure, where, when and how. Clinicians marshal appropriate resources, none of which are under their exclusive control and take account of what skills are available, as well as the patient's circumstances, consent and ability to comply.

Monitoring is a repeated assessment, which takes place after treatment. It is focussed on the set of symptoms, signs and investigations that best indicate progress. During this phase, new problems may come to light, requiring that a new diagnostic review is initiated.

In Figure 8, a diagnosis of myocardial infarction initiates myocardial infarction care planning. This involves two tasks: monitor electrocardiograph (ECG) and administer morphine. The patient consents to receiving morphine and the task is realised by the health care practitioner giving morphine. The monitor ECG task is realised by the ECG machine's leads being attached to the patient's chest and the machine displaying a trace.

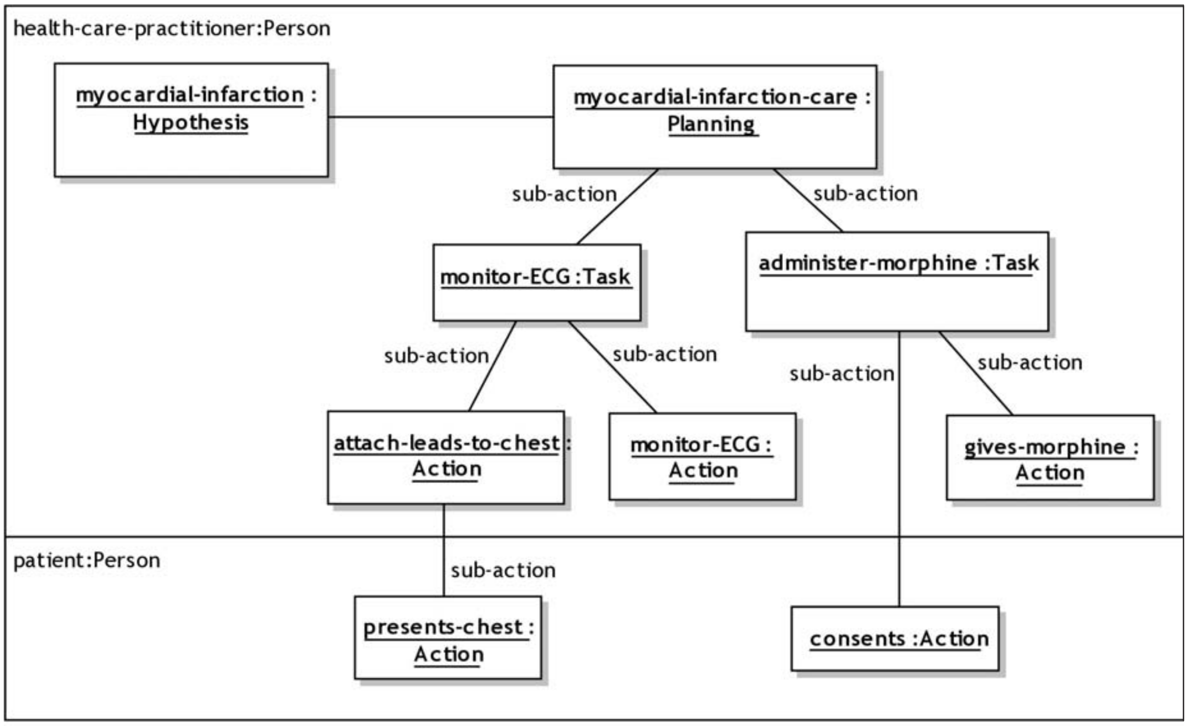
Organisational Memory

An example plan is provided for part of the management of ovarian cancer (Shaw, Wolfe, Devaja, & Raju, 2003). The hypothesis that a woman has ovarian cancer initiates the task of planning for a laparotomy (a procedure to assess the presence and extent of disease in the abdomen).

The laparotomy task requires that a midline incision is performed (the details of which are not shown). Next peritoneal fluid or washings should be sampled in order to determine whether the disease has spread from the ovaries to other tissues, which has implications for further treatment. Determining the correct stage requires the surgeon to take a sample of peritoneal fluid or if there is none, to perform a peritoneal lavage and then to take a sample of the resulting fluid in the abomen.

In figure 9, the task to sample peritoneal fluid or washings begins by asking the surgeon to examine for peritoneal fluid. Two possible outcomes are shown by the 'expects' relation: either fluid is present or absent in the abdominal cavity. If

Figure 8. Representation of the early management of a heart attack



fluid is found, a sample is taken. If there is none, peritoneal lavage is performed and a sample of the lavage fluid (washings) taken.

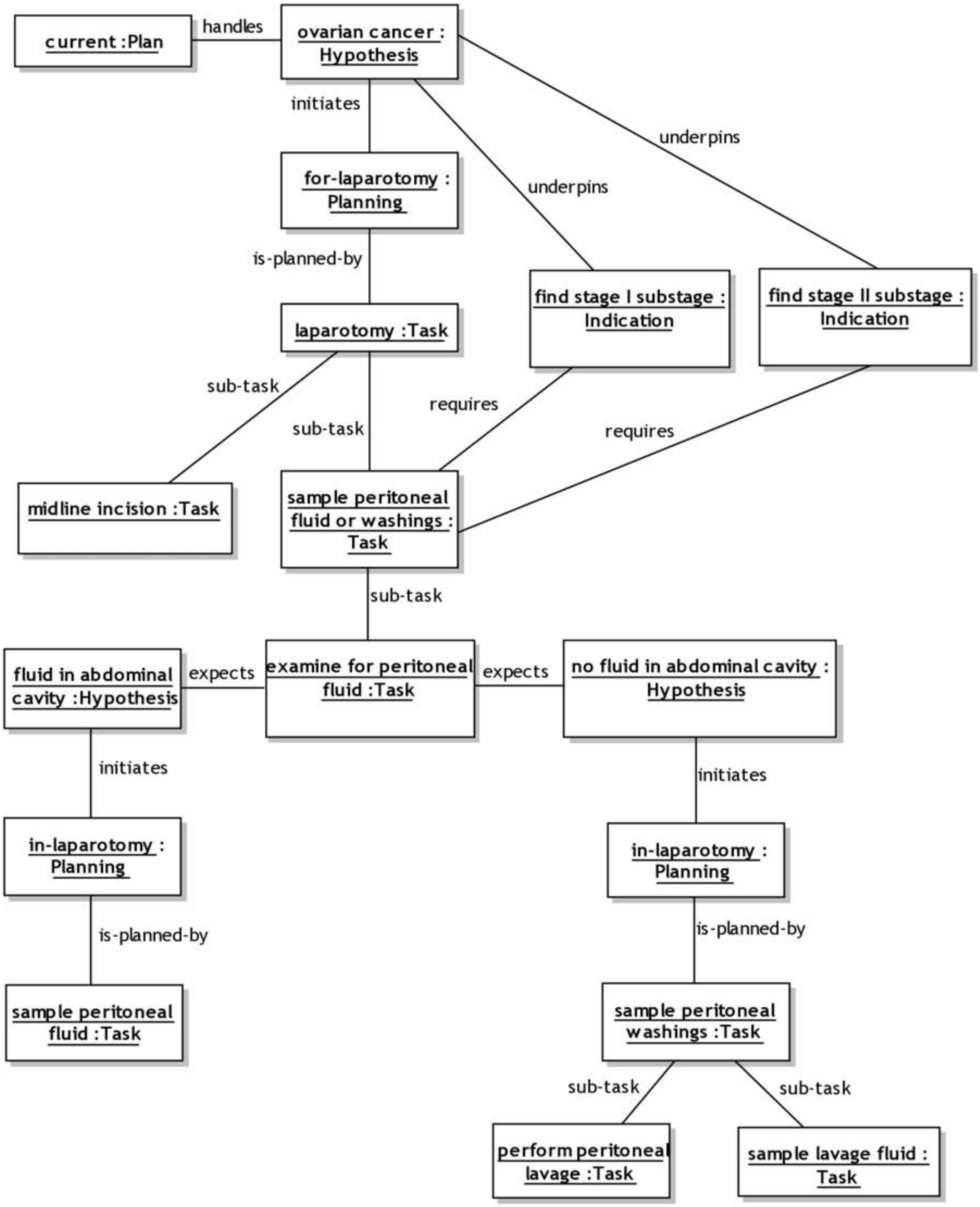
It should be noted that there is a requirement to determine the sequence of peer tasks in a plan. In Figure 9, the tasks should be carried out in left-to-right order.

Whereas the health care practitioner performs actions on a person and gains feedback from observation of that individual, QA performs actions on plans and gains feedback from observation of the results. Figure 10 shows how the QA process might be represented using classes from the model. Initially observations of the process are analysed to generate a hypothesis about how it might be improved. Next the alteration is planned, and a task defined which is realised by an action to change the process. The effects of the alteration are then monitored by gathering further data.

CRITIQUE OF THE QA MODEL

The QA model of healthcare information systems is based on assumptions that may be familiar with medical as well as ICT professionals. It implicitly assumes that reality can be described in a relatively straightforward manner. Patients as well as medical professionals are viewed as rational individuals who seek to communicate in order to achieve a mutually beneficial outcome. The technology required to underpin the QA system has not been considered in any detail and is presumed to be unproblematic. Use of technology follows functional requirements. Briefly, the model we have developed follows the positivist mainstream model of information systems research and practice. This approach has the advantage of being familiar to many of the relevant stakeholders of

Figure 9. Plan for the early stages of a laparotomy for ovarian cancer



healthcare information systems. At the same time it may cause problems. A primary indicator of the shortcomings of the mainstream understanding of information systems is the persistently high failure rate. Despite decades of research on information systems, the majority of systems can still be considered failures due to price overruns, poor specifications, lack of user uptake etc. Wilson & Howcroft (2002) have pointed out that the concept of failure is problematic per se. It is probably unproblematic to state that the history of ICT projects in the NHS is a history of failures.

The Critical View

Developing a new approach, such as the QA approach we are suggesting here, should thus consider early on whether there are factors that are likely to cause systems to fail despite sound conceptual underpinnings. We will use this section to sketch a possible counterargument to our QA approach in order to then propose how the model could be used to address these.

For this purpose we will briefly look at the position of Critical Research in Information Systems (Howcroft & Trauth, 2005) and explore which issues this may raise for our model. Critical Research in information systems (CRIS) is an approach to IS that draws from critical theories in the social sciences and attempts to discover angles typically overlooked by traditional research. A main aim of CRIS is to promote emancipation understood as the ability of individuals to live a self-determined life. CRIS is a useful choice of approach to our QA model because it emphasises aspects of social reality that our model so far neglects, such as organisational and national politics, gender, class, conceptualisation of technology and others. Moreover, CRIS, because of its emphasis on emancipation, has an ethical underpinning (Stahl, 2008), which maps well onto the implied ethical dimension of healthcare. The purpose of healthcare provision in general can be seen as emancipatory.

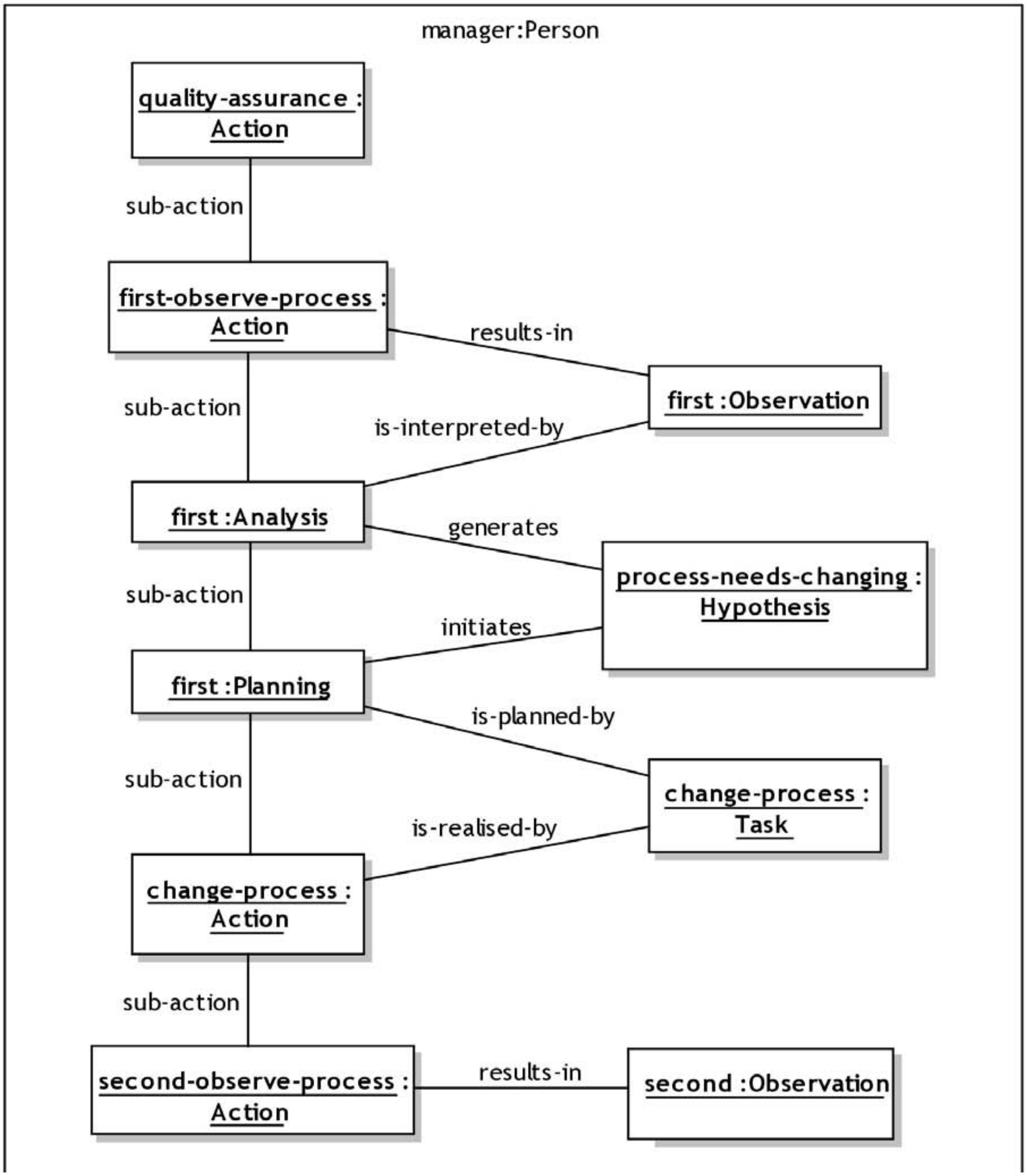
CRIS draws on a range of theoretical roots and it is impossible to undertake a comprehensive analysis of our model from a CRIS point of view. We will therefore draw on the CRIS literature that explicitly refers to healthcare IS in order to identify dominant issues that our approach so far has not covered.

Rationality

A good point to start a critique of mainstream IS that might be applied to our model is the concept of rationality. Like most complex concepts this one is difficult to grasp and define. Its clearest example may be the autonomous individual on whom neoclassical economic theory is built. Such an individual is rational because she has a complete set of preferences and acts in order to maximise her utility according to these preferences. Translated into a healthcare setting, this means that individuals, be they patients, doctors, or any other stakeholders, act in a way to maximise the overall utility. It is easy to see that this will break down at the point where preferences are not identical. The patient may want a maximum of healthcare, whereas the doctor may view this as medically unwarranted and the manager as too expensive. In addition, patients are often described as irrational when their actions do not contribute to their health, or doctors are seen as irrational when they do not follow organisational goals.

The concept of rationality has been critiqued for a variety of reasons. It may simply not be possible for humans to be rational in the sense described above. Our individual preferences are not complete and often contradictory. In addition we lack the knowledge and cognitive capacities to make optimal decisions. A system based on the idea that people are and will be have rationally is thus likely to face problems. An additional problem arises when technical systems are introduced to increase the rationality of healthcare provision. Empirical evidence suggests that the ‘irrational’ nature of human interaction does not change by

Figure 10. Representation of the QA process (Note: the vertical swim-lane)



the introduction of information systems. In fact the introduction of such systems often introduces new irrationalities (Berg, 1999).

A further problem of rationality arises due to competing demands. We have already indicated that healthcare IS are often seen as ways of saving money (Palfrey et al., 2004a). This is a legitimate aim. However, one should see that it will in many cases conflict with the similarly legitimate aims of other stakeholders (Adams & Fitch, 2006). The use of information systems to promote a financial perspective on rationality can thus be seen as an attempt to promote a particular agenda.

A further problem of rationality is that there are different types of rationality that determine our social reality. Information systems tend to represent an abstract rationality, which is arguably often not compatible with the practical rationality of healthcare practitioners. Hanlon et al. (2005) give an example of the NHS direct system, a nurse-based 24 hour health advice system, whose technical base represents a rationality that is not compatible with the rationality of the nurses operating it. A different example of problems of competing rationality is developed by Klecun & Cornford (2005) who show that a traditional view of rationality when used for evaluating healthcare systems fails to pick up relevant issues.

Concepts of Technology

A central question in critical discourses revolves around the conceptualisation of technology. Critical scholars often draw on other discourses such as the social construction of technology but also on traditional critical theory to develop an account of how the very concept of technology affects social outcomes (Feenberg, 1991; Feenberg, 1999). The point here is that technology is not a neutral tool that can be used to whatever purpose the user decides to employ it. Instead, technology is seen as endowed with certain values and affordances that favour certain uses over others.

This point is linked with questions of technical determinism. Much mainstream work on ICT seems to assume that technologies have certain uses that they are built for and that users will make use of the options of technology in the way they were planned for. On the other hand there are numerous examples of technology either not being used or being used for purposes different from those envisaged. This has to do with what has been termed the "interpretive flexibility" of technology (Doherty, Coombs, & Loan-Clarke, 2006) (or interpretative flexibility (Cadili & Whitley, 2005)).

An important aspect of the concept of technology is the capacity of ICT to capture reality. In our model this issue is highlighted by the distinction between humanoid and mechanoid observations. Technologies are much better at capturing some aspects of reality than humans and vice versa. Healthcare information systems are likely to favour mechanoid observations because they are easier to integrate in technical contexts. This is likely to lead to reductionist perspectives on healthcare which can blend out the immeasurable, which arguably is often an important aspect of medical practice (Hanlon et al., 2005).

The main point here is that a naïve reliance on an intuitive understanding of technology is not likely lead to the success of a new approach. If the QA model is to be successful, then design and implementation should be aware of competing demands on technology but also different users' conception of technology.

Politics and Hidden Agendas

One reason why the above two points are of relevance to our approach is that technology is often used for political purposes. Such purposes can stem from organisational politics as well as national politics. The primary example of this is the growing influence of financial considerations. One main benefit of healthcare IS is that they tend to allow a more detailed breakdown of costs of treatments and a clearer allocation of these costs to different stakeholders. At the same time this leads to a strengthening of cost considerations when compared with others.

The UK government has promoted new ICTs in the NHS partly on the grounds of facilitating more choice for patients. This can be seen as a positive aim as few would dispute that the ability to choose one's doctor is bad. However, one needs to understand that this rhetoric of choice can also lead to a fundamental restructuring of healthcare provision and change the balance between market and state allocation of resources (Mol, 1999).

A different example is the distribution of power in organisations. Traditionally, healthcare in western countries tends to be very much centred on doctors. They hold the knowledge; they make decisions and allocate resources. Doctors' autonomy is a highly valued tradition. However, in complex modern healthcare organisations, power is increasingly taken away from doctors and moved towards managers. Such power struggles are normal and can be found in most sectors and organisations. What is important for us to note is that technology can be used as a tool in such struggles. This can lead to the acceptance or rejection of a technology

Social Consequences of Technology

A final point worth mentioning here has to do with the social consequences of technology. The wide availability of healthcare information via the internet has already started to impact on doctor-patient relationships. Patients are better informed and often have specific demands on doctors. Doctors, on the other hand, often resist this change of role which threatens their traditional position of authority.

A further social consequence of the introduction of ICT into healthcare is that it will inevitably lead to changes in procedures. The mere fact that data is to be recorded changes the way doctors interact with patients. This is of course usually intended and thus not to be lamented. However, the changes will often go beyond what was envisaged. If, for example, a system captures the number of patient a doctor sees, then this is likely to affect management's view of the doctor. As a consequence the doctor is likely to pay attention to the number of patients seen and may make choices on which patients to see. An unintended consequence may be that easier cases will find it easier to be treated than difficult ones because they take less time and improve the doctor's performance record. This is what Zuboff (1988) described as "informating", a property of ICT that not only captures but also produces information, which then changes the original processes.

While the nature of interaction between stakeholders can change, the very practice of medicine can also be changed. Again, this is intended, and our QA model explicitly aims to improve healthcare provision by allowing doctors to better understand the consequences of their decisions. On the other hand, there is a danger that it will lead to increased bureaucracy and medicine by algorithm. The danger of "cookbook medicine" based on standards and protocols developed on the basis of collected data (Berg, 1997) is not to be underestimated.

The QA Model Response

The above critique of the QA model does not claim to be complete. Its purpose is to show that there are aspects of healthcare IS that our model does not capture but that still have the potential to affect its success.

We believe that all of the points are valid and relevant but do not have to lead to the downfall of the QA model. The important point to avoid these issues is to start the QA process with a suitable interpretation of what QA is about. QA is an iterative process that allows continuous interaction with the aim of improving outcomes. This means that it must be open to changes in focus and criteria of quality as well as a shifting view of relevant data and ways of collecting it. Understood this way, QA can be seen as a standardised ongoing conversation about important characteristic of a process.

Such an open understanding of QA would pre-empt much of the critique discussed earlier. It would not make assumptions about appropriate standards of reality and allow for a questioning of implied standards via the QA process. It would be open to different concepts of technology including the resulting means of collecting, formatting, and storing information. These larger contextual issues, including political and social consequences of technology, may be impossible to include in the technical model that we have started to develop in the *Background*. However, the QA process as a whole will have to be sensitive to them, given that they are arguably important not only for user acceptance of technology but for the entire QA process in healthcare.

One could argue that this will require something like a 2nd order QA process. We need to think about some way of continually ensuring that the QA process is of high quality. Again, there is a question whether this can be technically implemented and in what way it will require organisational changes.

A final issue has to do with development and implementation of a QA system. While we have tried to make a sound statement on some of the conceptual basics, the critique has shown that context sensitivity will be required. It is unlikely that the same implementation of the same system in different contexts will lead to comparable results. This is where the socio-technical approach to systems design and development (Mumford, 2003) is likely to be able to address many of the challenges by allowing for participation of a range of stakeholders, most importantly of end users.

CONCLUSION

We have argued that healthcare organisations should focus on establishing QA and then invest in information systems to provide timely data to help engage clinicians in the process. We used object-oriented analysis to develop a class model describing Deming's form of QA, assuming that healthcare can be modelled as a set of interdependent processes.

Our model could provide organisations with a memory of a process's history as well as detailed data about practise and its effects. In conjunction with research, such an information system would deliver timely data to support systematically making changes to healthcare procedures. This should result in care that provides the patient with the solution to their problem and that minimises their contact with health services, thereby increasing capacity and productivity. If this is indeed correct, healthcare organisations should obtain a return on their outlay on IS.

We took a step back to look at possible counterarguments against our approach as might be voiced by critical scholars. We suggest that our model is open to some critical arguments but understanding QA as a standardised, ongoing conversation about the important characteristics of a process overcomes many such objections. This review also highlighted the need to develop information systems in harmony with the needs of their many stakeholders.

Future Research

The class model needs to be validated by examining whether a wide of variety of use-cases induce changes.

How objects in the model are used to represent health care processes needs to be standardised as well as how they are named by terminologies for diagnoses, clinical and administrative procedures.

In principle, the level of detail in the model offers the possibility of defining the meaning of diagnostic codes for diseases, in terms of actions, observations and analyses. The value of this capability in actual use will need to be assessed.

Little in our class model is specific to medicine. It could support comprehensive data collection not only about healthcare but also about the various non-clinical supporting processes. To realise this, collection of data would need to be more detailed and from a wider range of staff than existing systems. Will user interfaces need to change in order to cope? Will the availability of these additional data be useful to healthcare organisations?

The next step of our research will be to examine these questions as well as the effect of the model on clinical processes. We plan to build a prototype and undertake a quantitative and qualitative evaluation in an environment where a comparison can be made with the effects of alternate software systems.

REFERENCES

Adams, C., & Fitch, T. (2006). Social Inclusion and the Shifting Role of Technology: Is Age the New Gender in Mobile Access? In *Social Inclusion: Societal and Organizational Implications for Information Systems* (pp. 203-215).

Ammenwerth, E., Brender, J., Nykanen, P., Prokosch, H. U., Rigby, M., & Talmon, J. (2004). Visions and strategies to improve evaluation of health information systems - Reflections and lessons based on the HIS-EVAL workshop in Innsbruck. *International Journal of Medical Informatics*, *73*, 479–491. doi:10.1016/j.ijmedinf.2004.04.004

Ammenwerth, E., Eichstadter, R., Haux, R., Pohl, U., Rebel, S., & Ziegler, S. (2001). A randomized evaluation of a computer-based nursing documentation system. *Methods of Information in Medicine*, *40*, 61–68.

Ammenwerth, E., Graber, S., Herrmann, G., Burkle, T., & Konig, J. (2003). Evaluation of health information systems-problems and challenges. *International Journal of Medical Informatics*, *71*, 125–135. doi:10.1016/S1386-5056(03)00131-X

Berg, M. (1997). Problems and promises of the protocol. *Social Science & Medicine*, *44*, 1081–1088. doi:10.1016/S0277-9536(96)00235-3

Berg, M. (1999). Patient care information systems and health care work: a sociotechnical approach. *International Journal of Medical Informatics*, *55*, 87–101. doi:10.1016/S1386-5056(99)00011-8

Booch, G. (1994). *Object-Oriented Analysis and Design with Applications*. (2nd Ed.). Redwood City, CA: The Benjamin/Cummings Publishing Company, Inc.

Brush, J. E., Balakrishnan, S. A., Brough, J., Hartman, C., Hines, G., & Liverman, D. P. (2006). Implementation of a continuous quality improvement program for percutaneous coronary intervention and cardiac surgery at a large community hospital. *American Heart Journal*, *152*, 379–385. doi:10.1016/j.ahj.2005.12.014

Buetow, S. (2005). Why the need to reduce medical errors is not obvious. *Journal of Evaluation in Clinical Practice*, *11*, 53–57. doi:10.1111/j.1365-2753.2004.00497.x

Cadili, S., & Whitley, E. A. (2005). On the interpretative flexibility of hosted ERP systems. *The Journal of Strategic Information Systems*, *14*, 167–195. doi:10.1016/j.jsis.2005.04.006

Deming, W. E. (1990a). Common Causes and Special Causes. In *Out of the Crisis* (pp. 309-370). Cambridge, UK: Cambridge University Press.

Deming, W. E. (1990b). Operational Definitions, Conformance, Performance. In *Out of the Crisis* (pp. 276-296). Cambridge, UK: Cambridge University Press.

Deming, W. E. (1990c). Principles for transformation. In *Out of the Crisis* (pp. 18-96). Cambridge, UK: Cambridge University Press.

Deming, W. E. (1990d). Quality, Productivity, Lower costs. In *Out of the Crisis* (pp. 2-17). Cambridge, UK: Cambridge University Press.

Deming, W. E. (1990e). Service Organisations. In *Out of the Crisis* (pp. 183-247). Cambridge, UK: Cambridge University Press.

Doherty, N. F., Coombs, C. R., & Loan-Clarke, J. (2006). A re-conceptualization of the interpretive flexibility of information technologies: redressing the balance between the social and the technical. *European Journal of Information Systems*, *15*, 569–582. doi:10.1057/palgrave.ejis.3000653

Dorr, D., Bonner, L. M., Cohen, A. N., Shoai, R. S., Perrin, R., & Chaney, E. (2007). Informatics systems to promote improved care for chronic illness: A literature review. *Journal of the American Medical Informatics Association*, *14*, 156–163. doi:10.1197/jamia.M2255

Feenberg, A. (1991). *Critical theory of technology.* New York: Oxford University Press.

Feenberg, A. (1999). *Questioning technology.* NetLibrary, Inc.

Hanlon, G., Strangleman, T., Goode, J., Luff, D., O'Cathain, A., & Greatbatch, D. (2005). Knowledge, technology and nursing: The case of NHS direct. *Human Relations*, *58*, 147–171. doi:10.1177/0018726705052179

Herbst, K., Littlejohns, P., Rawlinson, J., Collinson, M., & Wyatt, J. C. (1999). Evaluating computerized health information systems: hardware, software and human ware: experiences from the Northern Province, South Africa. *Journal of Public Health Medicine*, *21*, 305–310. doi:10.1093/pubmed/21.3.305

Homer, C. J., Forbes, P., Horvitz, L., Peterson, L. E., Wypij, D., & Heinrich, P. (2005). Impact of a quality improvement program on care and outcomes for children with asthma. *Archives of Pediatrics & Adolescent Medicine*, *159*, 464–469. doi:10.1001/archpedi.159.5.464

Howcroft, D., & Trauth, E. M. (2005). *Handbook of critical information systems research theory and application.* NetLibrary,Inc.

Jaspers, M. W. M., Knaup, P., & Schmidt, D. (2006). The computerized patient record: Where do we stand? *Methods of Information in Medicine*, *45*, 29–39.

Johnston, G., Crombie, I. K., Alder, E. M., Davies, H. T. O., & Millard, A. (2000). Reviewing audit: barriers and facilitating factors for effective clinical audit. *Quality & Safety in Health Care*, *9*, 23–36.

Klecun, E., & Cornford, T. (2005). A critical approach to evaluation. *European Journal of Information Systems*, *14*, 229–243. doi:10.1057/palgrave.ejis.3000540

Moehr, J. R., Anglin, C., Schaafsma, J., Pantazi, S., & Grimm, N. (2006). Lest formalisms impede insight and success: Evaluation in health informatics - A case study. *Methods of Information in Medicine*, *45*, 67–72.

Mol, A. (1999). Ontological politics: a word and some questions. In J.Law & J. Hassard (Eds.), *Actor network theory and after* (pp. 74-89). Oxford, UK; Malden, MA: Blackwell/Sociological Review.

Mumford, E. (2003). *Redesigning human systems.* Hershey, PA: Information Science Reference.

Nardonne, D. (1990). Collecting and Analysing Data: Doing and Thinking. In H.K.Walker, W. D. Hall, & J. W. Hurst (Eds.), *Clinical Methods.* Stoneham, MA.: Butterworth Publishers.

Palfrey, C., Thomas, P., & Phillips, C. (2004a). Mulitple Perspectives and Decision Making. In *Effective Health Care Management: An Evaluative Approach* (1st Ed., pp. 55-60). Oxford, UK: Blackwell Publishing.

Palfrey, C., Thomas, P., & Phillips, C. (2004b). Performance management: Concepts and approaches. In *Effective Health Care Management: An Evaluative Approach* (1st Ed., pp. 93-99). Oxford, UK: Blackwell Publishing.

Panella, M., Marchisio, S., & Di Stanislao, F. (2003). Reducing clinical variations with clinical pathways: do pathways work? *International Journal for Quality in Health Care*, *15*, 509–521. doi:10.1093/intqhc/mzg057

Rahimi, B., & Vimarlund, V. (2007). Methods to evaluate health information systems in healthcare settings: A literature review. *Journal of Medical Systems*, *31*, 397–432. doi:10.1007/s10916-007-9082-z

Rogerson, S. (2000), Ethicol: Electronic Patient Records, *IMIS Journal, 10*(5), retrieved from: http://www.ccsr.cse.dmu.ac.uk/resources/general/ethicol/Ecv10no5.html

Rubenstein, L. V., Meredith, L. S., Parker, L. E., Gordon, N. P., Hickey, S. C., & Oken, C. (2006). Impacts of evidence-based quality improvement on depression in primary care: A randomized experiment. *Journal of General Internal Medicine*, *21*, 1027–1035. doi:10.1111/j.1525-1497.2006.00549.x

Shaw, M. C., Wolfe, C. D., Devaja, O., & Raju, K. S. (2003). Development of an evidence-based algorithm for the management of ovarian cancer. *European Journal of Gynaecological Oncology*, *24*, 117–125.

Shekelle, P. G., Morton, S. C., & Keeler, E. B. (2006). *Costs and Benefits of Health Information Technology. (Prepared by the Southern California Evidence-based Practice Center under Contract No. 290-02-0003.)* (Rep. No. 132). Rockville, MD: Agency for Healthcare Research and Quality.

Stahl, B. C. (2008). The ethical nature of critical research in information systems. *Information Systems Journal*, *18*, 137–163. doi:10.1111/j.1365-2575.2007.00283.x

van't Riet, A., Berg, M., Hiddema, F., & Sol, K. (2001). Meeting patients' needs with patient information systems: potential benefits of qualitative research methods. *International Journal of Medical Informatics*, *64*, 1–14. doi:10.1016/S1386-5056(01)00185-X

Walshe, K., & Freeman, T. (2002). Effectiveness of quality improvement: learning from evaluations. *Quality & Safety in Health Care*, *11*, 85–87. doi:10.1136/qhc.11.1.85

Welch, S. J., & Allen, T. L. (2006). Data-driven quality improvement in the emergency department at a level one trauma and tertiary care hospital. *The Journal of Emergency Medicine*, *30*, 269–276. doi:10.1016/j.jemermed.2005.07.007

Wilson, M., & Howcroft, D. (2002). Re-conceptualising failure: social shaping meets IS research. *European Journal of Information Systems*, *11*, 236–250. doi:10.1057/palgrave.ejis.3000437

Wyatt, J. C., & Wyatt, S. M. (2003). When and how to evaluate health information systems? *International Journal of Medical Informatics*, *69*, 251–259. doi:10.1016/S1386-5056(02)00108-9

Zuboff, S. (1988). *In the age of the smart machine the future of work and power*. New York: Basic Books.

KEY TERMS AND DEFINITIONS

Continuous Quality Improvement (CQI): The application of Deming's form of QA to healthcare (see *Quality Assurance* below).

Critical Research in Information Systems (CRIS): An approach that draws from critical theories in the social sciences and attempts to discover angles typically overlooked by traditional research. A main aim of CRIS is to promote emancipation, understood as the ability of individuals to live a self-determined life.

Electronic patient record (EPR): allows health care providers, patients and payers to interact more efficiently and in life-enhancing ways. It offers new methods of storing, manipulating and communicating medical information of all kinds, including text, images, sound, video and tactile senses, which are more powerful and flexible than paper based systems. The policy of governments appears to favour a national healthcare infrastructure with a longitudinal patient record covering a patient's complete medical history from the cradle to the grave. (Rogerson, 2000)

Healthcare Information Systems: An information system (IS) is a system of persons, equipment and manual or automated activities that gather, process and report on the data an organization uses. A healthcare information system is one used by an organisation involved in the delivery of health care.

Object-Oriented Programming: A programming paradigm that uses "objects" and their interactions to design applications and computer programs. Programming techniques may include features such as encapsulation, modularity, polymorphism, and inheritance.

Quality Assurance: W Edwards Deming defined quality assurance as the continuous, systematic, iterative improvement of processes by obtaining feedback from clients and from staff. It may be viewed as a standardised, ongoing conversation about the important characteristics of a process.

Rationality: Best exemplified by the autonomous individual on whom neoclassical economic theory is built. Such an individual is rational because she has a complete set of preferences and acts in order to maximise her utility according to these preferences.

Stakeholder: A person, company, etc., with a concern or (esp. financial) interest in ensuring the success of an organization, business, system, etc. (taken from OED Online: http://dictionary.oed.com/).

This work was previously published in Handbook of Research on Advances in Health Informatics and Electronic Healthcare Applications: Global Adoption and Impact of Information Communication Technologies, edited by K. Khoumbati, Y.K. Dwivedi, A. Srivastava, and B. Lal, pp. 333-352, copyright 2010 by Medical Information Science Reference (an imprint of IGI Global).

Chapter 7.9

Improving the Quality of Healthcare Research Data Sets

Biswadip Ghosh
Metropolitan State College of Denver, USA

ABSTRACT

The goal of many healthcare research projects and evidence based medicine programs within healthcare organizations is to support clinical care team members by mining evidence from patient outcomes to support future treatment recommendations. In these research studies, the data is often extracted from secondary sources such as patient health records, benefits systems, and other nonresearch data sources. Good data is important to facilitate a good research study and to support clinical decisions using the results. Often multiple applicable healthcare data sources are available for a research study, some of which may be internal to the organization, while others may be external, such as state or national databases. This chapter attempts to develop an understanding of how the quality of data for healthcare research data sets can be established and improved when using secondary data sources, such as clinical or benefits databases, which were created without primary intentions for research use.

INTRODUCTION

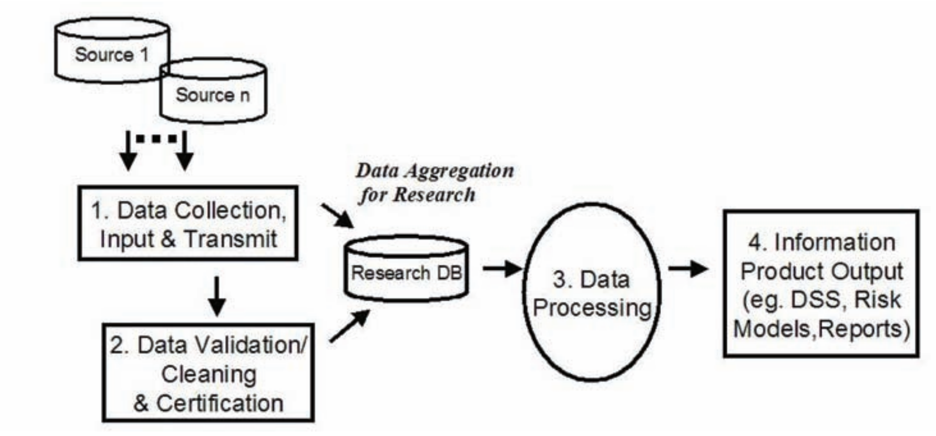
Asserting data quality is a critical component of any information systems based research project (Brodie, 1980). In healthcare organizations, research is often conducted using secondary data sources such as databases set up for patient medical records, insurance billing and benefits administration. As in other domains, data quality problems are increasing in such organizational databases (Wang, Strong and Firth, 1995; Storey and Miller, 1995). Prior studies have reported that between 50-80% of records in many such databases may be inaccurate, incomplete or ambiguous (Redman, 1998). The ramifications of using poor quality data in a research study can be quite costly –incorrect results that are flawed and unusable. Information systems built upon data sets of poor data quality with missing information and processes that allow information to bypass key managers can lead to catastrophic failures (Fisher and Kingma, 2001). To build validity in research results, data quality must be established, particularly when using secondary data sources, which are subject to multiple recording bias (Terris, Litaker and Koroukian, 2007). This chapter addresses several techniques that are suitable for implementation via organizational processes, managerial actions and technological and statistical approaches that can help build data quality. A case study is also illustrated that uses these techniques to establish data quality for data obtained from secondary data sources, such as patient records and benefits databases for use in a healthcare research project.

This chapter applies a data product lifecycle approach towards improving data quality. This approach views data as a product, and uses a value stream for the product similar to manufacturing processes (Lee and Strong, 2003). Data quality is an overarching concept that must be addressed in the entire process starting from data collection to data storage to the end production of the data product (e.g. reports and a decision model) and its usage. Data quality cannot not be simply viewed as the aggregate quality of the data elements; rather it must also include the quality of the data collection process, the support of the access methods and ways in which users manipulate the data, the actual processing of the data and the usage of the end (information) product produced from the data. Dimensions such as efficiency and timeliness of the collection phase, the completeness and accuracy of the data items, the accessibility and security of the data and the data output products by the different users, all play a large role in the definition of data quality. This concept of a data lifecycle is extremely important in the establishment of data quality. The role of different organizational stakeholders in establishing data quality and the interventions required to ensure data quality can be better evaluated using the lifecycle approach (Lee and Strong, 2003).

A typical data lifecycle for a research study using secondary data is shown in Figure 1.

Data from multiple secondary sources are extracted, transmitted and collected (step 1) into the research database (DB). The collected data is checked for inconsistencies, incompleteness and other validity problems during the database storage phase (step 2). Rather than rejecting problematic records and causing data loss, records with inconsistencies are flagged and systems are used to clean and subsequently certify the aggregated data in the research database. Appropriate updates (step 2) are made and data quality managers then certify the data set. The data is then processed (step 3) into information products, which are output (step 4) for users to access and use. Note that each step in the lifecycle must focus on the data as well as the management of the data by the people in the process. Hence, each step in the

Figure 1. Typical data lifecycle



illustrated process has organizational and managerial elements. How this triad of (1) technology, (2) organizational practices and (3) management practices can address the threats to data quality and enhance quality will be described in this chapter.

DATA QUALITY CHARACTERISTICS

The research literature in data quality has established multiple dimensions in the definition of data quality (Wang and Strong, 1996; Strong, Lee and Wang, 1997a). Some definitions view data quality as an intrinsic property of the data and include such characteristics as accuracy, completeness and objectivity of the data. The intrinsic category also has organizationally derived characteristics that include such factors as reputation and believability of the data as well. But other definitions provide a much broader concept of data quality that also includes an extrinsic category that stems from the organizational standpoint of data quality. The later view accepts the fact that the quality of data cannot be established without the inclusion of additional factors that originate from (a) the management of the data and (b) the users of the data and information products produced from the data. This extrinsic category therefore also includes the access and ease of understanding and use of the data. The extrinsic category can be influenced by such factors as the volume of data, the timeliness of availability of the data as well as the means of accessibility – both technologies and processes and security of data storage/access. For this study, data quality consists of the following four categories– (1) Intrinsic, (2) Accessibility, (3) Contextual and (4) Representational (Strong, Lee and Wang, 1997a). The last three categories are referred to as the extrinsic categories of data quality. Each of the data quality categories is defined by several dimensions and the threats to each category can originate from multiple sources.

Intrinsic Data Quality

The Intrinsic data quality is defined by the actual problems with the data. Such problems may result in problems in accuracy, where the data is incorrect, or lacks objectivity because there was subjective judgement involved in the collection of the data. Such issues may also arise if multiple sources exist for the same data and they conflict with each other. The reputation of the sources of data can also influence the believability of the data. In such situations, additional organizational approaches must be established to improve the validity of the data by introducing data certification processes.

Accessibility Data Quality

Accessibility is an important dimension for data quality as proper access has to be provided to the right people to the data during all phases of the data lifecycle – collection, cleaning, processing and output. If access is too restrictive in the collection phase, then incorrect and incomplete data may be collected. During the data cleaning phase, the key members of the data collection team must be given access to correct, update and certify their representational data. All of these activities require adequate technology support together with management of access rights. Any deficiency in the technology infrastructure supporting the data project will lead to data quality issues.

Access can also be too restrictive, where the right users do not get access to the data and/or the end information product results from the processing of the data. Data access can be too loose and result in unauthorized users getting access to data and compromising the integrity of the data in the process. The volume of data can also be an issue leading to data quality problems. Proper partitioning of the data can help if there is a large volume of data to work with, which may become cumbersome and delay all phases of the data lifecycle. Partitioning also allows the data to be made avail to the right subset of users. In a distributed environment, when data is obtained from multiple sources and users, there is a need for coding and standardization of fields and values, otherwise objectivity can be compromised.

Representational Data Quality

This category of data quality issues arise from concerns about the interpretability and understandability of the data. These issues are profound when data collection and/or consumption is distributed across different groups. Timeliness of the data must be supported by encouraging prompt updates from the users. Standards and uniform coding allow for better representational quality of the data and less inconsistencies due to multiple data sources. Such standards and coding can be encouraged thorough organizational training and development activities and data lifecycle management.

Contextual Data Quality

Contextual data quality represents the issues when the data collected does not support the requirements of the project. Perhaps the data fields have not been correctly defined or the data is not measured and/or organized properly. Projects related to the data collection, processing and information generation results in some key elements missing leading to a lack of meaning in the results for the users. Ensuring completeness of the data fields and their proper definition are required during both the build and execution phases of the data lifecycle to ensure that the efforts surrounding the data project result in useful data and data products.

ASSESSING DATA QUALITY

Measures of data quality have been described in other studies (Ware and Gandek, 1998; Lezzoni, 1997; Gandek, et. al., 1998). Such measures fall into (1) the checking for completeness of the data set, (2) passing validation checks for value ranges (systolic blood pressure between 50-250), (3) establishing relationship among fields (eg: date of death after date of birth) and (4) coding accuracy and consistency across sources. Other checks include the use of statistical scales such as correlations among items to assess discriminant and convergent validity, reliability metrics such as Cronbach's alpha and measures of centrality, variance and range.

From the data lifecycle approach to collecting data and using data as an input to the information product additional data quality measurement items are necessary. These include the assessment of the resources being used to efficiently collect data, to check the data against validation rules, the timely resolution of exceptions, conflicts, and quality problems uncovered by the checks, the methods of organizing and partitioning the large data sets and the means of access to the data across the system are important as well.

Table 1 summarizes the four categories of data quality – intrinsic, accessibility, representational and contextual, by defining those categories and their dimensions and lists the possible measurements to assess each of the categories.

THREATS TO DATA QUALITY

This section elaborates on the threats to data quality. Prior research has also identified several threats to data quality (Strong, Lee and Wang, 1997b). These threats can compromise data quality if not addressed with adequate organizational, managerial or technological solutions during the data lifecycle. These threats are also common in the health informatics domain and often lead to

Table 1. Summary of dimensions of data quality and their assessment

Data Quality Categories	Dimensions	Measurement Items
Intrinsic	Accuracy, believability, objectivity and without multiple source conflicts	Completeness of dataset and fields
Accessibility	Role specific access rights for users, Partitioning, Technology to support efficient data lifecycle.	Adequate collection resources, Partitioning and Access
Representational	Interpretability and understandability of the data, Timeliness and the Establishment of Standards	Agreement on coding and subjective scales, Timeliness of collection and resolution of exceptions
Contextual	Definition of fields; Proper meaning and organizational purpose, Completeness	Number of validation rules passed; Number of conflicts and duplications removed

problems in producing quality clinical research data sets. The threats to data quality along with some solutions to avert the threat in healthcare research are discussed below.

Multiple Sources

Multiple sources for the same piece of data has the potential to produce conflicting values. The conflict maybe in the way the data is coded, or the value itself. For example in the healthcare setting, a database targeted at recording patient health records may have fields coded and stored lees stringently than a systems geared for insurance billing. The patient records may contain multiple treatment and symptoms in textual form, while the later only contains the primary disease codes and treatment codes that are reported for insurance purposes. Distributed heterogeneous systems without proper integration mechanisms lead to inconsistent definitions, formats, rules and values of data.

Such contradictions create problems, when data extracts received from such data sources are processed with automated programs to generate the research data set. The original meaning of data may be lost or distorted as data flows between systems and is retrieved from a different system, time and place for the same or different purpose. In these scenarios, data quality must be established with organizational interventions and processes to have human data collectors certify the research data sets, when discrepancies arise. Data aggregation processes must be established along with common norms and knowledge across the dispersed data collection team. Data management processes such as timely and secure data transmissions, aggregation and certification help to resolve issues arising from distributed heterogeneous systems.

Subjective Judgments

The data collection process in healthcare often involves subjective judgment of one or more human users. For example, a particular patient’s symptoms and their severity, such as regarding whether they are life threatening or less adverse are often the judgement call of the clinician at the patient’s side. However, once the value is entered into the system, the value is treated as a fact. Data collection at multiple hospitals can produce even greater issues – as the training and practices of the clinicians performing the data collection may be greatly different. The data collected and used in different areas of specialization are coded differently, leading to data quality issues. Some departments may still collect patient data using detailed notes in a patient record system, while other department may be collecting the same data using electronic forms that require selection of a range for each patient parameter. Such divergence in coding of data collected through subjective judgments cannot be simply processed with automated programs to generate the research data set. It is impossible to establish data quality without organizational interventions and establishment of processes to have human data collectors certify the research data sets for data elements identified as requiring subjective judgement in the collection stage.

Healthcare organizations have highly organic structures with limited formalization or standardization of behaviors of the clinicians (Ghosh and Scott, 2008). The clinical staff – physicians and nurses mostly work in highly specialized jobs and departments in a fairly autonomous fashion. Hence codes and conventions across disciplines are hard to establish. While technology can help somewhat in transcribing between formats, it is impossible to establish data quality without organizational interventions and establishment of processes to have human data collectors convert the clinical data into research data sets using uniform coding schemes. These are well supported using data entry templates that guide the data collector to enter fields in the right coding for the research data set and training to calibrate data collectors on the data scales.

Limited Computing Resources

The deployment and use of computing resources are extremely important in all stages of the data product lifecycle. Technology can play an important role in the collection, update and certification, protection and access of the data and its end products. Without adequate computing resources, which data collectors can efficiently use in the collection phase, the chance of data not being recorded increases leading to data loss and incomplete records. Likewise, if the technology is slow, a bottleneck situation is created leading to further data loss. As technology advances and becomes cheaper and faster, powerful devices can be placed with the data collectors and during the use stage of the data product cycle to allow for ubiquitous use and improve the quality of data. In the surgical setting, by providing hand held devices to nurses equipped with templates and forms for data entry, the research team can ensure that all the needed data fields about the patient are captured and coded per the requirements of the research study.

Access to data during the data product lifecycle is an important requirement to allow certification of data quality. Users collecting and/or using the data need to have efficient and easy access to the data to input, review, update and use. Any problems with access can lead to loss of data and lower data quality. In healthcare, regulations require that only authorized people, who are caring for a patient to be able to view the patient's data. Hence security policies in healthcare can restrict access and not allow others involved in collecting, processing or using the research data from accessing the data. This trade-off between security and accessibility can be resolved by de-identifying patients in their data, as well as proper training in data security and privacy for staff, who are involved in the data product lifecycle.

The volume of data poses unique access problems. Patient record systems often contain millions of records and capture minute details about the patient's interactions across all departments and specializations that the patient comes in contact with at the hospital. However, a research study may only need a certain set of patients over a defined short range of dates and a type of care. In this scenario, access to records may be unnecessarily slowed down by the volume of the data set. In such cases, data collectors and users can be reluctant to collect, update and use the data due to access speed/convenience issues. To address these problems is it advisable to receive extracts of the patient records that are relevant to the research study with only the relevant fields (for the research study) and then perform subsequent manipulations of the data in a separate store from the original data system. Another technique used involves partitioning the data so that selected users only access the data they are responsible for.

This also increases the access speed and provides some security as well.

Input Rules Too Restrictive

Input rules that are too restrictive may impose unnecessary controls on data input and lose data that has important meaning. Data entry clerks may also skip entering data into a field that imposes difficult checking, resulting in data loss. They might enter a different arbitrary value just to get past the checking and hence compromise the accuracy of the data in the process. The better approach is to allow data to be collected, but questionable values or empty fields could be flagged for future resolution in the data cleaning process. Again organizational interventions and establishment of processes will have to be done to have human data collectors either correct fields that may be inconsistent or certify those fields as actually correct (exceptions), even though values may violate consistency rules.

Changing Data Needs

Often the form in which the data is collected, stored and/or used can change over time particularly if a research study is replicated or completed multiple times. This may lead to data quality issues as the data could have been coded in a way to support one research project that makes it unusable for a different study. Moreover, certain data fields may be missing as well. It is desirable to be able to go back to the original data source - clinical, billing, etc. and be able to produce a new research data set once again. This is only possible if a repeatable set of process steps have been established, recorded and tested of how those data sets are being manipulated to produce the research data set.

FRAMEWORK TO ESTABLISH DATA QUALITY

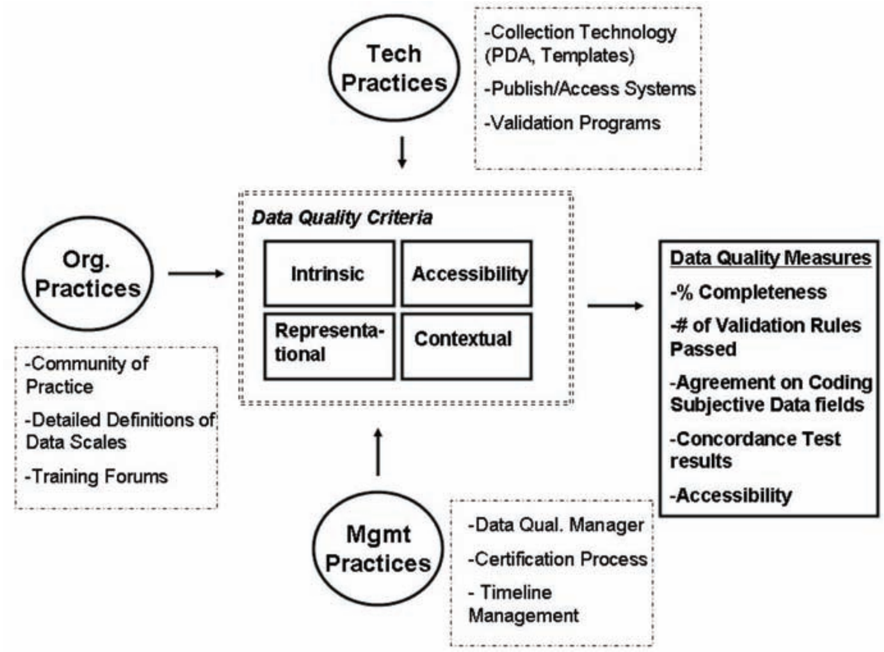
The threats to data quality can be alleviated by treating the generation of the research study data set as an information product and applying techniques and processes to strengthen the data quality. The methods to improve the data quality and the quality of the information products generated from that data can be classified into three approaches: (1) organizational, (2) managerial and (3) technological. For most information systems scenarios, all three approaches must be combined to address the multitude of threats to data quality described in the previous section. Figure 2 shows the research framework with the four dimensions of data quality and the three categories of practices to improve data quality together with measurement items.

Organizational Practices

Organizational approaches must be established when data collection or usage activities spread across multiple departments, who may or may not have standardized approaches to handling data. Often these data lifecycle activities span department boundaries and common understanding must be established between members across departments for the success of data projects. Organizational practices can also help to build bridges to allow data related activities to transcend formal organizational charts.

Some of the important organizational practices include (1) establishing communities of practice, (2) holding periodic forums/conferences, (3) developing a sharing culture and (4) supporting continuous training and education. Communities of practice foster an environment conducive to learning and innovation with respect to data quality activities. A community of practice is defined as a group of people bound together by shared practices, experiences and expertise for a command

Figure 2. Data quality improvement framework



purpose (Wenger and Snyder, 2000). The essential feature of a community of practice is that mutual engagement through interpersonal interaction is an essential activity that allows a sense of joint enterprise in a loosely connected team (Brown and Duguid, 1991). The users involved in these activities can share their experience with others across department boundaries as well as tap into the expertise of others by posing questions to the community. Such sharing builds standards and commonality of operating methods among data lifecycle staff, even when across their reporting departments, standards rarely exist.

A complementary channel to the informal communities of practice is the hosting of formal forums and conferences on a periodic basis. Such forums bring all stakeholders together as such events should be designated as mandatory participation. Events held every 6 months are a good frequency for most projects that are not undergoing too much change. For data projects that are just starting up or encountering a lot of change, more frequent forums must be held, perhaps quarterly or even monthly. The forums also encourage sharing and build appreciation of all the stakeholder's roles, perspectives and concerns. They are a channel to disseminate up to date information on project status and introduce new practices into the group in a formal way.

The efforts to build culture among the stakeholders and all users involved in the data lifecycle can be approached through multiple channels, both formal and informal. The culture should promote trust and safety to report any data quality problems. By building group identification among members of the data project, regardless of their physical dispersion or reporting departments a cohesive culture can emerge that can help in times of project crises. Culture also promotes shared norms and expectations and builds trust among the group.

Finally, training and certifications must be a central part of the organizational approach. Refresher courses on regulations, data privacy, technology and other aspects must be completed by all users. This places an emphasis on learning among the group members and protects against the abuse of data. In the healthcare setting, the data is often patient identifying and if improperly handled can lead to significant privacy issues for the organization.

Managerial Practices

Managerial practices are important components of countering many of the threats to data quality by putting a focus on the complete data lifecycle. Managerial practices must encourage the management of the data together with the products of the data. A simplistic focus on only data quality without a comprehensive approach to improve the quality of the overall data product lifecycle is not desired as the focus of the organization shifts to the wrong goal. Managerial attention in the data lifecycle involves defining and staffing the roles in the process and also staffing a data quality manager who is responsible for the managing the information processes and products. Managerial attention must be also focused on finding out about any new knowledge and implementing them in the process to improve data quality in a continuous fashion.

The managerial practice also involves setting goals such as the timely aggregation of data, appointing staff, who can view and/or update the data and assigning roles to users and defining who can access what in the final product. The data manager is not usually responsible for the storage and networking infrastructure, as the IT staff takes care of that. However, the data manager's responsibilities span the data lifecycle and the quality of all data and data products. Managerial attention must also be placed on the organizational practices that have been established earlier and ensuring that those activities are working suitably.

Technological Practices

Technological approaches to improving data quality include taking steps to address threats such as possible accessibility and security issues as well as working with large volumes of data by partitioning them into manageable pieces. Building software code to check data elements as they are entered into the repository and the execution of consistency checks can also be done with the aid of technology. Care must be taken to not burden the data entry person with too restrictive entry rules, or that might result in loss of data. The better approach is to allow the data to be input and stored, but flagged for further investigation and needing possible correction before use.

Technology also can be used in the data collection stage by providing forms and templates to the data collectors to use during that process (Chen, et.al., 2007). This allows for standardization of the data collection process across departments thorough the use of software. Technology, such as wireless handheld devises may be put in to the hands of the data collectors to allow for a more efficient collection process. The end result of the data collection, the data product itself can be placed in the users hands to also increase the adoption and use of the data product. Technology can also be used to perform format conversions and allow data from multiple sources to be aggregated. Statistical tools can be used to compare the concordance of two data sources, when there are common fields between those sources. Metrics that report the agreement between the sources can be used as confidence boosters in the aggregation of data fields.

Table 2 summarizes the threats to data quality and potential approaches to alleviate the threats.

CASE STUDY

This remaining portion of the chapter illustrates the practices of a live healthcare research project that has implemented many of these interventions to improve data quality. The goal of the healthcare research project illustrated here is to produce a

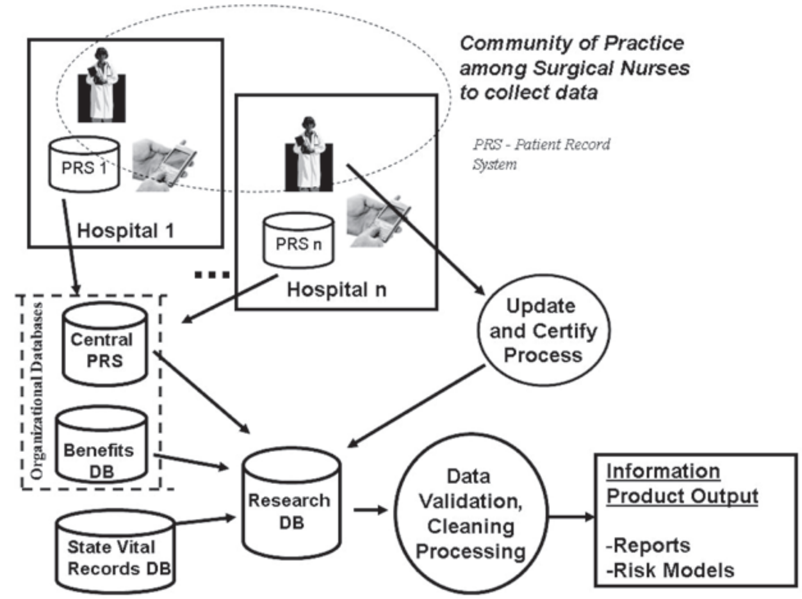
Table 2. Summary of data quality threats and alleviating practices

Threat to Data Quality	Data Quality Category that is Impacted		
	Organizational Intervention	Managerial Intervention	Technology
Multiple Data Sources	Establish Knowledge sharing Communities of Practice/forums	Data aggregation and certification process	Concordance Testing; Database Validation Checks
Subjective Judgments	Establish Norms on Values and training data collectors	Defining levels for a variable to make it a more objective measure; Process to certify final research data set	Data collection Templates with choice boxes; Aggregation of data using database programming
Limited computing Resources	Training on technology to allow efficient use	Control access rights to data by partitioning data and assigning responsibilities and user roles	Update computers; Handhelds to assist in data collection Partitioning Data set
Restrictive Input Rules	Prevent data loss by training users on data entry forms/templates	Establish process of flagging and fixing defects	Data Validation rules and integrity checks
Changing Data Needs	Future data needs planning and training activities	Select new data to capture per requirements	Save copies of original data sets with more variables outside the research data set.

surgical risk model to be used by surgeons to make decisions on the expected mortality or morbidity of performing an elective surgery. The model is produced based on data collected on past surgeries and their outcomes – including mortality, morbidity and other complications. Over 35 variables indicating the conditions of the patients before and after surgery such as blood pressure, weight, height, past surgical history, alcohol use, etc. are collected and used to generate the regression model supporting the decision support system. The risk model is updated every quarter based on new surgeries (and their outcomes) that took place in the past quarter. Data is collected throughout the quarter using a defined process. The data is certified at the end of the quarter, before the statistical processing is done to generate the risk model and distribute it to the surgeons. The surgeons use the risk model to assess the risk of a surgical procedure for their patents on an ongoing basis.

The healthcare system in which this project is being conducted is a national system, with multiple hospitals, where surgeries are performed. Most of the hospitals use a single patient record system, into which information collected on patient visits and treatment and procedures are recorded. Patient record systems can be a source of medical data about the patient but have certain characteristics that make it difficult to process the data in the system. Data may include images, such as X-rays, as well as physician's notes that are in free format. Such free format notes may be processed using sophisticated text mining to find usable data for research purposes (Cam, Efthimiadis and Hammond, 2008). Moreover, in a distributed health care network, practices surrounding what needs to be recorded and the conventions around the data entry into the patient record system varies greatly across hospitals and care facilities and as well as across specializations within those hospitals and care facilities. Additionally, some hospitals are using their own patient records system, which is different from the central system used by the health care provider network. When a patient subscribing to the healthcare system visits one of those centers, often the data is only migrated several months later through a manual process into the central patient record system. The process is illustrated in Figure 3.

Figure 3. Data lifecycle for healthcare research project



The healthcare system also maintains an administrative/benefits system that tracks additional biographical information about the patients/subscribers and benefits received. This later system also tracks the deaths, as a death benefit is paid to the patient's beneficiary of record. While occasionally some deaths may occur during a hospital stay or patient visit, most deaths happen outside the healthcare system's facilities. Therefore, death information is entered when a relative claims a death with a death certificate. For patients without beneficiaries, state or national death registries need to be manually checked by the research personnel to pull death information into the healthcare systems database on a periodic basis. Death information is particularly important as the risk model utilizes mortality and morbidity rates within 30 days of surgery, rates during the 30-90 days after surgery, rates during the 90-180 days after surgery, rates during the 180-360 days after surgery and rates during the 360day-3years after surgery for different surgeries.

Threats to Data Quality

The healthcare system has deployed necessary systems to electronically store patient records and information about their benefits. These databases are not primarily research oriented. Hence, standards are poor, and the data put into these systems vary greatly across hospitals and the clinicians doing the recording. Yet these secondary databases can provide a rich source of research data, which can be used when adequate steps have been established to clean and certify the data. The threats described earlier in this chapter all exist for this scenario as well. Multiple data sources often contain data for a patient and they need to be consolidated when the patient undergoes a surgery and becomes part of the pool of patients who have had surgery and now their data is used to produce the risk model every quarter going forward.

Table 3 summarizes the threats to data quality and the approaches used to counter the threats in this case study.

Table 3. Data quality threats and interventions pursued

Threat to Data Quality	Origins of the Threat	Interventions Used to Improve Research Data Quality
Multiple Data Sources	Multiple hospitals and providers using different patient record systems	Creating a data certification process (Managerial) Data validation checking for ranges, values and field comparisons (Technological) Use of data source concordance tests to establish reliability of data from multiple sources (Technological)
Subjective Judgments	Patient data entry and the coding of variables vary greatly between hospitals, providers and specializations.	Standardization of the coding of the variables that are part of the research study and training and support for nurses/physicians to adopt standards (Organizational) Provide templates & FAQ on handheld devices to ensure adherence to data collection standards (Technological) A research focused database in common format was created to receive and store patient records of surgeries and updates for patients who have become part of the "surgical pool", every quarter. (Technological)
Limited computing Resources	The system handles a very large volume of surgeries as the total number of subscribers is over a million strong. The centralized patient record system and the benefits systems are hosted on mainframes, where typical jobs can wait several hours to complete due to the number of users trying to access the system simultaneously. Multiple users with different roles needing access to different data/model.	A research focused database was created to receive and store patient records of surgeries and updates for patients who have become part of the "surgical pool", every quarter. (Technological) Handheld appliances with data entry templates provided to clinicians to ease data collection. (Technological) Establish Web site with different user roles to support correct level of access to the research data (Technological) Support clinicians in a community of practice to ensure stakeholders understand each others roles (Organizational) Handheld appliances with the risk model provided to surgeons to use in their patient evaluations (Technological)
Restrictive Input Rules	Extracts and Feeds received from multiple systems result in validation issues when put into the research data warehouse.	Database procedures and code is created to check for data to be in specified ranges and also fields are checked against each other for value conflicts (Technological) The invalid data is not rejected, rather violations are flagged for later verification by humans – tracked by a data quality manager (Managerial)
Changing Data Needs	New types of surgeries and/or new research publications require that different variables be collected for new risk models.	Support clinicians in a community of practice to ensure they understand each data element and new ones as well (Organizational) Database extracts can be merged into the research database to bring in new variables (Technological)

Summary of Methods to Improve Data Quality

The following sections describe the main practices (summarized in the table 3) used to improve data quality in the research data set.

Use of Data Concordance Tests

Concordance Tests take comparisons of records using prevalence-adjusted and bias-adjusted kappa scores to establish confidence before mapping research constructs to data items and proceeding with the research study (Looney, 2002). Kappa scores can be computed on categorical data and is useful for assessing the agreement between multiple data sets. An important first step in this study was to confirm death events, the date of death, and cause of death by comparing and verifying records from multiple data stores – benefits, state and national sources, particularly when none of the databases might be considered a gold standard for death events. The sensitivity of the risk algorithm to correct recording of patient deaths implied a need to perform verification across multiple data sources. The first step was to evaluate reliability for death events reported in the benefits system and the patient's home state vital records system, where death events are recorded. Second, the accuracy for date of death for those identified events was assessed via comparison between state vital records and the benefits system as well. Again the state vital records is not a gold standard as the death may have happened in a different state and may not have propagated to the patient's residence-state vital records system yet. Prevalence-adjusted and bias-adjusted kappa's were calculated to get a measure of agreement between two data sources. Kappa scores in the high 90% (above 97%) signified satisfactory concordance between data sources- the benefits system and the state vital records. This raised the confidence of using the benefits system (an internal organizational database) as a source of information on patient death events.

Use of Technology: Database Servers and Handhelds

The data project was supported by technology in several places. In the collection phase, surgical nurse recorders in each hospital were given handheld devices with data collection templates to make their data collection more efficient. These devices allowed the nurses to collected data using ranges of values from menus. Unlike the patient record system, the menu based handhelds allowed for standardization of data across multiple facilities. Data from both sources were used – the clinical records and the handhelds. However, the clinical records were mainly to ascertain the number of surgeries in a quarter and to ensure the nurses did submit data for each surgery from their handhelds. Technology in the form of a server, database management system and web portal site, allowed the authorization of the right data collectors to use the site to view, update and certify the surgical data for their patients only. Finally the risk model (a regression model linking the multiple patient variables to the outcomes of surgery – no complications, complications with morbidity and mortalities over the different post surgery time periods) was also installed on a handheld device for distribution and use by surgeons in assessing the risk of a patient for an elective surgery. Threats to data quality from accessibility, security and inadequacy of technology were clearly addresses in this project.

Database Validation Processes

The database is setup with programmed objects to check for completeness and validity of the fields. The programming checks include:

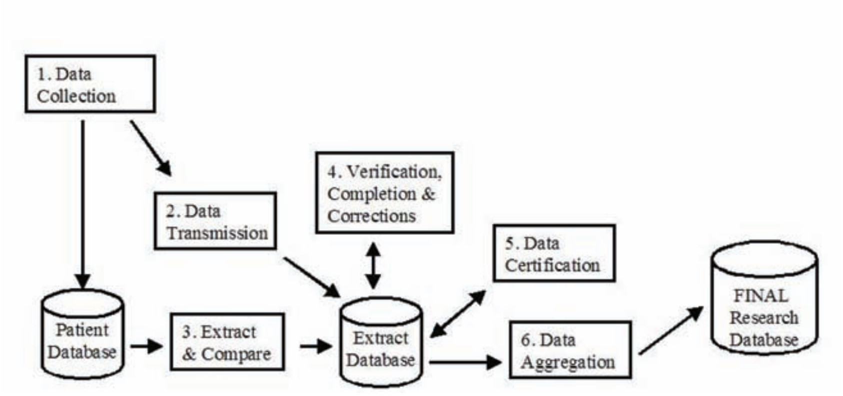
1. Check for the completeness of the records: All fields are present and all surgeries for the period are accounted for.
2. Check for range of Values: e.g. systolic blood pressure between 50-250.
3. Check for consistency between fields: e.g. date of death after death of birth.
4. Check for duplication and flag all exceptions for manual certification.

Validation failures are flagged for manual certification using the data certification process described below. The data quality manager is responsible for the timely resolution of data quality failures.

Building Communities of Practice

Communities of practice focus on fostering an environment conducive to learning and innovating with respect to data quality activities among the stakeholders of the data project. They create a learning culture, build trust and encourage sharing of experiences learned from participation in the data lifecycle. When questions might arise about a data field, its coding, etc. the community of practice allows the dissemination of up to date information and fosters an appreciation of each stakeholder's role and responsibility. As such threats to data quality arising from multiple data sources and the subjectivity of each hospitals data recording procedures were alleviated. In this

Figure 4. Data cleaning/certification process



research project, communities of practice were established for the surgical nurse recorders to help them understand the meaning of data items being captured for the research study through monthly conference calls, an email distribution list, a FAQ web page and a web based discussion board.

The Data Certification Process and the Data Quality Manager

A data quality manager was in charge of the quarterly data certification process. Each recorded surgery from the patient record system was collected into the research data base and surgical nurses were asked to make updates to the data from their handheld devices. After this was done, each hospital's designated contact person (i.e. the surgical nurse recorder) had to certify the data as correct. The data quality manager was responsible for this process and made sure that timely certifications were done, so that the research data could be used to generate the data products – reports and the risk model. Therefore the data quality manager through their managerial activities was able to alleviate the threats to data quality arising from multiple data sources, hospital systems and manage any fallout from the input data checking process.

The certification processes was done at two points, the first part was at the input stage, where data fields flagged as problematic (failed checking or missing values) were corrected by the surgical nurses using web based forms. The nurses collected the data on their handheld devices as a supplementary system to the patient record system. The second part of the certification process involved certifying the final set of patient surgery cases in the past quarter before the processing was started. This was the responsibility of the chief of surgery for each hospital, who relied heavily on the surgical nurses. The data quality manager was fully responsible for the smooth running of the data certification process and timely updated to defective data. (See Figure 4)

RESULTS

The results from the data quality improvement program were positive. All fields were represented by discrete input scales to avoid semantic data entry problems. A brief survey to assess the agreement of the data collectors on the meaning of the data fields and the correct interpretation of input rating values showed strong agreement. Kappa scores in the 90% were obtained when comparing ratings entered by multiple collectors on given patient scenarios. Over 100 validation checks are programmed in the database, and the data set has to pass each one every quarter. The completeness of the data set is estimated to be close to 100%. All indications suggest that the triad of practices established have substantially improved the quality of the data set.

CONCLUSION

Healthcare research data is often extracted from secondary sources such as patient record systems and patient benefits and other non-research data sources. The quality of such data can be problematic as multitude of threats exist that can hamper data quality. In this chapter, practices to establish data quality suitable to support research studies were illustrated. Good data is important to facilitate a good research study and resulting clinical decisions. Good quality data, which is timely and accurate and can be easily represented and understood, can significantly improve healthcare research projects and patient outcomes. A case study was also illustrated that uses these techniques to establish data quality for data obtained from secondary data sources, such as patient records and benefits databases for use in a healthcare research project. This chapter applied a data product lifecycle approach towards improving data quality. This approach views data as a product, and uses a value stream for the product similar to manufacturing processes. Data quality is an overarching concept that must be addressed in the entire process starting from data collection to data storage to the end production of the data product and it usage. A multifaceted approach involving managerial practices, organizational practices and technological practices were implemented to counter threats to data quality. These practices are fairly generic and allow for use in many different data projects. However, these practices require a strong commitment of resources – labor, capital and equipment. The application of such magnitude of resources should be commensurate upon the needs for data quality and a cost benefit analysis should be done. A future research may address these issues of cost benefit tradeoffs and quantify the measures of data quality and the relationships between these interventions and what threats/dimensions of data quality they address.

REFERENCES

Broodie, M. L. (1980). Data quality in information systems. *Information & Management*, *3*, 245–258. doi:10.1016/0378-7206(80)90035-X

Brown, J., & Duguid, P. (1991). Organizational learning and communities of practice: Toward a unified view of working, learning, and innovation. *Organization Science*, *2*, 40–57. doi:10.1287/orsc.2.1.40

Cam, K. M., Efthimiadis, E. N., & Hammond, K. W. (2008, January 7-10). An investigation on the use of computerized patient care documentation: Preliminary results. In *Proceedings of the 41st Hawaii International Conference on Systems Science*, Waikaloa, HI.

Chen, R., Enberg, G., & Klein, G. O. (2007). Julius–a template based supplementary electronic health record system. *BMC Medical Informatics and Decision Making*, *7*(10), 15–23.

Fisher, C. W., & Kingma, B. R. (2001). Criticality of data quality as exemplified in two disasters. *Information & Management*, *39*, 109–116. doi:10.1016/S0378-7206(01)00083-0

Ghosh, B., & Scott, J. E. (2008, January 7-10). Knowledge management for healthcare organizations: Comparing strategies with technical support. In *Proceedings of the 41st Hawaii International Conference on Systems Science,* Waikaloa, HI.

Lee, Y. W., & Strong, D. M. (2003). Knowing-why about data processes and data quality. *Journal of Management Information Systems*, *20*(3), 13–39.

Lisa, I., & Iezzoni, L. I. (1997). Assessing quality using administrative data. *Annals of Internal Medicine, 127*(8-2), 666-674.

Looney, S. W. (2002). *Biostatistical methods*. Totowa, NJ: Humana Press.

Redman, T. C. (1992). *Data quality: Management and technology*. New York: Bantam Books.

Strong, D. M., Lee, Y. W., & Wang, R. Y. (1997a). Data quality in context. *Communications of the ACM*, *40*(3), 103–110. doi:10.1145/253769.253804

Strong, D. M., Lee, Y. W., & Wang, R. Y. (1997b). Ten potholes in the road to information quality. *IEEE Computer*, *30*(8), 38–46.

Strong, D. M., & Miller, S. M. (1995). Exceptions and exception handling in computerized information processes. *ACM Transactions on Information Systems*, *13*(2), 206–233. doi:10.1145/201040.201049

Terris, D. D., Litaker, D. G., & Koroukian, S. M. (2007). Health state information derived from secondary databases is affected by multiple sources of bias. *Journal of Clinical Epidemiology*, *60*(8), 734–741. doi:10.1016/j.jclinepi.2006.08.012

Wang, R. Y., Storey, V. C., & Firth, C. P. (1995). A framework for analysis of data quality research. *IEEE Transactions on Knowledge and Data Engineering*, *7*(4), 623–640. doi:10.1109/69.404034

Wang, R. Y., & Strong, D. M. (1996). Beyond accuracy: What data quality means to data consumers. *Journal of Management Information Systems*, *12*(4), 5–34.

Ware, J. E., & Gandek, B. (1998). Methods of testing data quality, scaling assumptions, and reliability: The IQOLA project approach. *Journal of Clinical Epidemiology*, *51*(11), 945–952. doi:10.1016/S0895-4356(98)00085-7

Wenger, E. C., & Snyder, W. M. (2000). Communities of practice: The organizational frontier. *Harvard Business Review*, *78*, 139–145.

This work was previously published in Handbook of Research on Information Technology Management and Clinical Data Administration in Healthcare, edited by A. Dwivedi, pp. 305-320, copyright 2009 by Medical Information Science Reference (an imprint of IGI Global).

Chapter 7.10

Space–Time Cluster Analysis:

Application of Healthcare Service Data in Epidemiological Studies

Joseph M. Woodside
Cleveland State University, USA

Iftikhar U. Sikder
Cleveland State University, USA

ABSTRACT

Spatial epidemiological approach to healthcare studies provides significant insight in evaluating health intervention and decision making. This article illustrates a space-time cluster analysis using Kulldorff's Scan Statistics (1999), local indicators of spatial autocorrelation, and local G-statistics involving routine clinical service data as part of a limited data set collected by a Northeast Ohio healthcare organization (Kaiser Foundation Health Plan of Ohio) over a period 1994—2006. The objective is to find excess space and space - time variations of lung cancer and to identify potential monitoring and healthcare management capabilities. The results were compared with earlier research (Tyczynski, & Berkel, 2005); similarities were noted in patient demographics for the targeted study area. The findings also provide evidence that diagnosis data collected as a result of rendered health services can be used in detecting potential disease patterns and/

or utilization patterns, with the overall objective of improving health outcomes.

INTRODUCTION

The increasing demand for health data analysis in spatial and temporal scale has made emerging technologies such as Geographic Information Systems (GIS) an essential tool for healthcare information systems. In healthcare settings application of such new technology are proving useful in the analysis of health data and planning of healthcare services (Pfeiffer, Robinson, Stevenson, Stevens, Rogers, & Clements, 2008). The ability of GIS to manage and retrieve georeference data has demonstrated its value in the integration of complex epidemiological models through visualization of spatial and temporal relationships. This has been recognized by the World Health Organization (WHO):

Geographical information systems (GIS) provide ideal platforms for the convergence of disease-specific information and their analyses in relation to population settlements, surrounding social and health services and the natural environment. They are highly suitable for analyzing epidemiological data, revealing trends and interrelationships that would be difficult to discover in tabular format. Moreover GIS allows policy makers to easily visualize problems in relation to existing health and social services and the natural environment and so more effectively target resources. (World Health Organization, 2008)

Geographical analysis is not only important for the identification of patterns of healthcare outcomes it also offers insight into understanding the association or linkage to political processes and policy makers (Cromley, 2002; Gatrell, 2002). Health data from managed health care organizations offers the opportunity to analyze unusual geographical patterns of disease. Routine, aggregated healthcare data stored in health systems can be utilized to identify disease clusters or utilization patterns. Recently methods have been sought to further improve identification within case and disease management programs.

The real world clinical service data stored in healthcare information systems provides opportunity to analyze spatio-temporal patterns at finer granularity. The investigation of space and space-time epidemiological patterns often gives rise to the explanation of factors that might create an adverse health condition. This study uses routine, aggregated service data to find excess space and time variations in rendered services where the primary diagnosis was lung cancer. From the health care management point of view, if clusters are detected and explanatory factors linked, this understanding allows for better patient care, i.e. serving a particular population with targeted specialists, and preventing spread of disease amongst populations. This research aims to study different clustering methods of the spatial and spatio-temporal patterns of lung cancer particularly for routine clinical service data collected by a Northeast Ohio healthcare organization (Kaiser Foundation Health Plan of Ohio) over a period from 1994 – 2006.

METHODOLOGY: SPACE-TIME CLUSTER ANALYSIS

The question whether diseases such lung cancer or breast cancer are spatially clustered is an active research area (Lawson, Biggeri, Böhning, Lesaffre, Viel, & Bertollini, 1999; Laywson & Denison, 2002; Marshall, 1991; Tango & Takahashi, 2005). Since the detection of spatial and temporal patterns of clusters of lung cancer is sensitive to the clustering algorithm, it is difficult to evaluate results from a single method (Jacquez & Greiling, 2003). Currently, most of the comparative analysis of disease clusters depends on simulated data (Ozonoff, Bonetti, Forsberg, &

Pagano, 2005). Tycznski developed a broad atlas of cancer in Ohio which involved a "smoothing" method where weighted averages of cancer per county were calculated versus geographic location of patients with cancer at the time of diagnosis. However, the clusters are generated by considering only spatial aspect. The temporal characteristics of the cluster are not reported (Tyczynski, et al., 2005).

In recognition of the usual epidemiological definition of cluster, this study adopts the formal definition of cluster which refers to the patterns of location of disease cases, relative to the pattern of non-cases (Wakefield, Kelsall, & Morris, 2000). In principle, since the cases are more clumped than non-cases, the difference between the two patterns is statistically recognizable. Intuitively, a cluster is an excess value which exceeds the normal value for the space and/or time. The closer a cluster population is defined, the excess value will be greater for the cluster population, and the significance will be greater. The closer a cluster population is defined, the greater the excess value will be for the cluster population, and the significance will be greater. Initial assessments of clusters include reviews of cases, boundaries of space and time, estimated number of cases, estimates of standardized mortality ratios, statistical significance, and public communication. Cluster analysis has been frequently used to identify occurrence of morbidity or unusual localized trends in disease patterns (Alexander, 1992).

A considerable amount of research in temporal and spatial context in 'scan' statistics has been invested in identifying disease clusters. The theory has been successfully applied in a wide variety of epidemiological studies for cluster detection (Viel, Arveux, Baverel, & Cahn, 2000; Perez, Ward, Torres, & Ritacco, 2002; Sankoh, Ye, Sauerborn, Muller, & Becher, 2001). It has been identified as the most powerful method for detecting local clusters (Kulldorff, Tango, & Park, 2003; Song, & Kulldorff, 2003). Ideally, this method is suitable where one needs to scan for clusters in space that vary over time. Since the method for detecting clusters is entirely unsupervised, there is no need for *a priori* knowledge for the population size. The method is based on the concept of 'windows' which are defined to contain a fixed population (N^*), and are centered on each area centroid. The algorithm identifies a significant excess of cases within a predefined moving window that exhaustively searches all existing space-time locations and keeps increasing size in space time until it reaches a maximum limit. The maximum number of cases $M = \max_j Y_j(N^*)$ across the windows is used as a test statistic. In this case *j* represents the indexes of the areas defended in N^*. It is also possible to use a fixed number for the population by introducing predefined constraints (e.g., the number population with a circle should be less than a specified fraction of the total population of the study area). Hjalmars et al. (1996) and Kulldorff et al. (1997) applied a similar method to detect childhood leukemia and breast cancer incidence. The test statistic is based on maximum likelihood ratio statistic across all circles.

$$L = \max_j \left(\frac{Y_j}{E_j} \right)^{Y_j} \left(\frac{Y_+ - Y_j}{Y_+ - E_j} \right)^{Y_+ - Y_j} I(Y_j > E_j) \qquad (1)$$

Here, Yj and Ej represent the observed and expected number of cases within the window j . The indicator function I(.) becomes 1 when the observed number exceeds the expected number of cases within the window; otherwise the value is 0. When the window with greatest exceedance is encountered, the sampling distribution of likelihood ratio is determined using a Monte Carlo test of cases across windows under a random distribution assumption. Thus under the repeated permutation, the distribution of likelihood statistic, the null hypothesis is developed. The result is significant at 0.05 levels if the likelihood ratio is among the top 5% of all the values. It is also possible to determine secondary cluster with a lower significance level.

We applied the SaTScan method for a spatial and space-time analysis for detecting local clusters (Kulldorff, 1997). Due to temporal trends, clusters may be generated for a ramp up or down in data trends. For this reason, the space-time permutation model automatically adjusts for these temporal data trends. In the study we used case data, with the spatial location represented by zip code centroid latitude and longitude, and with time represented by service month. The actual number of cases in a cluster is compared with the expected count if the spatial and temporal locations of all records were independent. A cluster is determined to be present in a spatial location, if, during the time period, there are excess cases or recess within the surrounding areas. Using a cylindrical window with a spatial base and time as height, the space-time statistic is defined. The window is moved in space and time, and a cylinder is created for each possibility. The algorithm accounts for multiple testing by calculating the maximum likelihood of occurrence for all possible cluster locations and sizes (Kulldorff, 1997, 2001). In this study, retrospective analysis was performed in terms of months, with periods representing January 1994 through May 2006. In each window, the alternative hypothesis concludes that there is heightened risk.

The Poisson model is used for the space-time permutation probability model as this allows for covariate adjustments, in this case age and gender. This likelihood function is maximized over all windows, and the maximum likelihood window describes the prevalent cluster. The test statistic is calculated by generating a large random sample from the data generated under the null hypothesis. Monte Carlo testing is used to obtain the predicted value. In this study, Monte Carlo replications were generated to produce a P-value to 0.001. Covariates were used since clustering can occur due to covariates. Covariates are adjusted to prevent this false clustering. The time precision was monthly and ranged from January 1994 through May 2006 based on available data at time of collection. The maximum spatial and temporal cluster size was the default 50% of cases (Kulldorff, 2005). The scant statistic generated both primary and secondary clusters and the output was reported in ASCII format, which contains a log likelihood ratio and the significance level for the study area. The output file was finally imported in standard GIS environment of ArcGIS to visualize cluster location for further spatial analysis. The Poisson model was also used for the purely spatial probability model, and follows closely with the space-time permutation model. However this model utilizes a population file which includes information regarding the at risk population, and was taken from the 1999 US Census Bureau Zip Code file, with regard to total 1999 population for each zip code. As this file did not include additional population attributes such as age and gender, the case file along with the population file excluded these for this model (Kulldorff, 1997; U.S. Census Bureau, 1999).

Spatial autocorrelation analysis provides both global and local clusters which can be detected by Moran's I statistic. The global pattern can be detected from Moran's Scatterplot, where the slope of the regression line represents Moran's I. We applied the local indicators of spatial autocorrelation (LISA) method using sample cases in each zip code. The local Moran statistic for location i is given as follows (Wong & Lee, 1999):

$$I_i = z_i \sum_j w_{ij} z_j \tag{2}$$

Where z_i, z_j are the deviations from the mean for associated x, and where z_i is the z-score of x_i. A high Moran's I indicates associated values, whereas a low value indicates non-associated values. The row-standardized matrix, used to estimate weights for each of the unit's neighbors, is defined as wij (Wong, et al., 1999). When the study involves the measurement of Moran's I for rates, the underlying assumption of stationarity may be violated due to intrinsic variance instability of the rates. Since the population at risk in the study area varies significantly across patient zip codes, variance instability may lead to spurious inference for Moran's I. To account for this effect, the Empirical Bayes (EB) standardization was performed (Assuncao, & Reis,) using zip code population as the base variable. The standardized rate was used to calculate the univariate LISA. The spatial autocorrelation analysis utilized local tests for Moran's I statistic, with significance maps generated to the P-value of 0.05 (Anselin, Syabri, & Kho, 2004). Sensitivity analysis was done by changing the number of permutations (9999 times) for different significance cutoff values.

While Moran's I is effective in identifying presences of clustering of similar values clustering, it cannot differentiate between high and low values. Another spatial autocorrelation statistic, the general G-statistic (Getis & Ord, 1992), is able to detect hot and cold spots. The G-Statistic also uses cross-product statistics to measure spatial association, similar to Moran's I. The local G-statistic is the local version of the general G-statistic, and it indicates how the value of each unit is associated with surrounding units within distance *d* (Wong, et al., 1999).

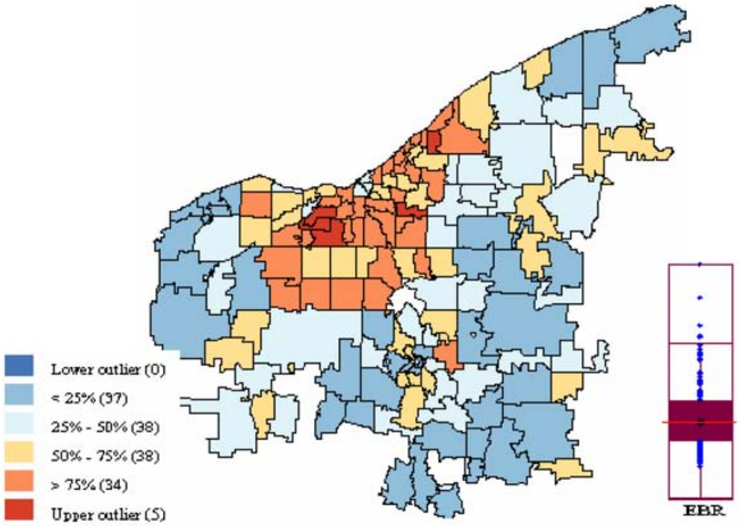
$$G_i(d) = \left(\frac{\sum_j w_{ij}(d) x_j}{\sum_j x_j} \right) \quad j \neq i \qquad (3)$$

Here, $w_{ij}(d)$ is the weight, with distance *d*, and the weight is 1 if *j* is within *d* of *i*; otherwise weight is 0. The cross product of the points *i* and *j* are represented by $x_i x_j$. A high $G_i(d)$ indicates a spatial association of similar high values; a low $G_i(d)$ indicates low and below-average values. A z-score near 0 indicates no spatial pattern; a highly negative z-score indicates low values; and a highly positive z-score indicates high values (Wong, et al., 1999). We applied the local G-statistic using samples cases in each zip code. The standardized Empirical Bayes rate was used to estimate the G-statistics.

DATA COMPILATION AND ANALYSIS

The study included the area of Northeast Ohio. The service data was collected from Kaiser Foundation Health Plan of Ohio with appropriate approval from the Internal Review Board. It includes the routine clinical service data of over the service period of January 1994 through May 2006. The case file contains information about the cases where each record represented an individual service (Kulldorff, 2005). The dataset was anonymised to avoid disclosure of individual information. In addition, a limited number of attributes was authorized for addressing the specific research objective in finding excess space-time variations of lung cancer. Among the attributes available in the case file are primary diagnosis, patient zip code, service month, age, and gender. Service month was the month of service/diagnosis where data was collected and available for use beginning in January 1994 through May 2006; the attribute age represents the age at date of service. In cases where multiple services/diagnoses existed, only the first occurrence for each individual was used to avoid cluster creation through repeat services. The dataset was generated during 07/2006 and included all services rendered or received to date. For services rendered at external locations, several months may have elapsed before service information was received, and may be excluded from this study for this reason. It would be possible to periodically re-run past results to ensure the latest dataset available. Due to system memory requirements (32-bit Windows memory allocation size), and software limitations, individual diagnoses were required to be selected and scanned (Kulldorff, 2005). International Classification of Diseases, (Ninth Revision) Clinical Modification (ICD-9-CM) Code 162.XX was used to represent

Figure 1. Empirical Bayes (EB) smoothed box map of lung cancer in Northeast Ohio during 1994-2006



the diagnosis for lung cancer. The aggregation unit of geographic location used is the five-digit US zip code. The coordinates were then mapped in ESRI's ArcGIS 9.0. Geocoding was performed through assignment of coordinates (latitude and longitude) to each patient zip code. The coordinate file contains the geographic coordinates for each location id specified in the case file. Coordinates were specified using latitude and longitude of each 5-digit patient zip code entered in decimal degrees, and, where identical, one or more coordinates were combined for a single location. Each patient zip code was geocoded to the centroid using a US census 1999 zip code file containing the latitude and longitude. For graphical analysis and to reflect the majority of sample records, a fourteen-county region with contiguous zip codes was used to represent the Northeast Ohio region. The dataset used for the analysis included a total of 2,364 records or unique initial service claims for patients having included the ICD-9-CM Code 162.XX (lung cancer) as the primary diagnosis, and 152 unique patient zip codes.

To account for the inherent variance instability of rates (Bailey & Gatrell, 1995) of lung cancer incidence, empirical Bayes smoothing was performed (Clayton & Kaldor, 1987), whereby the raw rates were adjusted towards the overall average of the study area. The technique consists of computing the weighted average between the raw rates for each zip code and the study area average with weights proportional to the underlying population at risk. In other words, small zip codes (i.e., with a small population at risk) will tend to have their rates adjusted considerably, whereas for larger zip codes, the rates will barely change (Clayton & Kaldor, 2005). The empirical Bayes (EB) smoothed box map in Figure 1 shows that 5 zip codes are in the upper outlier and as many as 34 zip codes are within 75 percentiles.

RESEARCH RESULT

The spatial scan statistic result shows that there exists a cluster of lung cancer in the Northeast

Figure 2. The area of statistically significant (p <= 0.05) lung cancer using a spatial autocorrelation and scan statistic for space and space-time model.

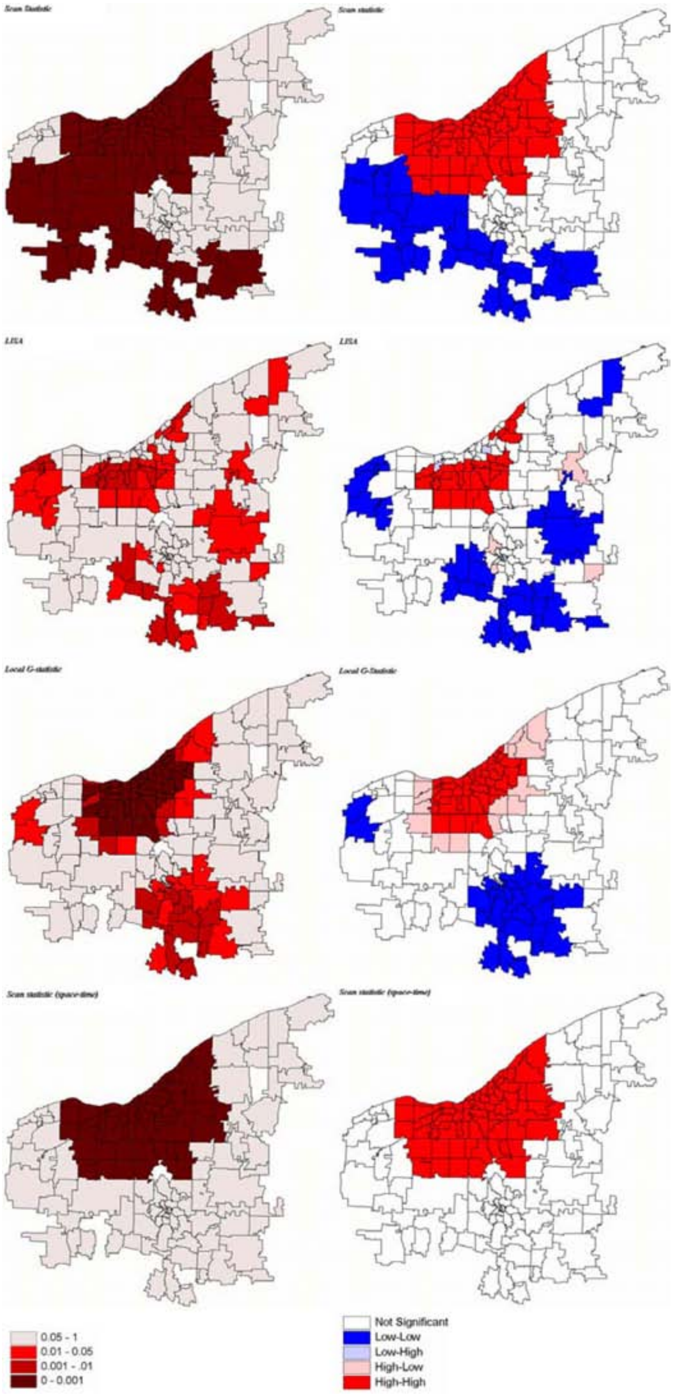


Table 1. P-value distribution of area, sample cases, zip codes, average age and gender attributes of the cluster(s) for each method

P-Value		Space-Time Scan Statistic	Spatial Scan Statistic	G-statistic	LISA
0.05 – 1					
	% Area	74.30%	43.00%	63.20%	63.00%
	Cases	2261	364	362	1122
	Zip #	108	54	63	88
	Avg Age	67.7	66.4	65.7	67.1
	Male	1276	218	207	637
	Female	985	146	155	485
0.01 - 0.05					
	% Area	-	-	14.90%	25.20%
	Cases	-	-	252	640
	Zip #	-	-	22	37
	Avg Age	-	-	69.6	67
	Male	-	-	138	346
	Female	-	-	114	294
0.001 – 0.01					
	% Area	-	-	8.40%	8.70%
	Cases	-	-	195	483
	Zip #	-	-	17	21
	Avg Age	-	-	66.7	69.2
	Male	-	-	100	281
	Female	-		95	202
0 - 0.001					
	% Area	25.70%	57.00%	13.50%	3.10%
	Cases	103	2000	1555	119
	Zip #	44	98	50	6
	Avg Age	65.6	67.8	67.9	69.2
	Male	55	1113	886	67
	Female	48	887	669	52

Ohio region. Areas of excess were detected with statistical significance using a spatial Poisson probability model for services with a diagnosis of lung cancer. The results show that a statistically significant cluster exists with a relative risk (RR) of 4.164 at P-value of 0.001 that includes 72 zip codes. The results also listed another statistically significant cluster with RR of 0.186 and P-value of 0.001, and contained 28 zip codes within the contiguous sample area. As expected, the significance levels match closely with the geographic sample distribution. The space-time scan statistic result also shows that there exists a cluster of lung cancer in the region for the space-time scan statistic. With spatial-temporal data and covariates considered, statistically significant areas of excess were also detected using the space-time scan statistic for services with a diagnosis of lung cancer. Clusters were scanned first only for location of patient zip code, and then scanned with the addition of an attribute (age, gender). Furthermore, clusters were scanned using five-year age brackets. The results show that a statistically significant cluster (P-value <= 0.01) exists. The primary cluster detected is a geographically contiguous area in Northeastern Ohio, with a relative risk (RR) of 1.784 and significant P-value of 0.001. The cluster contained 44 zip codes within the contiguous sample area and spanned a time period of 7/1/1999 – 8/31/2002. The location of the cluster changes when including time, as compared with the purely spatial model. The primary cluster shows no geographic change when adjusted for attributes. It was found that adjustment of attributes is not required as the cluster location does not change when attributes are introduced Secondary clusters were identified, but were not statistically significant.

The LISA analysis indicates a cluster of high incidence of lung in the region with statistically significant clusters (P-value <= 0.05), containing 64 zip codes within the study area. The local G-statistic result shows that there exists a hot spot of lung cancer in the region. The results also show that statistically significant clusters (P-value <= 0.05) consist of 89 zip codes. Figure 2 shows the spatial statistic significance graphs for the SatScan, LISA, and local G-statistic. The figure also shows the space-time scan statistic significance graphs. Table 1 shows the significance level measured by the P-value at the 0.001, 0.01, and 0.05 levels. The corresponding percentage area, (where the total area of significance was divided by the total area for which sample cases existed), the number of sample cases, number of zip codes contained, average age, and county by gender are included, with each method listed as a column.

The scan statistic result shows that there exists a cluster of lung cancer in the region for the purely spatial statistic. Areas of excess were detected with statistical significance using a purely spatial Poisson probability model for services with a diagnosis of lung cancer. The results show that a statistically significant high value cluster (P-value <= 0.05) exists and contains 72 zip codes. The results also listed another statistically significant low value cluster containing 28 zip codes within the contiguous sample area. The results list 54 zip codes as not significant. The scan statistic result also shows that there exists a cluster of lung cancer in the region for the space-time scan statistic. The results show that a statistically significant high value cluster (P-value <= 0.01) exists. The cluster contained 52 zip codes and spanned a time period of 7/1/1999 – 8/31/2002. Two of the zip codes contained similar coordinates, which left 50 unique zip code locations. No low value clusters were identified. The LISA result shows statistically significant cluster of lung cancer in the region for the purely spatial statistic. The results show that statistically significant clusters (P-value <= 0.05) exist, and contained 87 not significant, 31 low-low, 2 low-high, 4 high-low, and 28 high-high value zip codes.

The local G-statistic result shows that there exists a cluster of lung cancer in the region for the purely spatial statistic. The results show that statistically significant clusters (P-value <= 0.05) exist, and contain 63 not significant, 31 low-low, 0 low-high, 16 high-low, and 42 high-high value zip codes. Figure 2 shows the purely spatial statistic cluster graphs for the scan statistic, LISA, and local G-statistic. It also shows the space-time statistic significance graphs for the scan statistic.

DISCUSSION

This study detected several high and low association clusters using the spatial and space-time methods. When comparing the various methods of the scan statistic, LISA, and local G-statistic, spatial association areas are somewhat similar geographically. The local G-statistic returned the highest number of records (2002) with regard to significance at the 0.05 level. The scan statistic method also returned a similarly high number of associated records (2000) as the local G-statistic. The LISA method returned a comparatively smaller number of significant records (1242); however when comparing LISA geographically to the scan statistic and local G-statistic, LISA appears to exclude bordering zip codes included in the other methods. Conversely, LISA had the highest number of records (1122) that were not significant, followed by the scan statistic (364) and local G-statistic (362). The scan statistic contained the highest number of high-high cluster records (1896), followed by the local G-statistic (1377) and LISA (1069). The local G-statistic had the highest number of high-low spatial outlier records (419), followed by LISA (31) and scan statistic (N/A). Only LISA contained low-high spatial outlier records (31). The local G-statistic contained the highest number of low-low records (206), followed by scan statistic (104), which the output indicated low only, and LISA (100).

When accounting for temporal trends using the scan statistic, this study detected only one area of excess lung cancer spanning the three-year period of the study using a space-time method. The SatScan space-time statistic returned the fewest number of records (103) and geographic location in terms of significance and clustering, and it was different geographically from the purely spatial methods in that the majority of high value association cases and area was not contained within Cuyahoga County, but rather in Stark and Summit Counties. In addition, no low value association clusters were detected, as with the purely spatial methods. The introduction of time allows for a more focused area and localized study region. Since the health data from managed health care organizations are aggregated at the zip code level, the smallest mapping unit discernible in a GIS map is the zip code polygon of the study area. Compared to long temporal range (1994-2006) of the study, the temporal occurrence of cluster was found significant only within the three years of 1999-2002. The narrow temporal concentration and high relative risk suggests that further investigation is required to understand the causal factor within the time period.

The application of scan statistic is specifically useful when there is a plausibility of a single hotspot. Since the likelihood ratio is derived from a single hot/cold spot, the possibility of detecting multiple hot/cold is ruled out in the scan statistic algorithm. Moreover, scan statistic detects space-time clusters by using cylindrical windows; hence the result needs to be interpreted with respect to the choice a specific shape of the window. While the cluster is detected by rejecting the null hypothesis, the circular spatial window tends to detect a larger cluster than the true cluster by absorbing surrounding regions where there is no elevated risk (Tango & Takahashi, 2005). The relatively large cluster area detected in this study could be interpreted as the result of the boundary effect of the circular window. The effect could be confirmed by comparing the result with a flexibly shaped scanning window which allows for irregular shapes (Tango, et al., 2005). Moreover, the results need to be interpreted by comparison with other spatial cluster algorithms (e.g., spatial filtering [34], generalized additive models (GAM) (Ozdenerol, Williams, & Kang, & Magsumbol, 2005), and Bayesian disease mapping (BYM)) (Besag, York, & Mollie, 1991). When utilizing spatial autocorrelation (LISA), the number of significant records is reduced due to the generation of larger P-values. The spatial autocorrelation of simulated rates creates large variances in LISA values, leading to insignificant P-values, as neighboring values are more likely to be jointly low or high (Goovaerts & Jacquez, 2004). The local G-statistic produces the highest number of significant records, but also produces the highest number of spatial outlier records, which, when accounted for, produce a more similar, but still higher records count than LISA. The local G-statistic uses a z-score scale around 0 to indicate clustering situations, which leads to a classification for all non-zero significant records.

In comparison with Tycznski's study (2005), this study reviewed spatio-temporal clusters of lung cancer cases to identify areas of interest, whereas the former study considered overall mortality rates of all cancer types within Ohio to determine time trends. Several key areas can be synthesized between the two studies to provide further topics of interest. Tycznski notes that lung cancer was the leading cause of death across categories; this fact coincides with the focused interest of this study on the leading cause of cancer death. Tycznski also notes higher mortality rates in Blacks as compared with Whites, and recommends focused efforts on this demographic. In this study a spatial cluster is found surrounding Cuyahoga County, which, when compared with surrounding Northeast Ohio counties, has a greater percentage of the Black population. When incorporating temporal trends into the study, an additional area of interest is identified within Northeast Ohio.

PRACTITIONER IMPLICATIONS

Practioner-based usage of this study falls into two general categories: identification and prevention. Detection of lung cancer, or other chronic diseases identified through spatial and temporal clusters can discover population areas of interest, can gauge the effectiveness of disease reduction methods within a given population area, and is considered an important public health measure. This study compares the results of three different methods to gain greater insight and better reflect spatial and temporal variations, as related to identification and/or monitoring current programs. Increasing disease rates may trigger increased focus or re-direction of current efforts. Decreasing rates may be utilized as validation for current efforts, improvement value, or as a component of a shared knowledge base for other efforts. Early detection programs along with case and disease management programs can also utilize geographic modeling information to determine the overall program design and success factor achievement. The program design may vary by geographic location, or may be used to identify the optimal program methodology for the particular locality (2005).

As an important step in enhanced treatment, efforts have been made to materialize best practices of disease therapies. Identification is made through geographical variances, and can trigger alerts to dedicated specialists for discovery of previously unknown opportunities. Activities following the discovery of identified areas may include patient/provider education, therapy identification, locality factors, and identification for early treatment, among others. This type of geographical evaluation has occurred with early-stage breast cancer. Geographic information systems and associated analysis can instruct physicians, patients, and other medical personnel in resource distribution, costs, health outcomes, and patient satisfaction. The location, service provider, and services performed can be analyzed by geographic area to identify effective methods. Once identified, these methods can be standardized to improve consistency across many locations, in order to gain effectiveness. Further granularity can be provided to allow for reduced area identification, in which specific disease control strategies can be implemented to supplement broader programs (Gregorio, Kulldorff, Barry, Samocuik, & Zarfos, 2001).

Other studies have sought to determine variances between local and global populations. Findings have suggested that differences in survival rates are not a result of biological factors, but rather treatment and prevention factors. These include disease stage at diagnosis, effects of compound diseases, and general treatment factors. Temporal trends are required in addition to spatial trends to locate areas whose intervention would prove most beneficial. Prior studies have examined geographic locations to determine physician and medical shortages. The findings suggest that while the existing supply is in fact adequate, the distribution is not optimal. This creates access restrictions across previously unseen urban, suburban, and rural areas. Literature suggests that the physician specialty combination as well as distribution of non-physician clinicians is vital for health outcomes. Accessibility measures require accuracy to appropriately capture the flows within service areas. Managed care plans have the ability to improve access and utilization of preventative care. These managed care plans generally provide more preventative services which result in improved outcomes over fee or service based plans (Mobley, Root, Anselin, Lozano-Gracia, & Koschinsky, 2006).

Whether a singular method or rather a combination of factors prove effective when adapted to the patient set, it is imperative to provide tools to successfully identify patients and program outcomes through monitoring, and enact additional programs to prevent future diseases and complications. This contributes to the overall management goal of improving quality of care, while reducing overall costs, thus ensuring high-quality, affordable healthcare.

CONCLUSION AND FUTURE DIRECTIONS

The spatial scan statistic, LISA, and local G-statistic were able to detect several areas of high and low value clusters. The space-time scan statistic identified one area of excess lung cancer spanning the three-year period of the study and produced a different result than a purely spatial scan statistic. The cluster remained unchanged and statistically significant even after covariate adjustment. The findings also provide evidence that diagnosis data collected as a result of rendered health services can be used in detecting potential disease patterns and/or utilization patterns throughout space and time. The methods shown are also useful for identifying which areas have the highest occurrence of a particular disease for the placement of facilities or specialists. Time can also be a factor for identifying more specific areas of interest, given a large geographic region. The possible boundary effect of circular window and space time-interaction resulting from geographical population shifts in the study area needs to be investigated. The popularly used Knox method (1964) and other tests for space-time interaction are required to confirm if the space-time clustering of lung cancer in the study area is a result of underlying geographical population distribution (Kulldorff, 1999). Unbiased space-time interaction tests and prospective space-time permutation analysis may also be performed as additional data is made available (Kulldorff, 2005; Hjalmars, & Kulldorff, 1999).

As managed care programs are initiated in areas of interest, additional localized studies can be utilized to track improvements in overall mortality rates as a result of the initiatives. By providing granularity to the zip code level in this study, focused geographic programs can be developed at strategic facility sites and can be modified based on ongoing spatio-temporal surveillance of the population. As health care entities seek to improve healthcare outcomes, these methods provide a useful tool in identifying geographic areas of interest.

While the research objective is not to identify a specific cause-and-effect relationship between lung cancer and environmental conditions such as air pollution or individual smoking habit, further research is needed to establish a space-time specific causal relationship and a latency period of cancer. Given the scope and objective of this study, it was not deemed necessary to collect additional detailed case data. For future study, additional attributes which are not available for the current dataset should be generated from a localized study that would include things such as ethnicity, socio-economic status of individual cases, exposure to tobacco smoke, and population migration. These attributes can be adjusted for in the model in order to determine effects. Localized studies can also determine utilization of services in which lung cancer diagnosis appears. This identification can be useful in managing the care for those with an identified diagnosis and determining frequency of services for those with an identified diagnosis.

REFERENCES

Alexander, F. F. (1992). Methods for the assessment of disease clusters. *Geographical & Environmental Epidemiology: Methods for Small-Area Studies* (pp. 238-247).

Anselin, L. (2005). *Exploring Spatial Data with GeoDa: A Workbook*. Center for Spatially Integrated Social Science.

Anselin, L., Syabri, I., & Kho, Y. (2004). *GeoDA: An Introduction to Spatial Data Analysis.*

Assuncao, R., & Reis, E. A.(n.d.). A new proposal to adjust Moran's I for population density. *Statistics in Medicine*, *18*, 2147–2161. doi:10.1002/(SICI)1097-0258(19990830)18:16<2147::AID-SIM179>3.0.CO;2-I

Bailey, T. C., & Gatrell, A. C. (1995). *Interactive Spatial Data Analysis.* New York, NY: John Wiley and Sons.

Besag, J. E., York, J. C., & Mollie, A. (1991). Bayesian image restoration with two applications in spatial Statistics. *Annals of the Institute of Statistical Mathematics*, *43*, 1–59. doi:10.1007/BF00116466

Clayton, D., & Kaldor, J. (1987). Empirical Bayes estimates of age standardized relative risks for use in disease mapping. *Biometrics*, *43*, 671–681. doi:10.2307/2532003

Cromley, E. K. (2003). GIS and disease. *Annual Review of Public Health*, *24*, 7–24. doi:10.1146/annurev.publhealth.24.012902.141019

Gatrell, A. (2002). *Geographies of health*. Malden, MA: Blackwell.

Getis, A., & Ord, J. K. (1992). The analysis of spatial association by use of distance statistics. *Geographical Analysis*, *24*, 189–207.

[Goovaerts, P., & Jacquez G. M. (2004). Accounting for regional background and population size in the detection of spatial clusters and outliers using geostatistical filtering and spatial neutral models: the case of lung cancer in Long Island, New York. *International Journal of Health Geographics.*

Gregorio, D. I., Kulldorff, M., Barry, L., Samocuik, H., & Zarfos, K. (2001). Geographical Differences in Primary Therapy for Early-Stage Breast Cancer. *Annals of Surgical Oncology*, *8*, 844–849. doi:10.1007/s10434-001-0844-4

Hastite, T. J., & Tibshirani, R. J. (1991). *Generalized Additive Models*. New York: Chapman and Hall.

Hjalmars, U., & Kulldorff, M. (1999). The Knox Method and Other Tests for Space-Time Interaction. *Biometrics.*

Hjalmars, U., Kulldorff, M., Gustafsson, G., & Nagarwalla, N. (1996). Childhood leukaemia in Sweden: using GIS and a spatial scan statistic for cluster detection. *Statistics in Medicine*, *15*, 707–715. doi:10.1002/(SICI)1097-0258(19960415)15:7/9<707::AID-SIM242>3.0.CO;2-4

Jacquez, G. M., & Greiling, D. A. (2003). Local clustering in breast, lung and colorectal cancer in Long Island, New York. *International Journal of Health Geographics*, 2.

Knox, G. (1964). The detection of space-time interactions. *Applied Statistics*, *13*, 25–29. doi:10.2307/2985220

Kulldorff, M. (1997). A special scan statistic. *Communications in Statistics Theory and Methods*, *26*, 1481–1496. doi:10.1080/03610929708831995

Kulldorff, M. (1997). A special scan statistic. *Communications in Statistics Theory and Methods*, *26*, 1481–1496. doi:10.1080/03610929708831995

Kulldorff, M. (1999, June). The Knox Method and other Tests for Space-Time Interaction. *Biometrics*, *55*, 544–552. doi:10.1111/j.0006-341X.1999.00544.x

Kulldorff, M. (2001). Prospective time periodic geographical disease surveillance using a scan statistic. *Journal of the Royal Statistical Society*, 61–72.

Kulldorff, M. (2005). *SaTScanTM v6.0: Software for the spatial and space-time scan statistics.* Information Management Services, Inc.

[Kulldorff, M., Tango, T., & Park, P. J. (2003). Power comparisons for disease clustering tests. *Computational Statistics and Data Analysis, 42*.

Lawson, A., Biggeri, A., Böhning, D., Lesaffre, E., Viel, J. F., & Bertollini, R. (1999). Disease Mapping and Risk Assessment for Public Health. In A. Lawson, A. Biggeri, D. Böhning, E. Lesaffre, J. F. Viel, & R. Bertollini (Eds.), *Disease Mapping and Risk Assessment for Public Health*. London: John Wiley & Sons.

Lawson, A., & Denison, D. (2002). *Spatial Cluster Modelling*. Boca Raton: CRC.

Marshall, R. J. (1991). A review of the statistical analysis of spatial patterns of disease. *Journal of the Royal Statistical Society. Series A, (Statistics in Society)*, *154*, 421–441. doi:10.2307/2983152

Mobley, L. R., Root, E., Anselin, L., Lozano-Gracia, N., & Koschinsky, J. (2006). Spatial analysis of elderly access to primary care services. *International Journal of Health Geographics*, 5.

Ozdenerol, E., Williams, B., Kang, S. Y., & Magsumbol, M. (2005). Comparison of spatial scan statistic and spatial filtering in estimating low birth weight clusters. *International Journal of Health Geographics*, 4–19.

Ozonoff, A., Bonetti, M., Forsberg, L., & Pagano, M. (2005). Power comparisons for an improved disease clustering test. *Computational Statistics & Data Analysis*, *48*, 679–684. doi:10.1016/j.csda.2004.03.012

Perez, A. M., Ward, M. P., Torres, P., & Ritacco, V. (2002). Use of spatial statistics and monitoring data to identify clustering of bovine tuberculosis in Argentina. *Preventive Veterinary Medicine*, *56*, 63–74. doi:10.1016/S0167-5877(02)00124-1

Pfeiffer, D. U., Robinson, T. P., Stevenson, M., Stevens, K. B., Rogers, D. J., & Clements, A. C. A. (2008). *Spatial Analysis in Epidemiology.* New York: Oxford University Press Inc.

Sankoh, O. A., Ye, Y., Sauerborn, R., Muller, O., & Becher, H. (2001). Clustering of childhood mortality in rural Burkina Faso. *International Journal of Epidemiology*, *30*, 485–492. doi:10.1093/ije/30.3.485

Song, C., & Kulldorff, M. (2003). Power evaluation of disease clustering tests. *International Journal of Health Geographics*, *2*, 1–8. doi:10.1186/1476-072X-2-9

Tango, T., & Takahashi, K. (2005). A flexibly shaped spatial scan statistic for detecting clusters. *International Journal of Health Geographics*, *4*, 4–11. doi:10.1186/1476-072X-4-11

Tango, T., & Takahashi, K. (2005). A flexibly shaped spatial scan statistic for detecting clusters. *International Journal of Health Geographics*, *4*, 1–15. doi:10.1186/1476-072X-4-11

Tango, T., & Takahashi, K. (2005). A flexibly shaped spatial scan statistic for detecting clusters. *International Journal of Health Geographics*, 4–11.

Tyczynski, J. E., & Berkel, H. J. (2005). Long-term all-sites cancer mortality time trends in Ohio, USA, 1970–2001: differences by race, gender and age. *BMC Cancer*, 5.

U.S. Census Bureau (1999). *U.S. Postal Service ZIP Codes.*

Viel, J. F., Arveux, P., Baverel, J., & Cahn, J. Y. (2000). Soft-tissue sarcoma and non-Hodgkin's lymphoma clusters and a municipal solid waste incinerator with high dioxin emission levels. *American Journal of Epidemiology*, *152*, 13–19. doi:10.1093/aje/152.1.13

Wakefield, J. C., Kelsall, J. E., & Morris, S. E. (2000). Clustering, cluster detection, and spatial variation in risk. In P. Elliot, J. C. Wakefield, N. G. Best, & D. J. Briggs (Eds.), *Spatial Epidemiology: Methods and Applications*. Oxford: Oxford University Press.

WHO. (2008). Public Health Mapping. *WHO.*

Wong, D. W. S., & Lee, J. (1999). *Statistical Analysis of Geographic Information*. Hoboken: Wiley.

This work was previously published in International Journal of Information Security and Privacy, Vol. 2, Issue 3, edited by H. Nemati, pp. 45-54, copyright 2008 by IGI Publishing (an imprint of IGI Global).

Chapter 7.11

A Neural Network Approach Implementing Non-Linear Relevance Feedback to Improve the Performance of Medical Information Retrieval Systems

Dimosthenis Kyriazis
National Technical University of Athens, Greece

Anastasios Doulamis
National Technical University of Athens, Greece

Theodora Varvarigou
National Technical University of Athens, Greece

ABSTRACT

In this chapter, a non-linear relevance feedback mechanism is proposed for increasing the performance and the reliability of information (medical content) retrieval systems. In greater detail, the user who searches for information is considered to be part of the retrieval process in an interactive framework, who evaluates the results provided by the system so that the user automatically updates its performance based on the users' feedback. In order to achieve the latter, we propose an adaptively trained neural network (NN) architecture that is able to implement the non- linear feedback. The term "adaptively" refers to the functionality of the neural network to update its weights based on the user's content selection and optimize its performance.

INTRODUCTION

The rapid progress in publishing articles and the huge amount of data being stored, accessed and transmitted in the biological and medical domain has led to the advent of applications that perform Natural Language Processing (NLP) in order to enable researchers, doctors and other actors in the aforementioned domain to search and retrieve the relevant content. In this context, the traditional approaches of searching, retrieving and organizing the medical data, using only text annotation, cannot describe the medical content with high efficiency. For this reason, several content-based retrieval mechanisms and approaches have been proposed, some of which work by extracting high level semantic features of the content.

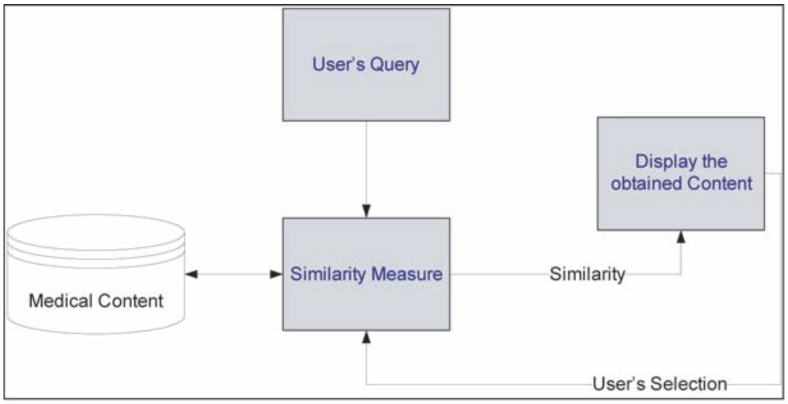
Despite, however, the fact that semantic segmentation has attracted much attention recently, other features that describe the content such as keywords or categories are usually used for implementing content-based retrieval algorithms. To reduce the limitations emerged by using low-level descriptors and simultaneously to increase the performance of content-based algorithms, the human can be considered as a part of the retrieval process, in an interactive framework. This means that initially the user evaluates the results, provided by the system and then the system adapts its performance according to the user's demands. In this framework, a feedback is established from the user to the system based on the most relevant articles, which is usually called relevance feedback. Such an approach, apart from eliminating the gap between high-level and low-level features, it also reduces the problems related to the subjectivity of humans, which often interpret the same medical content in a different way.

To address the content interpretation and classification, new adaptive and interactive management schemes should be introduced, which are capable of updating the system response with respect to the current user's information needs and preferences. One way to achieve adaptability of the system response to the users' needs is to modify the similarity measure used for ranking data. In this way, retrieval, organization and transmission of the information are updated in accordance with the humans' perception of the content through a dynamic real time learning strategy based on the users' interaction.

One of the interactive learning techniques is *relevance feedback* (originated from text-based information retrieval systems), which adapts the response of a system according to the relevant information feedback to it so that the adjusted response is a better approximation to the user's information needs. Usually, relevant information is provided by the user in an *interactive framework*, who evaluates the results according to his/her demands and preferences. Relevance feedback has been widely used in text-based information retrieval systems (J. Rocchio, 1971). Although it is not restricted to description environments where similarity measures are used, in databases where similarity-based queries are applied (Y. Ishikawa, 1998), relevance feedback refers to the mechanism which updates the similarity measure with respect to the relevant/irrelevant information, as indicated by the user. Relevance feedback confronts the subjectivity of humans in perceiving medical content and also eliminates the gap between high-level semantics and low-level features, which are often used for content description and modeling (Y. Rui, 1998). The following figure (Figure 1) presents a block diagram of a relevance feedback scheme.

To perform the relevance feedback mechanism a degree of importance should be assigned to each content descriptor, i.e., a different weighed factor to each element of the feature characterizing the medical content. After the first retrieval, the user assigns a degree of appropriateness for each article, which actual indicates the similarity degree of the respective article to the query. The weights are dynamically adapted based on the users' feedback, who selects the most appropriate articles among those retrieved by the system. Furthermore, we propose an enhancement to the relevance feedback mechanism by introducing nonlinearities in the parametric distance. This is implemented by an adaptively trained neural network classifier, the weights of which are adjusted according to the users' feedback. In this case, the network weights define the degree of importance for each descriptor, while the network output indicates the similarity of the examined article to the query one. The network weights are updated each time a new users' selection takes place so

Figure 1. Design of the relevance feedback mechanism for medical content retrieval systems



that they are closer to the user's selection while simultaneously results in a minimal degradation of the previously learned data.

Concluding, our approach proposes the use of a non-linear relevance feedback mechanism in content-based retrieval systems. To implement this mechanism we use a neural network that is able to dynamically adapt its performance by taking into account both the current knowledge and the previous one. As a result, after the user's feedback, the network output, is optimized since it also takes into account the user's selection. There has to be mentioned, that the proposed relevance feedback mechanism works efficiently independently from the content, which means that it is applicable not only to textual content but to images and video as well. This mechanism can be seen as an additional layer on the retrieval algorithms in medical databases and other sources of content, which improves the overall system performance in terms of the data that are finally obtained by the user.

The remainder of this chapter is structured as follows. The background section presents related work in the field of non-linear relevance feedback as a way to improve systems' performance. The research topic and the focus of our work, is describe thereafter. We present the problem of generalized non-linear relevance feedback and we propose a recursive algorithm for updating the similarity measure to the current users' information needs and preferences. Finally, "Future Trends" section includes a discussion on future research and potentials for the current study, while the chapter is summarized in the "Conclusion" section.

BACKGROUND

As already mentioned, one of the interactive learning techniques is *relevance feedback*, which adapts the response of a system according to the relevant information feedback to it so that the adjusted response is a better approximation to the user's information needs. In this context, recently relevance feedback algorithms have been extended from text-based information retrieval to content-based image retrieval systems. The area of image retrieval is even more complex due to the nature of the content: it is much harder to characterize and make queries on images than on textual information. Given that our approach can be applied to any information retrieval system we briefly present work in this area focusing on the more complex side: the one of the image retrieval in order to show that our approach advances this specific field of research in the most "complex" case. In (I. Cox, 1996), a probabilistic framework was reported based on a Bayesian formulation scheme. In (Y. Rui, 1998), a relevance feedback algorithm is introduced using as metric the weighted Euclidean distance and a heuristic scheme is adopted to perform the weight updating. However, this approach is a heuristic method and as mentioned in the conclusions of this chapter, there is a need for an optimal learning strategy. The first approaches towards this direction have been reported in (Y. Avrithis, 1998; A. D. Doulamis, 1999; Y. Ishikawa, 1998). In particular, in (Y. Avrithis, 1998; A. D. Doulamis, 1999) the weighted Euclidean distance is used as in (Y. Rui, 1998) and the weight updating strategy is performed by minimizing the response of the Euclidean distance metric over all selected samples. Instead, in (Y. Ishikawa, 1998), the generalized Euclidean distance is adopted as similarity metric to take into account the interconnection of different feature elements with each other. Feature element interconnection is also examined in (Y. Choi, 2000). However, the works of (Y. Avrithis, 1998; A. D. Doulamis, 1999) yield unstable performance in case of negative examples, while "smooth" the system response when many positive relevant images are selected. In addition, the work of (Y. Ishikawa, 1998) involves the inversion of the covariance matrix of the selected samples. It is clear, however, that the covariance matrix is not invertible if the number of selected samples is smaller than the size of image feature vectors, which is a common case in real situations. To confront this difficulty, the authors of (Y. Ishikawa, 1998) propose a solution based on the pseudo-inverse of the covariance matrix. Although, however, in theory, such an approach eliminates the singularity problems, in practice, the retrieval performance is not so satisfactory (Y. Rui, 2000). To reduce the aforementioned difficulties, a "hierarchical model" has been proposed in (Y. Rui, 2000) for decomposing the feature vectors into vectors of smaller size. In addition, the algorithm introduces a dynamic switch for performing the weight updating so as to decrease the effect of singularity. A different approach is presented in (Xiang Sean Zhou, 2001), where the relevance feedback problem is addressed using discriminant analysis. In particular, the algorithm proposes Biased discriminant analysis to face the symmetry between positive and negative examples under small training samples, enhanced by a kernel version to facilitate non-linearities. The method non-linearly transforms the feature vector space to adapt the system response to the current users' needs and preferences. However, only the vector norm is exploited in the proposed transformation, while a constant similarity measure is assumed, i.e., the Euclidean distance.

Other relevance feedback algorithms use the cross-correlation measure for similarity. Cross-correlation is a normalized measure, which expresses how similar/dissimilar two feature vectors are. A correlation-based relevance feedback scheme has been reported in (N. Doulamis, 2001), while a recursive learning strategy has been presented in (N. Doulamis, 2001; N. Doulamis 2001) to address the case of multiple feedback iterations. In these methods, the weights (model parameters) express the degree of relevance of the query feature vector to the vector of the selected samples. Again, the aforementioned approaches consider a constant type of similarity measure, e.g., the correlation criterion, regulating only the importance of extracted descriptors to the similarity metric, instead of the similarity type itself.

On the contrary, in this chapter, the problem of relevance feedback is addressed *in the most generic form* by optimally updating the similarity measure type to the current users' information needs and preferences. In this case, instead of adjusting the degree of importance of each descriptor, the similarity measure itself is estimated through an on-line efficient and recursive learning strategy. Therefore, no restrictions on the type of the similarity are imposed, in contrast to the aforementioned approaches, where only a specific type of similarity measure is considered, such as the Euclidean distance (Y. Avrithis, 1998 - Y. Rui, 2000) or the Cross-Correlation criterion (N. Doulamis, 2001 - N. Doulamis 2001). Initially, the similarity measure is assumed to be of any non-linear function type. In the following, the similarity is modeled as a non-linear parametric relation of known functional components (E. Kreyszig, 1989; G. Cybenko, 1989) using concepts derived from functional analysis. More specifically, it has been shown that any non-linear continuous function can be approximated with any degree of accuracy by considering functional components of non-constant, bounded and monotone increasing squashing functions. The contribution of each component to the similarity measure is estimated based on a set of selected relevant / irrelevant samples interactively provided by the user to express the current information needs. As a result, at each feedback iteration, the type of similarity measure is estimated resulting in a *generalized non-linear* relevance feedback scheme.

The contribution of each functional component to the similarity measure is *recursively* estimated through an efficient on-line learning strategy. In particular, the adaptation is performed so that a) the current selected content as expressed by a set of relevant/irrelevant samples is trusted as much as possible, while simultaneously b) a minimal modification of the already estimated similarity measure is encountered. For the satisfaction of the aforementioned conditions, a small modification of the model coefficients is assumed to be sufficient. Then, the first condition is simplified by applying a first order Taylor series expansion to the functional components, which results in a set of linear constraints of the current selected relevant/irrelevant samples. For the second condition, the sensitivity of the error between the system response and the actual degree of relevance, as provided by the user over an indicative learning set, is used. The algorithm results in a constraint minimization problem for the estimation of the coefficients of the functional components and therefore of the type of similarity measure, which approximates as much as possible the current users' information needs and preferences.

IMPROVING THE PERFORMANCE OF MEDICAL INFORMATION RETRIEVAL SYSTEMS

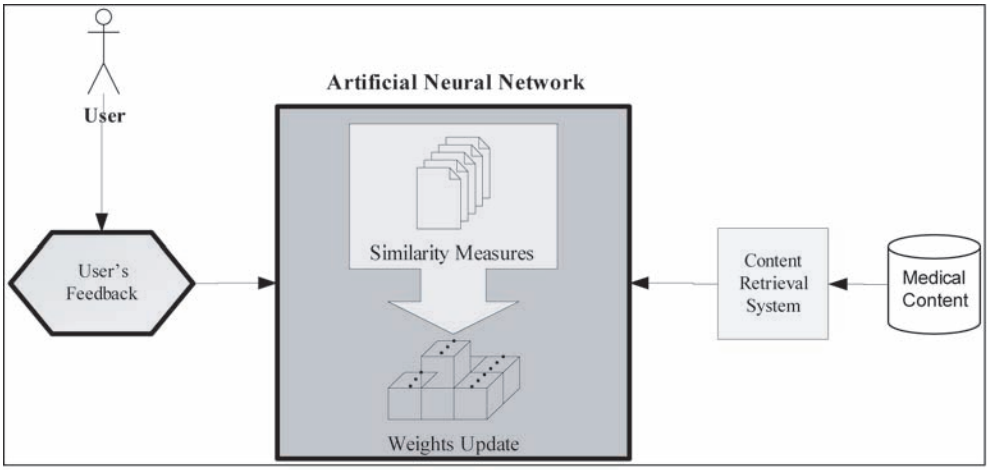
Based on the above, in this section we will briefly present the proposed architectural approach that includes an Artificial Neural Network (ANN) and the relevance feedback mechanism, the combination of which improves the performance of any medical information retrieval system. In general, an ANN is an information processing paradigm that is inspired by the way biological nervous systems, such as the brain, process information. The key element of this paradigm is the novel structure of the information processing system. It is composed of a large number of highly interconnected processing elements (neurones) working in unison to solve specific problems. ANNs, like people, learn by example.

Following the proposed architecture, we will describe the focus of our work which is the ANN's functions and the modeling of the similarity measures through the ANN in order to enable the latter to adjust its weights based on the feedback provided by the user.

Proposed Architectural Approach

The core component of the proposed architectural approach is an Artificial Neural Network used to model the similarity measure of a query for ranking the retrieved data. The aforementioned ANN is adaptable - meaning that the weight factors in its functions are adapted based on the relevance assigned by the user over all selected data. The selected data are the outcome of any content retrieval mechanism in a database / source with medical information. The information regarding the relevance of the results to the user's query is parsed into the ANN from the implemented relevance feedback mechanism as presented in the following figure (Figure 2).

Figure 2. Architectural approach



The process is initiated by the content retrieval system each time a user searches for medical content. Based on his / her search, the content retrieval system replies by providing a set of results. Afterwards these results are evaluated by the user who provides feedback on them to the ANN. The ANN "learns" from this process and updates the weights of its functions in order to provide better results in the next iteration. The key point in this process is how the weights are updated based on the user's feedback.

In the following paragraphs we will present an innovative approach that allows the weights update of the ANN's functions in order to include the user's feedback and improve the performance of content retrieval systems in future queries.

Similarity Measures

Regarding the ANN, one way to achieve adaptability of the system response to the users' needs is to modify the *similarity measure* used for ranking data. In this way, retrieval, organization and transmission of the information is updated in accordance with the humans' perception of the content through a dynamic real time learning strategy based on the users' interaction.

Let us assume in the following a *query by example* type of operation for content-based retrieval. This means that the user provides queries in the form of requests for content, which are analyzed similarly to the samples of the database. Thus, for each query by example, a feature vector is constructed to describe the query content. In the following, a similarity measure is applied to find a set of data that best match the query content. The most commonly used similarity measure for data retrieval is the Euclidean distance, where in its generalized form is defined as (G*eneralized Euclidean Distance*) (Y. Ishikawa, 1998; Y. Rui, 2000)

$$d(\mathbf{f}_q, \mathbf{f}_i) = (\mathbf{f}_q - \mathbf{f}_i)^T \cdot \mathbf{W} \cdot (\mathbf{f}_q - \mathbf{f}_i) \qquad (1)$$

In equation (1), vector $\mathbf{f}_q$ refers to the feature vector of the query, while $\mathbf{f}_i$ to the feature vector of the ith sample in the database. Vectors $\mathbf{f}_q$ and $\mathbf{f}_i$ are estimated as described previously. The **W** is a real symmetric matrix, which contains the weights that regulate the degree of importance of the feature elements to the similarity measure. In case that no interconnection among different feature elements is permitted, matrix **W** becomes diagonal and the resulted similarity measure is called *Weighted Euclidean Distance*. The weighted

Euclidean distance has been adopted in several relevance feedback schemes, such as the works of (Y. Rui, 1998; Y. Avrithis, 1998; A. D. Doulamis, 1999). On the contrary, in (Y. Ishikawa, 1998; Y. Rui, 2000), the generalized Euclidean distance has been involved.

Another interesting similarity measure adopted in the literature for relevance feedback is the cross-correlation criterion, which indicates how similar two feature vectors are and thus provides a measure for their content similarity (N. Doulamis, 2001- N. Doulamis, 2001). Furthermore, correlation remains unchanged with respect to feature vector scaling and translation. For example, adding or multiplying a constant value to all elements of a feature vector affects the Euclidean distance but not the correlation. One way for parametrizing the correlation-based similarity is (N. Doulamis, 2001)

$$\rho_{\mathbf{w}}(\mathbf{f}_q, \mathbf{f}_i) = \frac{\sum_{k=1}^{P} w_k \cdot f_{q,k} \cdot f_{i,k}}{\sqrt{\sum_{k=1}^{P} w_k^2 \cdot f_{q,k}^2} \cdot \sqrt{\sum_{k=1}^{P} f_{i,k}^2}} \qquad (2)$$

where $f_{q,k}$ and $f_{i,k}$ are the kth element of vectors $\mathbf{f}_q$ and $\mathbf{f}_i$ respectively. The variable P in (2) indicates the size of feature vector, while parameters w_k the relevance of the kth element of the query feature vector to the selected ones. An optimal learning strategy for estimating the weights w_k has been presented in (N. Doulamis, 2001; N. Doulamis, 2001) along with a recursive weight updating scheme for multiple feedback iterations.

In many relevance feedback approaches the similarity measure used is of constant type. In these scenarios, only regulation of the weighted factors w_k is permitted, which express the degree of importance of each descriptor to the similarity measure. Instead, a more powerful and efficient approach is to implement an on-line learning strategy, which assumes *any generic non-linear similarity measure* with the capability of adapting its type to the current users' information needs and preferences. In this case, instead of regulating the importance of each descriptor to the similarity measure, at each feedback iteration, the type of similarity measure is dynamically estimated, resulting in a *generic non-linear* relevance feedback scheme. In particular, the similarity measure, say $d(\cdot)$, is modeled as a continuous function $g(\cdot)$ of the difference between the query feature vector $\mathbf{f}_q$ and the feature vector $\mathbf{f}_i$ of the ith sample in the database.

$$d(\mathbf{f}_q, \mathbf{f}_i) = g(\mathbf{f}_q - \mathbf{f}_i) \qquad (3)$$

Equation (3) models any non-linear similarity measure of the query feature vector $\mathbf{f}_q$ and the ith sample in the database $\mathbf{f}_i$ so that the current user's information needs and preferences are satisfied as much as possible. The above equation is modeled through the proposed ANN.

However in equation (3), the feature vectors $\mathbf{f}_q$ and $\mathbf{f}_i$ are involved, which affect the retrieval results. It is clear that the more efficient a feature vector describes the content, the higher the retrieval performance is. In this chapter, we concentrate on the estimation of the most appropriate similarity measure $g(\cdot)$, which satisfies the user information needs and preferences as much as possible for a *given feature* vector representation.

Generalized Non-Linear Relevance Feedback

The main difficulty in implementing equation (3) is that function $g(\cdot)$ is actually unknown. For this reason, initially modeling of the unknown function $g(\cdot)$ is required in a parametric form. Modeling permits the estimation of similarity measure based on a set of relevant/irrelevant selected data.

Similarity Measure Type Modeling

Concepts derived from functional analysis are adopted in this chapter for modeling and parametrizing the unknown function $g(\cdot)$ (E. Kreyszig, 1989; G. Cybenko, 1989). Particularly, it can be proved that any continuous non-linear function can be expressed as a parametric relation of known functional components $\Phi_l(\cdot)$ within any degree of accuracy (E. Kreyszig, 1989). In this case, we have that

$$d(\mathbf{f}_q, \mathbf{f}_i) = g(\mathbf{f}_q - \mathbf{f}_i) \approx \sum_{l=1}^{L} v_l \cdot \Phi_l\left(\sum_{k=1}^{P} w_{k,l}(f_{q,k} - f_{i,k})\right) \tag{4}$$

where number L expresses the approximation order of function $g(\cdot)$. In equation (4), v_l and $w_{k,l}$ correspond to model parameters, while $\Phi_l(\cdot)$ corresponds to functional components. It is clear that the approximation precision increases, as the order L increases. Equation (4) is the equation used in the proposed ANN.

The most familiar class of functional components $\Phi_l(\cdot)$ is the sigmoid functions, which are equal to

$$\Phi_l(x) = 1/(1 - \exp(-a \cdot x)) \tag{5}$$

where a is a constant which regulates the curve steepness. It should be mentioned that the parameters v_l, $w_{k,l}$ of (4) *are not related* to the weighted factors (degree of importance) of the descriptors, which are used in the current relevance feedback approaches, such the ones in (Y. Rui, 1998; I. Cox, 1996 - N. Doulamis 2001). On the contrary, they express the coefficients (model parameters) on which function $g(\cdot)$ is expanded to the respective functional components.

From equation (4), it seems that $P \times L$ parameters are required to approximate any continuous similarity measure of order L. The number of parameters can be reduced by imposing constraints on v_l and $w_{k,l}$, which, however, restrict the type of similarity measure of (4). Particularly, let us assume that the same parameters are assigned to all functional components $\Phi_l(\cdot)$. This means that $w_{k,l} = w_{k,q}$ $\forall l,q$ and therefore $w_{k,l} = w_k$ since they depend only on the feature vector index and not on the index of the functional components. If we further assume that the functional components are linear, we conclude that

$$d(\mathbf{f}_q, \mathbf{f}_i) = \left(\sum_{l=1}^{L} v_l\right) \cdot \sum_{k=1}^{P} w_k(f_{q,k} - f_{i,k}) \tag{6}$$

which simulates the weighted Euclidean distance with free parameters the P variables w_k. In this case, the parameters v_l *d*o not affect the performance of the similarity measure since they just multiply the overall similarity.

Another interesting case results from the assumption that squared functional components $\Phi_l(\cdot)$ are considered, i.e., $\Phi_l(x) = x^2$. In this case, we have that

$$d(\mathbf{f}_q, \mathbf{f}_i) = \sum_{l=1}^{L} v_l \cdot \left(\sum_{k=1}^{P} w_k(f_{q,k} - f_{i,k})\right)^2 = \left(\sum_{l=1}^{L} v_l\right) \cdot \sum_{m=1}^{P} \sum_{k=1}^{P} w_k \cdot w_m(f_{q,k} - f_{i,k}) \cdot (f_{q,m} - f_{i,m}) \tag{7}$$

Other types of similarity measures are obtained by imposing constraints either on the parameters v_l and $w_{k,l}$ or on the type of the functional components $\Phi_l(\cdot)$. Imposing constraints on v_l, $w_{k,l}$ and $\Phi_l(\cdot)$ (and thus restricting the type of similarity measure that (4) models), we reduce the number of free parameters, and therefore the relevance feedback computational complexity. However, the most generic case is derived by setting no constraints on (4), which models any continuous non-linear function. All the other types of similarity measures can be considered as special cases of the generic one. In section 4, a recursive algorithm for estimating the free parameters is proposed for the general case. The same methodology can be applied for the special cases too, taking, however, into consideration the constraints.

Similarity Measure Type Estimation

Using, equation (4), it is clear that estimation of similarity measure is equivalent to the estimation of coefficients v_l, $w_{k,l}$. In particular, let us denote as $S^{(r)}$ a set, which contains selected relevant/ irrelevant samples at the r feedback iteration of the algorithm. The set $S^{(r)}$ has the form

$$S^{(r)} = \{\cdots,(\mathbf{f}_q - \mathbf{f}_i, R_i),\cdots\} = \{\cdots,(\mathbf{e}_i, R_i),\cdots\} \tag{8}$$

where $\mathbf{f}_q$ refers to the query feature vector, $\mathbf{f}_i$ to the feature vector of the ith selected sample and R_i to the respective degree of relevance. Negative values of R_i express irrelevant content, whereas positive values of R_i relevant content. Let us denote as $v_l(r+1)$, $w_{k,l}(r+1)$ the model parameters at the (r+1) feedback iteration. These coefficients are estimated so that, the similarity measure, after the rth feedback iteration, equals the degree of relevance assigned by the user over all selected data,

$$d^{(r+1)}(\mathbf{f}_q, \mathbf{f}_i) = g^{(r+1)}(\mathbf{f}_q - \mathbf{f}_i) = \sum_{l=1}^{L} v_l(r+1)\cdot\Phi_l\left(\sum_{k=1}^{P} w_{k,l}(r+1)\cdot(f_{q,k} - f_{i,k})\right) \approx R_i$$

with $i \in S^{(r)}$ (9)

where $d^{(r+1)}(\cdot)$ expresses the non-linear similarity measure at the (r+1)th feedback iteration of the algorithm.

Usually, the number of samples of set $S^{(r)}$ at the rth feedback iteration is much smaller than the number of coefficients v_l, $w_{k,l}$ that should be estimated. For example, a typical number for the coefficients is around 640 (L=10 and P=64), whereas the number of selected samples at a given feedback iteration is usually less than 10. Therefore, equation (9) is not sufficient to uniquely identify the parameters v_l, $w_{k,l}$. To achieve uniqueness in the solution, an additional requirement is imposed, which takes into consideration the variation of the similarity measure. In particular, among all possible solutions, the one that satisfies (9) and simultaneously causes a minimal modification of the already estimated similarity measure is selected as the most appropriate.

Let us denote as S a set, which contains relevant / irrelevant samples with respect to several queries. The set S is used for the initial estimation of the similarity measure based on a least squared minimization algorithm as described in section 5. At each feedback iteration, the set S is augmented by adding new selected relevant/ irrelevant samples. In order to retain a constant size of S, for computational efficient purposes, the older samples are removed from S as new samples added. Then, the requirement of the minimal modification of the already estimated similarity measure is expressed as

$$\text{minimize } B(r) = \left\| E^{(r+1)} - E^{(r)} \right\|_2 \tag{10}$$

where

$$E^{(r)} = \frac{1}{2}\cdot\sum_{i\in S}\{g^{(r)}(\mathbf{f}_q - \mathbf{f}_i) - R_i\}^2$$

corresponds to the error of the similarity measure over all data of S at the r$^{\text{th}}$ feedback iteration.

As a result, the model parameters of the similarity measure are estimated by the following constraint minimization problem

$$\text{minimize } B(r) = \left\| E^{(r+1)} - E^{(r)} \right\|_2 \tag{11a}$$

subject to

$$d^{(r+1)}(\mathbf{f}_q, \mathbf{f}_i) = g^{(r+1)}(\mathbf{f}_q - \mathbf{f}_i) = \sum_{l=1}^{L} v_l(r+1)\cdot\Phi_l\left(\sum_{k=1}^{P} w_{k,l}(r+1)\cdot(f_{q,k} - f_{i,k})\right) \approx R_i$$

with

$$(f_{q,k} - f_{i,k}) \in S^{(r)} \tag{11b}$$

The constraint term of equation (11b) indicates that, the proposed on-line learning strategy modifies the similarity measure so that, after the adaptation, the users' information needs are satisfied as much as possible. On the contrary, the term of (11a) expresses that the adaptation is accomplished with a minimal modification of the already estimated similarity measure.

Recursive Similarity Measure Adaptation

In this subsection, a recursive algorithm is presented to perform the constraint minimization of (11). Therefore, the scheme yields to a *Recursive Generalized Non-Linear Relevance Feedback* algorithm for information retrieval.

Let us consider that all coefficients $v_l(r)$, $w_{k,l}(r)$ are included in a vector, say $\mathbf{w}(r)$, i.e.,

$$\mathbf{w}(r) = [\cdots w_{k,l}(r) \cdots v_l(r) \cdots]^T \tag{12}$$

Vector $\mathbf{w}(r)$ is decomposed into

$$\mathbf{w}(r) = [vec\{\mathbf{W}(r)\}^T \, \mathbf{v}(r)^T]^T \tag{13}$$

where vector $\mathbf{v}(r)$ and matrix $\mathbf{W}(r)$ are related with the coefficients $v_l(r)$, $w_{k,l}(r)$ as

$$\mathbf{W}(r) = [\mathbf{w}_1(r) \cdots \mathbf{w}_L(r)] \text{ and } \\ \mathbf{v}(r) = [v_1(r) \cdots v_L(r)]^T \tag{14}$$

where

$$\mathbf{w}_l(r) = [w_{1,l}(r) \cdots w_{P,l}(r)]^T$$

and P the feature vector size. Operator $vec\{\cdot\}$ returns a vector formed by stacking up all columns of the respective matrix.

Let us now assume, that the model parameters at the $(r+1)$th feedback iteration, i.e., the $\mathbf{w}(r+1)$, are related to the model parameters $\mathbf{w}(r)$ at the rth iteration as

$$\mathbf{w}(r+1) = \mathbf{w}(r) + \Delta\mathbf{w} \tag{15}$$

where $\Delta\mathbf{w}$ refers to a small increment of the model coefficients. Equation (15) indicates that a small modification of the coefficients is adequate to satisfy the current user's information needs, expressed by (11b).

Adaptation to the Current Selected Relevant/Irrelevant Samples

In the following, we deal with the analysis of equation (11b), i.e., the constraint of the minimization. In particular, based on equation (15), linearization of the functional components $\Phi_l(\cdot)$ is permitted using a first order Taylor series expansion. Then, equation (11b) can be decomposed in a system of linear equations, as indicated by the following theorem

Based on the fact that the constraint expressed by equation (11b) under the assumption of (15) is decomposed to a system of linear equations of the form $\mathbf{c}(r) = \mathbf{A}(r) \cdot \Delta\mathbf{w}$, where vector $\mathbf{c}(r)$ and matrix $\mathbf{A}(r)$ depends only on the model parameters of the previous rth feedback iteration, vector $\mathbf{c}(r)$ expresses the difference between the desired degree of relevance R_i, assigned by the user, and the one provided by the system before the feedback iteration, i.e., using the parameters $\mathbf{w}(r)$.

In particular, vector $\mathbf{c}(r)$ is given as

$$\mathbf{c}(r) = [\ldots c^{(r)}(\mathbf{e}_i)\ldots]T, \text{ for all } \mathbf{e}_i \in S^{(r)} \text{ with}$$

$$c^{(r)}(\mathbf{e}_i) = g^{(r+1)}(\mathbf{e}_i) - g^{(r)}(\mathbf{e}_i) = R_i - g^{(r)}(\mathbf{e}_i) \tag{16}$$

where $\mathbf{e}_i = \mathbf{f}_q - \mathbf{f}_i$

Furthermore, matrix $\mathbf{A}(r)$ is given as

$$\mathbf{A}^T(r) = [\ldots \mathbf{a}^{(r)}(\mathbf{e}_i)\ldots], \text{ for all } \mathbf{e}_i \in S^{(r)} \tag{17}$$

where the columns $\mathbf{a}^{(r)}(\mathbf{e}_i)$ are given as

$$\mathbf{a}^{(r)}(\mathbf{e}_i) = [\mathrm{vec}\{\mathbf{e}_i \cdot (\mathbf{g}^{(r)})^T\}^T \mathbf{u}(r)^T]^T \tag{18}$$

where

$$\mathbf{u}(r) = \boldsymbol{\varphi}(\mathbf{W}^T(r) \cdot \mathbf{e}_i) \quad (19)$$

with $\boldsymbol{\varphi}(\cdot) = [\Phi_1(\cdot)...\Phi_L(\cdot)]^T$ a vector containing the functional components $\Phi_l(\cdot)$ [see equation (5)]. Vector $\mathbf{g}(r)$ is given as follows

$$\mathbf{g}(r) = \mathbf{D}(r) \cdot \mathbf{v}(r) \quad (20)$$

with matrix $\mathbf{D}(r)$ expresses the derivatives of the elements of vector $\mathbf{u}(r)$, i.e.,

$$\mathbf{D}(r) = diag\{\delta_1(r),...,\delta_L(r)\} \quad (21)$$

In (21) $diag\{\}$ refers to a diagonal matrix.

Since in our case the functional components $\Phi_l(\cdot)$ are the sigmoid, the

$$\delta_i(r) = u_i(r) \cdot [1 - u_i(r)] \quad (22)$$

Based on the previous equations, it can be seen that, vector $\mathbf{c}(r)$ and matrix $\mathbf{A}(r)$ are *only* related with the coefficients $v(r)$ and $w_{k,l}(r)$ of the rth feedback iteration.

Minimal Modification of the Similarity Measure

The term of equation (11a), which expresses the minimal modification of the already estimated similarity measure is decomposed under the assumption of equation (15) as follows

The effect of the small weight perturbation to the term of (11a) is provided by minimizing a squared convex function of the form

$$\frac{1}{2}\Delta\mathbf{w}^T \cdot \mathbf{J}^T(r) \cdot \mathbf{J}(r) \cdot \Delta\mathbf{w}\,,$$

where matrix $\mathbf{J}(r)$ is the Jacobian matrix of the error

$$E_i = \frac{1}{2} \cdot (g^{(r)}(\mathbf{f}_q - \mathbf{f}_i) - R_i)$$

over all samples of set S.

The Jacobian matrix $\mathbf{J}(r)$ is given as

$$\mathbf{J} = \begin{bmatrix} \vdots & \vdots & \vdots & \vdots & \vdots \\ \cdots & \dfrac{\partial E_i}{\partial w_{k,l}} & \cdots & \dfrac{\partial E_i}{\partial v_l} & \cdots \\ \vdots & \vdots & \vdots & \vdots & \vdots \end{bmatrix} \quad (23)$$

with the derivatives

$$\frac{\partial E_i}{\partial w_{k,l}} \text{ and } \frac{\partial E_i^{(r)}}{\partial v_l}$$

being expressed by the following equations

$$\frac{\partial E_i^{(r)}}{\partial w_{k,l}} = -t_i(r) \cdot v_k(r) \cdot \delta_l(r) \cdot e_{i,l}$$

and

$$\frac{\partial E_i}{\partial v_l} = -t_i \cdot u_l(\mathbf{e}_i) \quad (24)$$

with $t_i(r) = (g^{(r)}(\mathbf{f}_q - \mathbf{f}_i) - R_i)$ and $e_{i,l}$ the lth element of vector $\mathbf{e}_i = \mathbf{f}_q - \mathbf{f}_i$.

Based on the above, the recursive estimation of the model parameters for each feedback iteration is accomplished by calculating the small perturbation of the model coefficients $\Delta\mathbf{w}$ through the following constraint minimization problem

$$\text{Minimize } D = \frac{1}{2} \cdot \Delta\mathbf{w}^T \cdot \mathbf{J}^T \cdot \mathbf{J} \cdot \Delta\mathbf{w} \quad (25a)$$

$$\text{Subject to } \mathbf{c}(r) = \mathbf{A}(r) \cdot \Delta\mathbf{w} \quad (25b)$$

The main steps of the proposed generalized recursive non-linear relevance feedback scheme are the following:

1. Assume that the rth feedback iteration has been completed and the type of the similarity measure has been estimated as expressed

by the parameters **v**(r) and **W**(r). Then, the model parameters for the (r+1) iteration are updated with the following steps.

2. Estimate vector **c**(r) using (16) and matrix **A**(r) using (17 and 18).
3. Estimate matrix **J**(r) as in (23,24).
4. Apply the reduced gradient method for calculating the small increment of the model parameters Δ**w** (this method is described in the following paragraphs).
5. Update model coefficients using (15) and the model parameters **v**(r + 1) and **W**(r + 1).
6. The new similarity measure is expressed through (4).

The Reduced Gradient Method

Equation (25a) is a convex function since it is of square form (D. J. Luenberger, 1984). Furthermore, (25b) corresponds to linear constraints. As a result, only one minimum exists, which is the global one (D. J. Luenberger, 1984). One solution for minimizing (25) is to use Lagrange multipliers. However, in this case inversion of matrices of large size is involved, which is a process both computationally and memory demanded. For this reason, in this chapter an iterative constraint minimization technique is adopted to perform the constraint minimization of (25). Among other methods, such as the gradient projection (D. J. Luenberger, 1984), the reduced gradient method has been selected due to the fact that it demands less computational complexity, especially in case of few constraints, which is valid in our case.

The reduced gradient method is an iterative process, which starts from a feasible point (solution) and moves in a direction, which decreases the error function of equation (25a), while simultaneously satisfies the constraint defined by the equation (25b). A point is called feasible if it satisfies the constraints of (25b). To commence the algorithm, an initial feasible point Δ**w**(0) is required.

Initialization Phase

In our case, as initial feasible point, Δ**w**(0), the minimal distance from the origins to the constraint hyper-surface $\mathbf{c}(r) - \mathbf{A}(r)\cdot\Delta\mathbf{w} = \mathbf{0}$ is used. Therefore, Δ**w**(0) is given by minimizing the following equation

minimize $\left\|\Delta\mathbf{w}\right\|_2$ or $(\Delta\mathbf{w})^T\cdot\Delta\mathbf{w}$ equivalently (26a)

subject to $\mathbf{c}(r) - \mathbf{A}(r)\cdot\Delta\mathbf{w} = \mathbf{0}$ (26b)

Minimization of the (26a) subject to (26b) is achieved using Lagrange multipliers (D. J. Luenberger, 1984). In this case, the aforementioned minimization problem is written as

$$\Delta\mathbf{w}(0) = \underset{\Delta\mathbf{w}}{\operatorname{argmin}}\left((\Delta\mathbf{w})^T\cdot\Delta\mathbf{w} + \lambda^T\cdot(\mathbf{c}(r) - \mathbf{A}(r)\cdot\Delta\mathbf{w})\right) \tag{27}$$

where the elements of vector λ corresponds to the Lagrange multipliers. Differentiating equation (27) with respect Δ**w** and λ and setting the results equal to zero, we obtain

$$\Delta\mathbf{w}(0) = \mathbf{A}^T(r)\cdot(\mathbf{A}(r)\cdot\mathbf{A}^T(r))^{-1}\cdot\mathbf{c}(r) = \mathbf{Q}(r)\cdot\mathbf{c}(r) \tag{28a}$$

with $\mathbf{Q}(r) \equiv \mathbf{A}^T(r)\cdot(\mathbf{A}(r)\cdot\mathbf{A}^T(r))^{-1}$ (28b)

It should be mentioned that matrix $\mathbf{A}(r)\cdot\mathbf{A}^T(r)$ is of size $\zeta\times\zeta$, where ζ corresponds to the number of the imposed constraints, i.e., to the number of selected relevant/irrelevant data. This number is usually small, and inversion of matrix $\mathbf{A}(r)\cdot\mathbf{A}^T(r)$ does not demand high computational complexity and memory requirements.

Iteration Phase

At the mth iteration of the algorithm, the feasible point $\Delta\mathbf{w}(m)$ is arbitrarily partitioned into two groups; the first group contains the dependent (basic) variables, while the second the independent variables. Without loss of generality, we select the first elements of vector $\Delta\mathbf{w}(m)$ as dependent variables. Therefore,

$$\Delta\mathbf{w}(m) = [\Delta\mathbf{w}^D(m)^T \quad \Delta\mathbf{w}^I(m)^T]^T \qquad (29)$$

where $\Delta\mathbf{w}^D(m)$ is a vector, which contains the dependent variables, while $\Delta\mathbf{w}^I(m)$ the independent ones.

Using the constraint $\mathbf{c}(r) = \mathbf{A}(r) \cdot \Delta\mathbf{w}$, we can express the dependent vector $\Delta\mathbf{w}^D(m)$ with respect to the independent variables $\Delta\mathbf{w}^I(m)$ as follows

$$\mathbf{c}(r) = \mathbf{A}(r) \cdot \Delta\mathbf{w} \qquad (30)$$

where $\mathbf{A}^D(r)$ is the part of matrix $\mathbf{A}(r)$ which related to the dependent variables while the $\mathbf{A}^I(r)$ to the independent ones. Thus, $\mathbf{A}(r) = [\mathbf{A}^D(r)\ \mathbf{A}^I(r)]$. Matrix $\mathbf{A}^D(r)$ is always squared with size equals to the number of constraints ζ, thus $\mathbf{A}^D(r)$ is of $\zeta \times \zeta$ elements. This means that vector $\mathbf{c}(r)$ is of size $\zeta \times 1$. On the contrary, matrix $\mathbf{A}^I(r)$ is of size $\zeta \times \{L \cdot P - \zeta)$, where $L \cdot P$ corresponds to the number of the model parameters. Thus, vector $\Delta\mathbf{w}^I(m)$ is of size $(L \cdot P - \zeta) \times 1$.

At next iterations, the independent variables are updated towards the direction of the respective gradient,

$$\Delta\mathbf{w}^I(m+1) = \Delta\mathbf{w}^I(m) - \eta(m) \cdot \mathbf{r}(m) \qquad (31)$$

In equation (31), scalar $\eta(m)$ regulates the convergence rate of the weight updating, while $\mathbf{r}(m)$ refers to the reduced gradient, which is given as

$$\mathbf{r}^T(m) = \theta^T - \gamma^T \cdot (\mathbf{A}^D(r))^{-1} \cdot \mathbf{A}^I(r) \qquad (32)$$

where vectors θ and γ are provided by splitting the gradient of cost function D into the dependent and independent group

$$\nabla B(r) = \mathbf{J}^T(r) \cdot \mathbf{J}(r) \cdot \Delta\mathbf{w}(m) = [\theta^T \quad \gamma^T]^T \qquad (33)$$

The main steps of the reduced gradient method, which is used in our case for estimating the new network weights, are the following:

1. Initialization Phase
   a. Estimate the initial model increment $\Delta\mathbf{w}(0)$ using equation (28)
   b. Set m=0
2. Iteration Phase
   a. Estimate the reduced gradient $\mathbf{r}(m)$ using equation (32) and (33)
   b. Update the increment of the independent variables at the (m+1) iteration using (31)
   c. Estimate the increment of the dependent variables at the (m+1) iteration using (30)
   d. If the error

$$\left\| \Delta\mathbf{w}(m+1) - \Delta\mathbf{w}(m) \right\|_2 < T \ ,$$

where T a threshold then stop the iteration else Set m=m+1 and reinitiate the Iteration Phase.

Following the above analysis, it is clear that the proposed functions and the reduced gradient method allows the update on the weights of the ANN's equation (Equation (3)) in order to enable the integration of the relevance feedback (Equation (9)) as provided by the user.

EVALUATION

In this section, we briefly discuss some experimental results to evaluate the efficiency of the proposed generalized non-linear relevance feedback scheme for content-based retrieval from a database that contains medical data.

The aforementioned database was deployed in the National Technical University of Athens, enhanced by medical information obtained from the university's library. This information refers to scientific content: research papers, journals and case studies; the archives are used for conducting the presented experiments. The overall data set consists of around 15,000 data covering a wide variety of medical content. We also used a "parsing" service that searches in the database's content and annotates it in order to produce specific categories of the content (we concluded to 80 categories). As described previously in this book chapter, several data descriptors are extracted and organized - to which the proposed relevance feedback approach is applied. Each data descriptor includes segments properties that are used to describe this segment. These properties are the type of article, the keywords, the publication area, the authors and the publication date. To these segments we applied specific queries - as described in detail in the following paragraphs - to improve the performance of any retrieval system.

Objective Evaluation Criteria for the Retrieval Performance

Usually, the quantitative evaluation of a content-based retrieval system is performed through the *Precision-Recall Curve* measure.

Precision for a query *q [Pr(q)]* is defined as the ratio of the number of retrieved relevant images, say *N(q)* over the number of total retrieved articles, say *M* [36]. On the other hand, recall of a query *q [Re(q)]* is the ratio of the number of retrieved relevant articles *N(q)* over the total number of relevant articles in the database for the respective query, *G*(*q*) [36].

$$\Pr(q) = \frac{N(q)}{M}, \ \operatorname{Re}(q) = \frac{N(q)}{G(q)} \qquad (34)$$

In a real content-based retrieval system, as the number *M* of articles returned to the user increases, precision decreases, while recall increases. Because of this, instead of using a single value of Pr(*q*) or Re(*q*), the curve Precision-Recall is adopted.

In equation (34), precision and recall have been estimated for a given query *q*. However, to evaluate the performance of a content-retrieval system, many queries should be applied and the average value of precision/recall should be estimated. Assuming that *Q* queries are submitted, the average precision/recall, APr, ARe are defined as

$$\text{APr} = \frac{1}{Q}\sum_{q=1}^{Q}\Pr(q) \ \ \text{ARe} = \frac{1}{Q}\sum_{q=1}^{Q}\operatorname{Re}(q) \, (35)$$

The following figure (Figure 3) presents the average precision-recall curve as obtained by submitted around 3,000 randomly selected queries to the database at the fifth feedback iteration. As is expected, the best precision for every recall value is achieved using the proposed generalized non-linear relevance feedback scheme. This is due to the fact that in this case the type of the similarity measure is recursively updated to fit the current users' information needs. The second best precision performance is noticed for the correlation-based relevance feedback algorithm of Method 1 (N. Doulamis, 2001). This is mainly due to the fact that, in this case, the similarity measure is based on the correlation metric, which provides a better physical representation of the similarity content. In this figure, we have also depicted the performance of the algorithm of (Xiang Sean Zhou, 2001) - Method 2, which presents a slight worse performance compared to the correlation-based approach. It should be mentioned that for all the compared relevance feedback algorithms, the same feature vector representation was used. As a result, the highest retrieval performance obtained by the proposed non-linear relevance feedback scheme is due to the fact that the adopted similarity measure better models the user's information needs and preferences. This means that the proposed scheme estimates the non-linear relationship of the feature vectors used to describe the medical content characteristics and the actual user's information needs in perceiving the content. For this reason, better retrieval results are derived with respect to traditional approaches, where a similarity measure of constant type is used.

The precision values with respect to feedback iterations for recall 10% and 30% are shown in Figure 4 respectively for the aforementioned algorithms. The results have been evaluated on the entire database by submitting around 3,000 randomly selected queries.

In all cases, the precision increases with respect to feedback iterations, with a decreasing, however, improvement ratio, meaning that beyond a certain limit only a slight precision increase is accomplished. It can be seen that the proposed scheme outperforms the compared ones for each one of the feedback iterations.

THE SYSTEM FUTURE TRENDS

Notwithstanding, it is within our future plans to attempt to implement the NN along with the relevance feedback mechanism so as to allow the provision of the functionality that is described in this chapter as a service. As a result, this service could be used as a "filter" service to any information retrieval service providing the most relevant results to the users based on prior searches. The latter is considered of major importance since many approaches have been presented as ways to handle the information retrieval problem in biomedicine. For example, authors of (Min Hong, 2005) present a complete approach for biomedical information retrieval including classification of technical documents, continuous learning on user's interests and requests and provision of an interactive interface to navigate vast information spaces. Moreover, in (Hagit Shatkay, 2005) information retrieval problems focused in the biomedical field are discussed while literature (Y. Kagolovsky, 1998) describes information extraction from medical text resources. The outcome of these approaches can be optimized by a service that comprises both the method for the relevance feedback and the NN modeling described in this chapter.

CONCLUSION

Information retrieval in biomedicine is an important issue but due, however, to the subjective perception of humans as far as the content is concerned, adaptive management algorithms are required to update the system response to actual users' information needs and preferences. Adaptation of content management is achieved through on-line learning strategies, which modify the similarity measure used for ranking visual data.

Providing optimization capabilities to systems that deal with content retrieval - independently both from the content and from the retrieval technique, is a topic of interest in many research areas. To this direction we proposed an architecture that includes an artificial neural network and a relevance feedback scheme. The outcome of the relevance feedback scheme is encompassed into the neural network in order to allow its adaptability to the changes proposed by the user. In order to achieve the latter, the weights on the NN equation need to change in a way to reflect the user's feedback.

One method for on-line learning is *relevance feedback*, an adaptive mechanism, which modifies the response of a system according to the *feedback* about the *relevance* of selected samples so that the system response is adjusted to the current user's information needs. Although relevance feedback is not restricted to description environments where similarity measures are used, in databases where similarity-based queries are applied, relevance feedback refers to the mechanism which updates the similarity measure with respect to the relevant/irrelevant information, as indicated by the user. In this chapter, we address the problem of relevance feedback in the most generic form by updating the type of similarity measure itself, instead of adjusting the degree of importance of the descriptors to the similarity measure. Therefore, *a generalized non-linear* relevance feedback scheme is discussed.

In particular, functional analysis is used to model the non-linear similarity measure, by expressing it as a parametric relation of known monotone increasing functional components. Then, a recursive model parameter updating algorithm is adopted, which adapts the similarity measure type to the current users' information needs and preferences, as expressed by a set of selected relevant/irrelevant data. The adaptation is performed so that a) the current selected data are satisfied as much as possible and b) a minimal modification of the already estimated similarity measure (i.e., existing knowledge) is accomplished. Assuming that a small perturbation of the model parameters is adequate to satisfy the aforementioned conditions, the algorithm results in a constraint minimization problem for estimating the contribution of each functional component to the similarity measure.

The experimental results indicate that the presented *generalized recursive non-linear* relevance feedback scheme yields promising results and the proposed method provides better retrieval ranking due to the fact that no restrictions on the similarity type are imposed, as happens with the previous approaches and therefore better adaptation to the current users' information needs is accomplished. Another advantage of the proposed algorithm is the fact that it can be recursively implemented in case of multiple feedback iterations, in contrast to most of the previous approaches. This results in a computationally efficient algorithm, which further increases the effectiveness of the proposed method. In addition, the algorithm is robust regardless of the number of selected relevant/irrelevant samples, i.e., small selected samples are enough to accurately update the type of similarity measure, in contrast to some of the previously proposed techniques.

REFERENCES

Avrithis, Y., Doulamis, A. D., Doulamis, N. D., & Kollias, S. D. (1998). An Adaptive Approach to Video Indexing and Retrieval. *Proceedings of the International Workshop on Very Low Bitrate Video Coding (VLBV)*, (pp. 69-72), Urbana IL, October 1998.

Choi, Y., Kim, D., & Krishnapuram, R. (2000). Relevance Feedback for Content-based Image Retrieval using Choquet Integral. *Proceedings of the IEEE International Conference on Multimedia & Expo*, (pp. 1207-1210), New York, August 2000.

Cox, I., Miller, M. L., Omohundro, S. M., & Yianilos, P. N. (1996). Pichunter: Bayesian Relevance Feedback for Image Retrieval. *Proceedings of the International Conference on Pattern Recognition*, *3*, 362–369.

Cybenko, G. (1989). Approximation by Superpositions of a Sigmoidal function. *Mathematics of Control, Signals, and Systems*, *2*, 303–314. doi:10.1007/BF02551274

Doulamis, A. D., Avrithis, Y. S., Doulamis, N. D., & Kollias, S. D. (1999). Interactive Content-Based Retrieval in Video Databases Using Fuzzy Classification and Relevance Feedback. *Proceedings of the IEEE International Conference on Multimedia Computing and Systems (ICMCS), 2,* 954-958, Florence, Italy, June 1999.

Doulamis, N., & Doulamis, A. (2001). A Recursive Optimal Relevance Feedback Scheme for Content Based Image Retrieval," *Proceedings of the IEEE International Conference on Image Processing (ICIP), 2*, 741-744, Thessaloniki, Greece, October 2001.

Doulamis, N., Doulamis, A., & Kollias, S. (2001). Fuzzy Histograms and Optimal Relevance Feedback for Interactive Content-based Image Retrieval. *IEEE Transactions on Image Processing.*

Doulamis, N., Doulamis, A., & Ntalianis, K. (2001). Optimal Interactive Content-Based Image Retrieval," *Proceedings of the International Conference on Augmented, Virtual Environments and 3D Imaging*, 248-251, Myconos, Greece, May 2001.

Hong, M., Karimpour-Fard, A., Russell, R., & Hunter, L. (2005). Integrated Term Weighting, Visualization, and User Interface Development for Bioinformation Retrieval. *Artificial Intelligence and Simulation, Lecture Notes in Computer Science*, Springer Verlag.

Ishikawa, Y., Subramanya, R., & Faloutsos, C. (1998). Mindreader: Querying Databases through Multiple Examples. *Proceedings of the 24th VLDB conference*, New York, USA.

Kagolovsky, Y., Freese, D., Miller, M., Walrod, T., & Moehr, J. (1998). Towards improved information retrieval from medical sources. *International journal of medical informatics*.

Kreyszig, E. (1989). *Introductory Functional Analysis with Applications*. New York: Wiley & Sons.

Luenberger, D. J. (1984) *Linear and non Linear Programming*. Addison-Wesley.

Rocchio, J. (1971). Relevance Feedback in Information Retrieval. *The SMART Retrieval System: Experiments in Automatic Document Processing*, Prentice Hall.

Rui, Y., & Huang, T. S. (2000) Optimizing Learning in Image Retrieval. *Proceedings of the IEEE International Conference on Computer Vision and Pattern Recognition*, Jun. 2000.

Rui, Y., Huang, T. S., Ortega, M., & Mehrotra, S. (1998). Relevance Feedback: A Power Tool for Interactive Content-Based Image Retrieval. *IEEE Transactions on Circuits and Systems for Video Technology*, *8*(5), 644–655. doi:10.1109/76.718510

Salton, G., & McGill, M. J. (1982). *Introduction to Modern Information Retrieval*. New York: McGraw-Hill Book Company.

Shatkay, H. (2005). Information retrieval from biomedical text. *Briefings in Bioinformatics*, Henry Stewart Publications.

Zhou, X. S., & Huang, T. S. (2001). Small Sample Learning during Multimedia Retrieval using BiasMap. *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition,* Hawaii, December 2001.

This work was previously published in Information Retrieval in Biomedicine: Natural Language Processing for Knowledge Integration, edited by V. Prince; M. Roche, pp. 255-272, copyright 2008 by Information Science Reference (an imprint of IGI Global).

Chapter 7.12

Queuing Theory and Discrete Events Simulation for Health Care:

From Basic Processes to Complex Systems with Interdependencies

Alexander Kolker
Children's Hospital and Health Systems, Milwaukee, WI, USA

ABSTRACT

This chapter describes applications of the discrete events simulation (DES) and queuing analytic (QA) theory as a means of analyzing healthcare systems. There are two objectives of this chapter: (i) to illustrate the use and shortcomings of QA compared to DES by applying both of them to analyze the same problems, and (ii) to demonstrate the principles and power of DES methodology for analyzing both simple and rather complex healthcare systems with interdependencies. This chapter covers: (i) comparative analysis of QA and DES methodologies by applying them to the same processes, (ii) effect of patient arrival and service time variability on patient waiting time and throughput, (iii) comparative analysis of the efficiency of dedicated (specialized) and combined resources, (iv) a DES model that demonstrates the interdependency of subsystems and its effect on the entire system throughput, and (v) the issues and perspectives of practical implementation of DES results in health care setting.

INTRODUCTION: SYSTEM-ENGINEERING METHODS FOR HEALTHCARE DELIVERY

Modern healthcare achieved great progress in developing and manufacturing of medical devices, instruments, equipment and drugs to serve individual patients. This was achieved mainly by focusing public and private resources on research in the life sciences, as well as on design and development of medical clinical and imaging devices.

At the same time, relatively little technical talent and material resources have been devoted to improving operations, quality and productivity of the overall health care as an integrated delivery system. According to the joint report of the National Academy of Engineering and Institute of Medicine (Reid et al, 2005), the cost of this collective inattention and the failure to take advantage of the methods that has provided quality and productivity breakthroughs in many other sectors of economy are enormous.

In this report system-engineering methods have been identified that have transformed the quality, safety and productivity performance of many other large-scale complex industries (e.g. telecommunications, transportation, manufacturing). (Reid et al, 2005). These system-engineering methods could also be used to improve efficiency of health care delivery as a patient-centered integrated system.

Ryan (2005) summarized system-engineering principles for healthcare. A system is defined as a set of interacting, interrelated elements (subsystems) - objects and/or people- that form a complex whole that behaves in ways that these elements acting alone would not. Models of a system enable one to study the impact of alternative ways of running the system, i.e. alternative designs, different configurations and management approaches. This means that system models enable one to experiment with systems in ways that cannot be used with real systems.

The models usually include a graphic representation of the system, which is a diagram showing the flow of items and resources. A mathematical description of the model includes objective functions, interrelationship and constraints. The components of the mathematical model can be grouped into four categories: (i) decision variables that represent possible options; (ii) variables, parameters and constants, which are inputs into the model, (iii) the objective functions, which are the output of the model, and (iv) constraints and logic rules that govern operation of the system.

Large systems are usually deconstructed into smaller subsystems using natural breaks in the system. The subsystems are modeled and analyzed separately, but they should be reconnected back in a way that recaptures the most important interdependency between them. Lefcowitz (2007) summarized, for example, that '…maximization of the output of the various subsystems should not be confused with maximizing the final output of the overall system'. Similarly, Goldratt (2004, p. 211) states that 'a system of local optimums is not an optimum system at all; it is a very inefficient system'.

Analysis of a complex system is usually incomplete and can be misleading without taking into account subsystems' interdependency (see section 3.3). Analysis of a mathematical model using analytic or computer algorithmic techniques reveals important hidden and critical relationships in the system that allows leveraging them to find out how to influence the system's behavior into desired direction.

The elements included in the system model and required information depends on the problem to be solved. For the output of the model to be useful, the model must mimic the behavior of the real system.

According to the already mentioned report by The National Academy of Engineering and Institute of Medicine (Reid et al, 2005), the most powerful system-analysis methods are Queuing Theory and Discrete Event Simulation (DES).

Both methods are based on principles of operations research. Operations research is the discipline of applying mathematical models of complex systems with random variability aimed at developing justified operational business decisions. It is widely used to quantitatively analyze characteristics of processes with random demand for services, random service time and available capacity to provide those services. Operations research methodology is the foundation of the modern management science.

Health care management science is applied to the various aspects of patient flow, capacity planning, allocation of material assets and human resources to improve the efficiency of healthcare delivery.

For the last 40 years, hundreds of articles have been published that demonstrate the power and benefits of using management science in healthcare. Several reviews have appeared that specifically examine DES applications in healthcare, such as Jun et al (1999), Carter (2002) and the recent review by Jacobson et al. (2006) that provides new updates that have been reported since 1999.

In contrast to these reviews that mainly listed DES publications without much discussion on how and why the models actually work and deliver, the objective of this chapter is to present a detailed description of the 'inner workings' of DES models for some healthcare processes starting from basic applications and proceeding to rather advanced models.

It is also a goal to demonstrate the fundamental advantage of DES methodology over queuing analytic (QA) models. This is demonstrated by comparative analysis of both DES and QA applied to the same problems.

The focus of this chapter is DES of the various aspects of random and non-random patient flow variability and its effect on process performance metrics. Using concrete examples and scenarios, it was demonstrated how simple DES models help to gain understanding of the basic principles that govern patient flow with random and non-random variability. It is further demonstrated how more advanced DES models have been used to study system behavior (output) changes with the change of the input data and/or process parameters.

QUEUING ANALYTIC (QA) MODELS AND DISCRETE EVENT SIMULATION (DES)

Queuing Analytic Models: Their Use and Limitations

The term 'queuing theory' is usually used to define a set of analytic techniques in the form of closed mathematical formulas to describe properties of the processes with a random demand and supply (waiting lines or queues). Queuing formulas are usually applied to a number of pre-determined simplified models of the real processes for which analytic formulas can be developed.

Weber (2006) writes that '…There are probably 40 (queuing) models based on different queue management goals and service conditions…' and that it is easy '… to apply the wrong model' if one does not have a strong background in operations research.

Development of tractable analytic formulas is possible only if a flow of events in the system is a steady-state Poisson processes. On definition, this is an ordinary stochastic process of independent events with the constant parameter equal to the average arrival rate of the corresponding flow. Time intervals between events in a Poisson flow are always exponentially distributed with the average inter-arrival time that is the inverse Poisson arrival rate. Service time is assumed to follow an exponential distribution or, rather rarely, uniform or Erlang distribution. Thus, processes with a Poisson arrival of events and exponential service time are Markov stochastic processes with discrete states and continuous time.

Most widely used queuing models for which relatively simple closed analytical formulas have been developed are specified as *M/M/s* type (Hall, 1990; Lawrence and Pasternak, 1998; Winston and Albright, 2000). (*M* stands for Markov since Poisson process is a particular case of a stochastic process with no 'after-effect' or no memory, known as continuous time Markov process). These models assume an unlimited queue size that is served by *s* providers.

Typically *M/M/s* queuing models allow calculating the following steady-state characteristics:

- probability that there are zero customers in the system probability that there are *K* customers in the system
- the average number of customers waiting in the queue
- the average time the customers wait in the queue
- the average total time the customer spends in the system ('cycle time')
- utilization rate of servers, i.e. percentage of time the server is busy

As more complexity is added in the system, the analytic formulas become less and less tractable. Analytic formulas are available that include, for example, limited queue size, customers leaving the system after waiting a specified amount of time, multiple queues with different average service time and different providers' types, different service priorities, etc (Lawrence and Pasternak, 1998; Hall, 1990).

However the use of these cumbersome formulas even built in Excel spreadsheets functions (Ingolfsson et al, 2003) or tables (Hillier, Yu, 1981; Seelen et al, 1985) is rather limited because they cannot capture complexity of most healthcare systems of practical interest.

Assumptions that allow deriving most queuing formulas are not always valid for many healthcare processes. For example, several patients sometimes arrive in Emergency Department at the same time (several people injured in the same auto accident), and/or the probability of new patient arrivals could depend on the previous arrivals when ED is close to its capacity, or the average arrival rate varies during a day, etc. These possibilities alone make the arrival process a non-ordinary, non-stationary with after-effect, i.e. a non-Poisson process for which queuing formulas are not valid. Therefore, it is important to properly apply statistical goodness-of-fit tests to verify that the null-hypothesis that actual arrival data follow a Poisson distribution cannot be rejected at some level of significance.

An example of a conclusion from the goodness-of-fit statistical test that is not convincing enough can be found, for instance, in Harrison et al (2005). The authors tried to justify the use of a Poisson process by using a chi-square goodness-of-fit test. The authors obtained the test p-values in the range from 0.136 to 0.802 for different days of the week. Because p-values were greater than 0.05 level of significance, they failed to reject the null-hypothesis of Poisson distribution (accepted the null-hypothesis).

On the other hand, the fundamental property of a Poisson distribution is that its mean value is equal to its variance (squared standard deviation). However, the authors' own data indicated that the mean value was not even close to the variance for at least four days of the week. Thus, the use of a Poisson distribution was not actually convincingly justified for the patient arrivals. Apparently, chi-square test p-values were not large enough to accept the null-hypothesis with high enough confidence (alternatively, the power of the statistical test was likely too low).

Despite its rather limited applicability to many actual patient arrival patterns, a Poisson process is widely used in operation research as a standard theoretical assumption because of its mathematical convenience (Gallivan, 2002; Green, 2006; Green et al, 1991; McManus et al, 2003).

The use of QA theory is often recommended to solve many pressing hospital problems of patient flow and variability, calculating needed nursing resources, the number of beds and operating rooms (IHI, 2008; Litvak, 2007; McManus et al, 2004; Haraden et al, 2003). However, such a recommendation ignores some serious practical limitations of QA theory for hospital applications.

D'Alesandro (2008) summarized why QA theory is often misplaced in hospitals.

Some authors are trying to make queuing formulas applicable to real processes by fitting and calibration. For example, in order to use queuing formulas for a rather complex ED system, Mayhew and Smith (2008) made a significant process simplification by presenting the workflow as a series of stages. The stages could include initial triage, diagnostic tests, treatment, and discharge. Some patients experienced only one stage while others more than one. However, '… what constitutes a 'stage' is not always clear and can vary…and where one begins and ends may be blurred' (Mayhew and Smith, 2008). The authors assumed a Poisson arrival and exponential service time but then used actual distribution service time for 'calibration' purposes. Moreover, the authors observed that exponential service time for the various stages '…could not be adequately represented by the assumption that the service time distribution parameter was the same for each stage'. In the end, all the required calibrations, adjustments, fitting to the actual data made the model to lose its main advantage as a queuing model: its analytical simplicity and transparency. On the other hand, all queuing formulas assumptions and approximations still remained.

Therefore many complex healthcare systems with interactions and interdependencies of the subsystems cannot be effectively analyzed using analytically derived closed formulas.

Moreover, queuing formulas cannot be directly applied if the arrival flow contains a non-random component, such as scheduled arrivals (see sections 2.2.5, 2.3 and 3.2). Therefore, in order to use analytic queuing formulas, the non-random arrival component should be first eliminated, leaving only random arrival flow for which QA formulas could be used (Litvak, 2007).

Green (2004) applied *M/M/s* model to predict delays in the cardiac and thoracic surgery unit with mostly elective scheduled surgical patients assuming a Poisson pattern of their arrivals. The author acknowledged that this assumption could result in an overestimate of delays. In order to justify the use of *M/M/s* model the author argued that some '…other factors are likely to more than compensate for this'. However, it was not clear what those factors are and how much they could compensate the overestimated delays.

Still, despite their limitations, QA models have some place in operation research for application to simply structured steady-state processes if a Poisson arrival and exponential service time assumptions are accurate enough.

A number of specific examples that illustrate the use of simple QA models and their limitations are presented in the next sections.

Flu Clinic: Unlimited Queue Size with Steady State Operation

A small busy clinic provides flu shots during a flu season on a walk-in basis (no appointment necessary). The clinic has two nurses (servers). Average patient arrival rate is 54 patients per hour with about the same number of elderly and all others. Each shot takes on average about 2 min.

Usually there are quite a few people in the queue waiting for the shot. In order to reduce waiting time and the number of people in the queue, the staff conducted a brainstorming session. It was proposed to have one nurse to perform flu shots only for most vulnerable elderly patients, and another nurse to perform shots for all others. The staff began developing a pilot project plan to test this new operation mode on the clinic floor.

However, the clinic's manager decided first to test this idea using principles of management science and operations research. The manager assumed that analytical queuing formulas would be applicable in this case.

For the current operation mode, the following *M/M/s* analytical model with the unlimited queue size can be used:

Random patient arrivals are assumed to be a Poisson process with the total average arrival rate

λ=54 pts/hr, average flu shot time τ=2 min and the number of servers N=2.

The final (steady-state) probability that there are no patients in the system, p_0, is calculated using the formula (Hall, 1990; Green, 2006)

$$p_0 = [\sum_{n=0}^{N-1} \frac{a^n}{n!} + \frac{a^N}{N!(1-\rho)}]^{-1} \qquad (2.1)$$

where

$$\rho = a / N \;\; \rho = a / N$$

The average number of patients in the queue, L_q, is

$$L_q = a^{N+1} * p_0 / [N * N! * (1-\rho)^2] \qquad (2.2)$$

and the average time in the queue, t, is (the Little's formula)

$$t = L_q / \lambda \qquad (2.3)$$

Substituting in the formulas (2.1) to (2.3) N=2, λ=54 pts/hr, and τ=2 min=0.033 hrs, we get average L_q =7.66 patients, and the average waiting time, t, about 8.5 min. The clinic's average utilization is 90%.

In practice, an excel spreadsheet is usually used to perform calculations using queuing formulas.

The new proposed system that is supposed to perform better will consist of two dedicated patient groups that would form two separate queues, one for elderly patients and another for all others (two separate subsystems with N=1). Arrival rate for each patient group is going to be λ=54 /2=27 pts/hr.

Parameter

$$\rho = a = \lambda * \tau = 27\, pts / hr * 0.0333\; hr = 0.9\,.$$

Using formulas (2.1) to (2.3), we get the average number of patients in each queue Lq =8.1. Thus, the total queue for all patients will be 2*8.1=16.2 patients.

The average waiting time in the queue will be about 8.1/27=0.3 hours= 18 min.Thus, in the proposed 'improved' process the average waiting time and the number of patients in the queue will be about twice of those in the original process.

It should be concluded that the proposed improvement change that might look reasonable on the surface does not stand the scrutiny of the quantitative analysis.

The idea of separating one random patient flow with two servers on two separate random flows, each with one dedicated server, does not result in improvement because two separate servers cannot help each other if one of them becomes overworked for some time due to a surge in patient volume because of random variability of the patient flow.

This is an illustration of the general principle that the combined random work flow with unlimited queue size and no leaving patients is more efficient than separate work flows with the same total work load (see also section 2.3).

An example of using discrete events simulation (DES) to analyze the same process without resorting to analytical formulas will be given in section 2.

Flu Clinic: Unlimited Queue Size with Non-Steady-State Operation

The manager of the same clinic decided to verify that the clinic would operate smoothly enough with a new team of two less experienced nurses who would work only a little slower than the previous one. The average time to make a shot will be about 2.5 min (instead of average 2 min for more experienced staff, as in section 2.1.1). The manager reasoned that because this difference is relatively small it would not practically affect the clinic operation: the number of patients in the queue and their waiting time on the typical working day could be only a little higher than in the previous case or practically not different at all.

The manager plugged the average service time 2.5 min and the same arrival rate 54 pts/hr in the *M/M/s* queuing calculator. However the calculator returned no number at all, which means that no solution could be calculated. Why is that?

An examination of Equation (2.1) shows that if ρ becomes greater than 1 the last term in the sum becomes negative and the calculated p_0 also becomes negative, which does not make sense. (If ρ is equal to 1, the term becomes uncertain and the calculations cannot be carried out at all). The average service time in this example is only slightly higher than it was in the previous case. However, this small difference made parameter ρ greater than 1 ($\rho=1.125>1$). This explains why the calculations cannot be done using this value.

Queuing analytical formulas with unlimited queue size are applicable only for steady-state processes, i.e. for the established processes whose characteristics do not depend on time. The steady-state condition is possible only if $\rho < 1$, otherwise the above formulas are not applicable and the queue grows indefinitely.

In section 2.2.2 it will be demonstrated how DES methodology easily handles this situation and demonstrates growth of the queue.

Flu Clinic: Time-Varying Arrival Rates

In the previous section 2.1.2 parameters of the queuing system (average arrival rate 54 patients per hour and average shot time 2.5 min) made a patient flow a non-steady-state one for which QA model with unlimited queue size could not be used.

However, the clinic's manager realized that the average patient arrival rate varies significantly during a day, and that 54 patients per hour was actually a peak arrival rate, from noon to 3 pm. In the morning hours from 8 am to 10 am the arrival rate was lower, 30 patients / hour. From 10 am to noon it was 40 patients / hour, and in the afternoon from 3 pm to 6 pm it was about 45 patients / hour.

Thus, the manager calculated the average arrival rate for these time periods for the day. It turned out to be (30+40+54+45)/4=42.25 patients/hour. He/she plugged this number in the queuing calculator (along with the average time to make a shot 2.5 min), and obtained the average number of patients in queue L_q =6.1 patients, and the average waiting time about 8.6 min. Because the calculator produced some numbers the manager made a conclusion that this clinic process will be in a steady-state condition and that the waiting time and the number of patients in the queue is acceptable.

But is it a correct conclusion ? Recall that QA models assume that a Poisson arrival rate is constant during a steady-state time period (Hall, 1990; Lawrence et al, 2002; Green, 2006). If it is not constant, such as in this case, QA results could be very misleading. The wait time will be significantly greater in the mid-day period (and/or the steady-state condition will be violated). At the beginning and at the end of the day, though, the wait time will be much smaller. Because the arrival rate is included non-linearly in the exponential term of a Poisson distribution formula, the arrival rate cannot be averaged first and then substituted in the exponential term. (For non-linear functions, the average value of a function is not equal to the function of average values of its arguments).

As Green (2006) stated '…this illustrates a situation in which a steady-state queuing model is inappropriate for estimating the magnitude and timing of delays, and for which a simulation model will be far more accurate'.

It is tempting, as a last resort, to save the use of QA model by dividing the day into time periods in which arrival rate is approximately constant. Then a series of *M/M/s* models is constructed, one for each period. This approach is called SIPP (stationary independent period-by-period) (Green, 2006; Green et al, 1991).

If we apply this approach, the following results can be obtained:

- Time period 8 am to 10 am: L_q =0.8 patients in the queue, waiting time 1.6 min
- Time period 10 am to noon: L_q =3.8 patients in the queue, waiting time 5.7 min
- Time period noon to 3 pm: *no steady-state solution*
- Time period 3 pm to 6 pm: L_q =13.6 patients in the queue, waiting time 18.1 min

Notice how these results differ from those based on the averaging of the arrival rate for the entire day.

However this SIPP patch applied to QA models was found to be unreliable (Green, 2006; Green et al, 2001). This is because in many systems with time-varying arrival rates, the time of peak congestion significantly lags the time of the peak in the arrival rate (Green et al, 1991). These authors developed a modification called *Lag-SIPP* that incorporates an estimation of this lag. This approach has been shown to often be more effective than a simple SIPP (Green, 2006).

Even it is so, this does not make QA models application easier if there are many time periods with different constant arrival rates because many different *M/M/s* models need to be constructed accordingly to describe one process.

It will be demonstrated in section 2.2.4 how DES model easily and elegantly handles this situation with time-varying arrival rate.

ICU Waiting Time

This problem is presented by (Litvak 2007; Weber, 2006) to demonstrate how QA can be used to compare patient average waiting time to get into ICU if it has 5 beds and 10 beds and patient average arrival rate is 1 per day and 2 per day, accordingly. The average length of stay in ICU is 2.5 days. It is assumed that the length of stay in the ICU is exponentially distributed and, of course, that patient arrival is a Poisson process.

In order to apply QA formulas an additional assumption should be used that length of stay follows exponential distribution with the above average value.

Using *M/M/s* model it is easy to calculate that the average waiting time for 10 beds ICU is 0.43 hours, and that for 5 beds ICU is 3.1 hours. Average ICU utilization is 50%.

Thus, the waiting time for the larger unit is about 7 times shorter. Notice, however, that this result is valid only for exponential service and inter-arrival time. If other distributions with the same average are used we should get a different result.

For example, length of stay could be in the range from 2 to 3 days with the average 2.5 days, and be described by a triangle distribution. Or the length of stay could follow a long-tailed lognormal distribution, also with the same average of 2.5 days and standard deviation of, say, 2 days (these values would correspond to log-normal parameters 3.85 and 0.703).

Thus, QA does not distinguish between different distributions with the same averages. This is a serious limitation of QA.

It will be demonstrated in section 2.2.7 how easy it is to use DES for different length of stay distributions with the same average.

DES Models: Basic Applications

In contrast to queuing formulas, DES models are much more flexible and versatile. They are free from assumptions of the particular type of the arrival process (Poisson or not), as well as the service time (exponential or not). They can be used for the combined random and non-random arrival flow. The system structure (flow map) can be complex enough to reflect a real system structure, and custom action logic can be built in to capture the real system behavior.

Table 1.

Inter-arrival time, min	Service time, min
2.6	1.4
2.2	8.8
1.4	9.1
2.4	1.8

At the same time it should be noted that building a complex realistic simulation model sometimes requires a significant amount of time for custom logic development, debugging, model validation, and input data collection.

However, a good model is well worth the efforts because it becomes a powerful and practically the only real tool for quantitative analysis of complex hospital operations and decision-making.

Many currently available simulation software packages (ProcessModel, ProModel, Arena, Simula8, and many others) provide a user-friendly interface that makes the efforts of building a realistic simulation model not more demanding than the efforts to make simplifications, adjustments and calibrations to develop a rather complex but inaccurate queuing model.

Swain (2007), Abu-Taeh et al (2007), Hlupic (2000), Nikoukaran (1999) provided a review and a comparative study of dozens commercially available simulation packages.

A DES model is a computer model that mimics the dynamic behavior of a real process as it evolves with time in order to visualize and quantitatively analyze its performance. The validated and verified model is then used to study behavior of the original process and then identify the ways for its improvement (scenarios) based on some improvement criteria. This strategy is significantly different from the hypothesis-based clinical testing widely used in medical research (Kopach-Konrad et al, 2007).

DES models track entities moving through the system at distinct points of time (events). The detailed track is recorded of all processing times and waiting times. Then the system's statistics for entities and activities is gathered.

To illustrate how a DES model works step by step, let's consider a very simple system that consists of a single patient arrival line and a single server. Suppose that patient inter-arrival time is uniformly (equally likely) distributed between 1 min and 3 min. Service time is exponentially distributed with the average 2.5 min. (Of course, any statistical distributions or non-random patterns can be used instead). A few random numbers

Table 2.

Event #	Time	Event that happened in the system
1	2.6	1st customer arrives. Service starts that should end at time= 4
2	4	Service ends. Server waits for patient
3	4.8	2nd patient arrives. Service starts that should end at time =13.6. Server is idle 0.8 min
4	6.2	3rd patient arrives. Joins the queue waiting for service
5	8.6	4th patient arrives. Joins the queue waiting for service
6	13.6	2nd patient (from event 3) service ends. 3rd patient at the head of queue (first in-first out) starts service that should end at time 22.7
7	22.7	Patient #4 starts service and so on.

sampled from these two distributions are shown in Table 1.

Let's start our example simulation at time zero, t=0, with no patients in the system. We will be tracking any change or event that happened in the system.

A summary of what is happening in the system looks like Table 2.

These simple but tedious logical and numerical event-tracking operations (algorithm) are suitable, of course, only for a computer. However, they illustrate the basic principles of any discrete events simulation model, in which discrete events (changes) in the system are tracked when they occur over the time. In this particular example, we were tracking events at discrete points in time t=2.6, 4.0, 4.8, 6.2, 8.6, 13.6, 22.7.

Once the simulation is completed for any length of time, another set of random numbers from the same distributions is generated, and the procedure (called replication) is repeated. Usually multiple replications are needed to properly capture the system's variability. In the end, the system's output statistics is calculated, e.g. the average patient and server waiting time, its standard deviation, the average number of patients in the queue, the confidence intervals and so on.

In this example, only two patients out of four waited in the queue. Patient 3 waited 13.6-6.2=7.4 min and patient 4 waited 22.7-8.6=14.1 min, so the simple average waiting time for all four patients is (0+0+7.4+14.1)/4=5.4 min. Notice, however, that the first two patients did not wait at all while patient 4 waited 2.6 times longer than the average. This illustrates that the simple average could be rather misleading as a performance metric for highly variable processes without some additional information about the spread of data around the average (a so-called flaw of averages, see also concluding remarks for section 3.1).

Similarly, the simple arithmetic average of the number of waiting patients (average queue length) is 0.5. However a more informative metric of the queue length is the time-weighted average that takes into account the length of time each patient was in the queue. In this case it is (1*7.4+1*14.1)/22.7=0.95. Usually the time-weighted average is a better system's performance metric than the simple average.

DES models are capable of tracking hundreds of individual entities, each with its own unique set of attributes, enabling one to simulate the most complex systems with interacting events and component interdependencies.

Typical DES applications include: staff and production scheduling, capacity planning, cycle time and cost reduction, throughput capability, resources and activities utilization, bottleneck finding and analysis. DES is the most effective tool to perform quantitative 'what-if' analysis and play different scenarios of the process behavior as its parameters change with time. This simulation capability allows one to make experiments on the computer, and to test different options before going to the hospital floor for actual implementation.

The basic elements (building blocks) of a simulation model are:

- Flow chart of the process, i.e. a diagram that depicts logical flow of a process from its inception to its completion
- Entities, i.e. items to be processed, e.g. patients, documents, customers, etc.
- Activities, i.e. tasks performed on entities, e.g. medical procedures, exams, document approval, customer check-in, etc
- Resources, i.e. agents used to perform activities and move entities, e.g. service personnel, equipment, nurses, physicians
- Entity routings that define directions and logical conditions flow for entities

Typical information usually required to populate the model includes:

- Quantity of entities and their arrival time, e.g. periodic, random, scheduled, daily pattern, etc. There is no restriction on the arrival distribution type, such as a Poisson distribution, required by the QA formulas

- The time that the entities spend in the activities, i.e. service time. This is usually not a fixed time but a statistical distribution. There is no restriction to an exponential service time distribution that is typically required by the QA formulas
- Capacity of each activity, i.e. the max number of entities that can be processed concurrently in the activity
- The maximum size of input and output queues for the activities
- Resource assignments: their quantity and scheduled shifts

Analysis of patient flow is an example of the general dynamic supply and demand problem. There are three basic components that should be accounted for in such problems: (i) the number of patients (or any items) entering the system at any point of time, (ii) the number of patients (or any items) leaving the system after spending some time in it, (iii) capacity of the system that defines the number of items that can be processed concurrently. All three components affect the flow of patients (items) that the system can handle (the system's throughput). A lack of the proper balance between these components results in the system's over-flow and gridlock. DES methodology provides invaluable means for analyzing and managing the proper balance.

It will be demonstrated in the following sections that even simple DES models have a significant advantage over QA models. To illustrate this advantage side by side, DES methodology will be applied to the same processes that have been analyzed using QA in previous sections 2.1.1 to 2.1.4

Comparative Analysis of QA and DES Methodologies

Unlimited Queue Size with Steady-State Operation

Let's consider a flu clinic that was analyzed using QA in section 2.1.1.

DES model structure is presented on Figure 1. It simply depicts the arrived patient flow connected to Queue, then coming to the flu clinic (box called Flu_Clinic), and then exit the system. These basic model elements are simply dragged down from the pallet and then connected to each other.

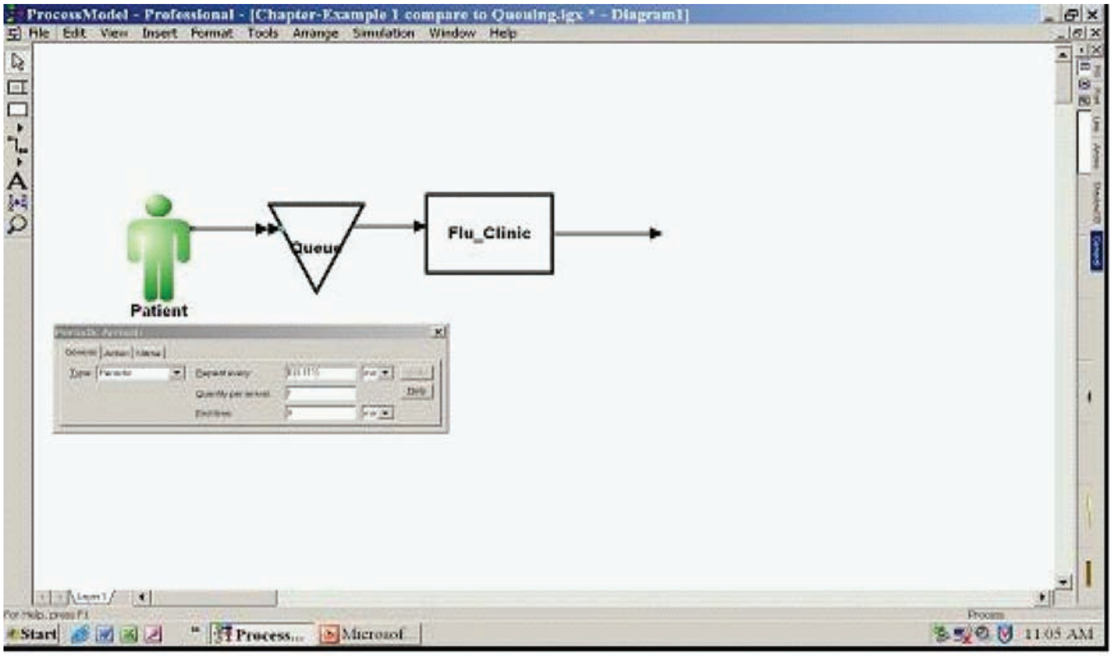
Next step is to fill in the process information: patients arrive periodically, one patient at a random exponentially distributed time interval with the average inter-arrival time 60 min/54=1.111 min, E(1.111), as indicated on the data arrival panel on Figure 1 corresponds to Poisson arrival rate of 54 patients per hour (E stands for exponential distribution). In the Flu_Clinic data panel the capacity input was 2 (two patients served concurrently by two nurses), and the service time was exponentially random with the average value 2 min, E(2). This completes the model set-up.

The model was run 300 replications at which a statistically stable simulation output was reached. Multiple replications capture the variability of patient arrivals and service time. Results are presented on Figure 2.

It is seen that the number of patients in the queue steadily increases until a steady-state operation (plateau) is reached. The average steady-state number of patients in the queue is 7.7 with some small fluctuations around this average (top plot).

The average waiting time is presented on Figure 2 (bottom plot). Similarly, the average steady-state waiting time 8.45 min was reached with some variations around the average. The average steady-state utilization is 89.8%.

Figure 1.Layout of the simulation model of flu clinic. Information on the panel indicates patient arrival type (Periodic) that repeats on average every E(1.111) min (E stands for exponential distribution)



Average number of patients in the queue (top) and average waiting time in the queue (bottom)

Thus, we received practically the same results with DES model as with QA model using about the same efforts. As an additional bonus with DES, though, we could watch how fast a steady-state operation was reached (a so-called warm-up period).

Unlimited Queue Size with Non-Steady State Operation

In section 2.1.2 QA model with the average service time 2.5 min could not produce results because a steady-state operation did not exist.

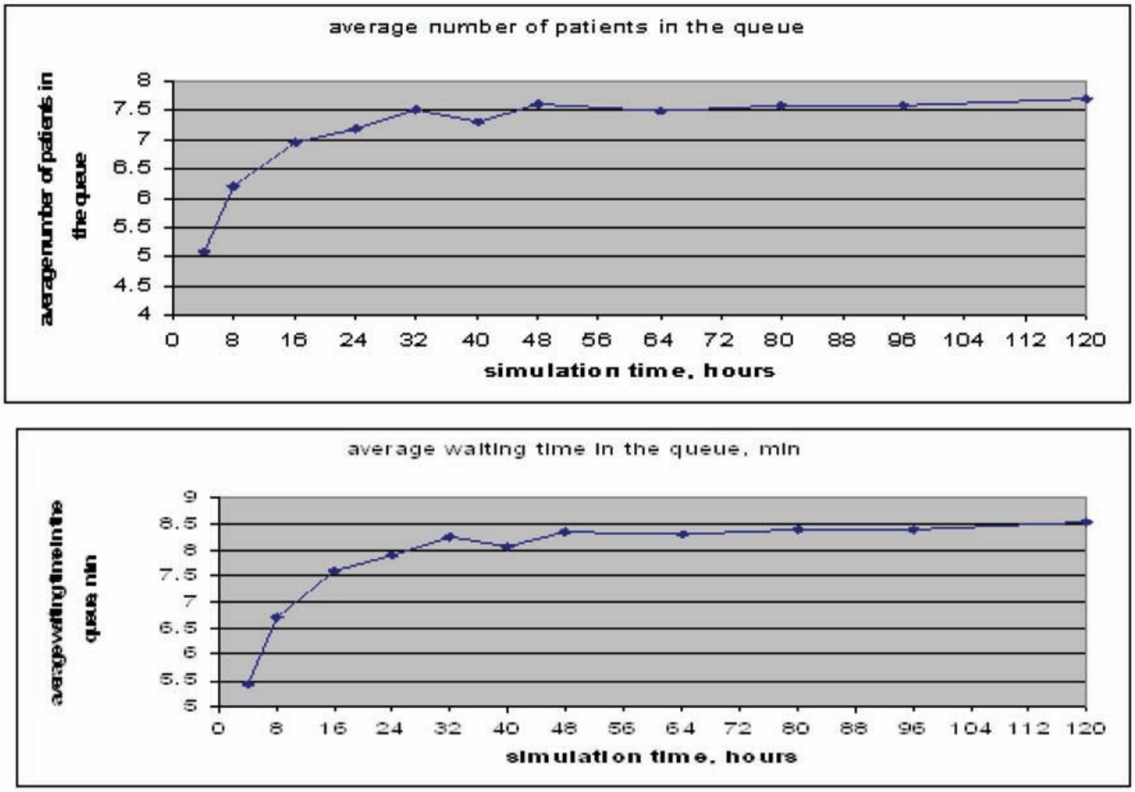
Using the same DES model described in the previous section we simply plug this average service time in the Flu_Clinic data panel making it E(2.5) min, and run the simulation model. Results are given on Figure 3.

Average number of patients in the queue (top) and average waiting time in the queue (bottom).

These plots demonstrate how the patient queue (top plot) and waiting time (bottom plot) grow with clinic operation time. The plots demonstrate no apparent trend to a steady-state regime (plateau). The growth goes on indefinitely with time.

This example also illustrates an important principle of ‘unintended consequences’. An intuition that is not supported by objective quantitative analysis says that a small change in the system input (service time from the average 2 min to 2.5 min) would result in a small change in the output (small increase in the number of waiting patients and their waiting time). For some systems this is indeed true. Systems in which the output is always directly proportional to input are called linear systems. However, there are quite a few systems in which this simple reasoning breaks down: a small change in the value of the system’s input parameter(s) results in a dramatic change (even qualitative change) in the system’s outcome (behavior), e.g. from a steady-state regime to a non-steady-state regime. Such systems are called

Figure 2. Unlimited queue size with steady-state operation



non-linear or complex systems despite the fact that they can consist of only a few elements.

Limited Queue Size with 'Inpatient' Patients Leaving the System

Unlimited queue size is not always a good model of real systems. In many cases patients wait in a waiting lounge that has usually a limited number of chairs (space). QA models designated *M/M/s/K* are available that include a limited queue size, *K* (Green, 2006; Lawrence and Pasternak, 1998; Hall, 1990). However analytic formulas become very cumbersome. If the QA model includes some patients that leave the system after waiting some time in the queue, the analytic formulas become almost intractable.

In contrast, DES models easily handle the limited queue size and patients leaving before the service began ('inpatient' patients).

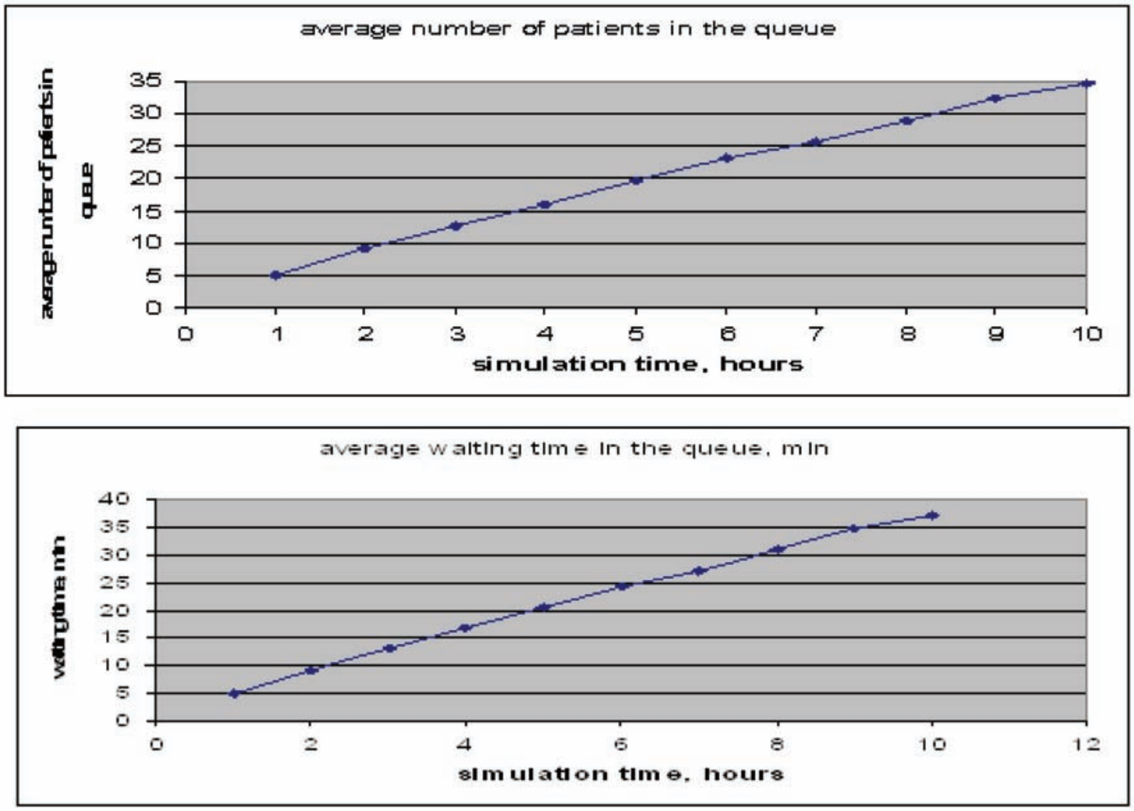
To illustrate, we use the same DES model as in 2.2.1 with only a slight modification to include a new limited queue size and 'inpatient' patients.

Suppose that the queue size limit is 10 (the max number of chairs or beds) and patients leave after waiting 10 min (of course, these could be any numbers including statistical distributions). We put 10 in the field 'Input queue size', and draw a routing 'renege after 10 min'. The new model is now ready to go. Simulation results are presented on Figure 4.

The difference between an unlimited queue size (section 2.2.2) and a limited one with leaving patients is significant.

The plots suggest that limited queue size results in a steady-state solution (plateau). (It could be

Figure 3. Unlimited queue size with non-steady state operation



proved that a steady-state solution always exists if the queue size is limited). The steady-state average number of patients in the queue is about 4.5 (top plot) and the average waiting time is about 5.6 min (bottom plot).

However the model's statistics summary also shows that 10% to 11% of patients are lost because they did not stay in the queue more than 10 min. Thus, this simple DES model gives a lot of valuable information and serves as powerful tool to find out how to better manage the flu-clinic.

Average number of patients in the queue (top) and average waiting time in the queue (bottom).

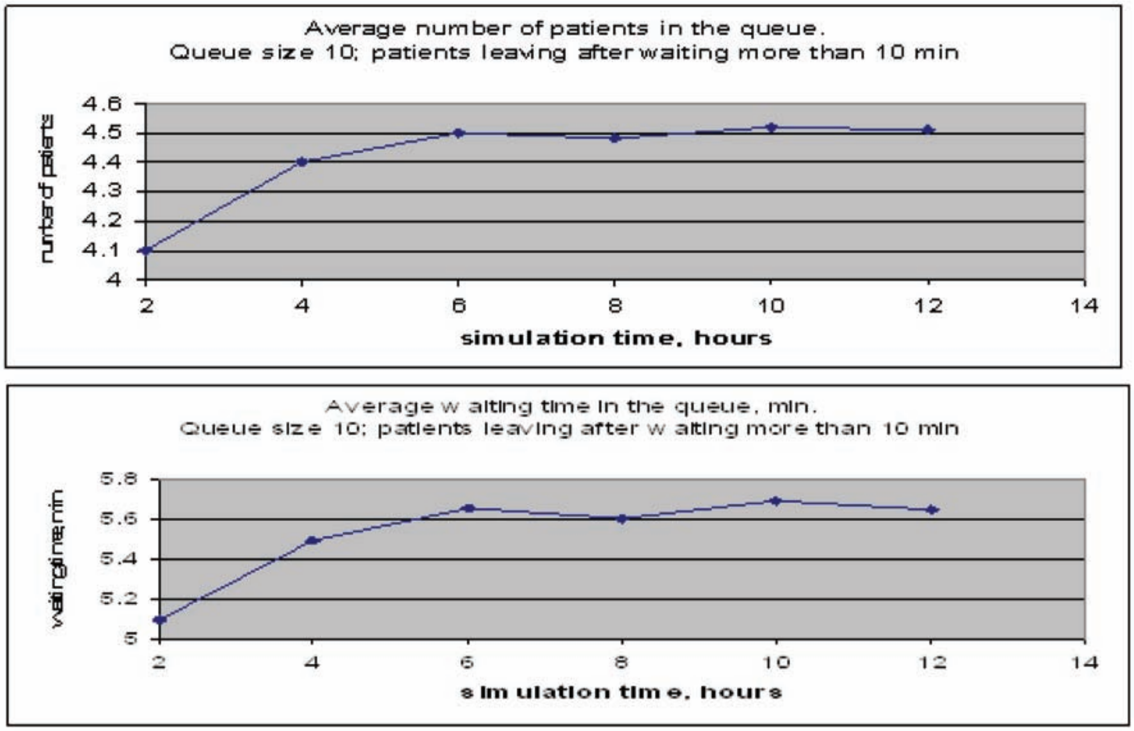
Arrivals with Time-Varying Poisson Arrival Rate

In section 2.1.3 it was discussed why the use of QA model with a Poisson time-varying patient arrival rate is rather unreliable.

Let's see how easy it is to use DES model to address the same problem.

The DES model structure (layout) for time-varying arrival rate is the same as it was used in section 2.2.1. The only difference is a different arrival routing type: instead of periodic arrival with the random inter-arrival time, an input daily-pattern arrival panel should be used. We use one day of the week, and input 60 patients from 8 am to 10 am (30 pts/hour *2); 80 patients from 10 to noon (40 pts/hour*2); 162 patients from noon to 3 pm (54 pts/hour*3); and 135 patients from 3 pm

Figure 4. Limited queue size with 'inpatient' patients leaving the system



to 6 pm (45 pts/hour * 3). The model of the entire day (from 8 am to 6 pm) is ready to go.

The following simulation results are obtained (compare with the approximated QA SIPP model results from section 2.1.3):

Time period 8 am to 10 am: L_q =0.6 patients in the queue, waiting time 0.84 min

Time period 10 am to noon: L_q =2.26 patients in the queue, waiting time 2.75 min

Time period noon to 3 pm: L_q =14.5 patients in the queue, waiting time 15.3 min

Time period 3 pm to 6 pm: L_q =20 patients in the queue, waiting time 25.5 min

It is seen that QA SIPP model over-estimates the queue at the beginning of the day and under-estimates the queue at the end of the day. Of course, only a DES model can provide results for the time period noon to 3 pm.

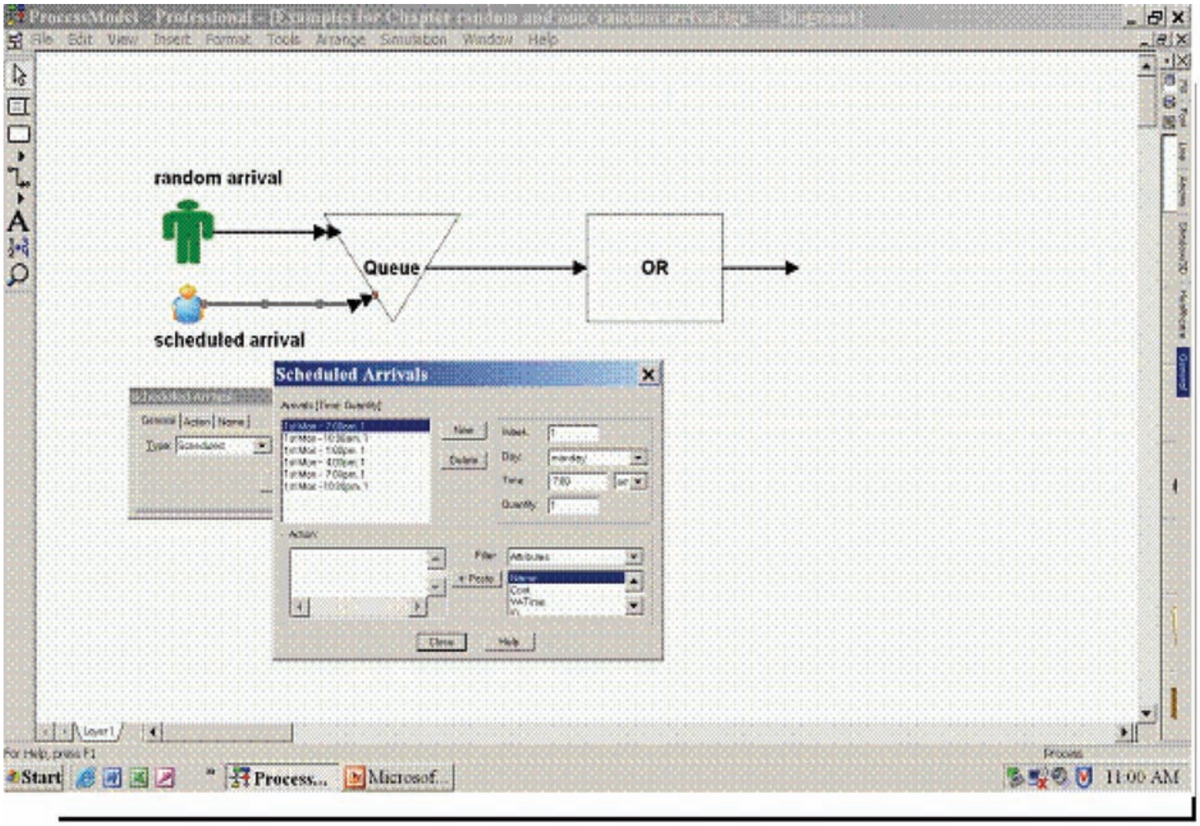
Mixed Patient Arrivals: Random and Scheduled

We frequently deal with mixed patient arrival pattern, i.e. some patients are scheduled to arrive on specific time while some patients arrive unexpectedly. For example, some clinics accept patients who made an appointment, but also accept urgent random walk-in patients. Operating room suites schedule elective surgeries while suddenly a trauma patient arrives and an emergency surgery is required. Such a mixed arrival pattern with a different degree of the variability requires a special treatment.

QA models should not be used if arrival flow contains a non-random component, i.e. it is not a Poisson random. Let's illustrate what happens if this principle is violated.

Suppose that there is one operating room (OR) and there are six scheduled surgeries for a day, at

Figure 5. Mixed patient arrivals: random and scheduled. Two arrival flows, one random, E(4) hours, and one with six patients scheduled at 7 am, 10 am, 1 pm, 4 pm, 7 pm, 10 pm, as indicated on the panel



7 am, 10 am, 1 pm, 4 pm, 7 pm, 10 pm. On this day six random emergency patients also arrived with the average inter-arrival time 4 hours, i.e. E(4) hours. Total number of patients for one day is 12.

If QA model is applied assuming that all 12 patients are random arrivals, then we would get arrival rate 12 pts/24= 0.5 pts per hour. Using the average surgery time 1 hour, E(1) hours, we get the average number of patients in the queue, L_q = 0.5, waiting time in queue, W_q=1 hour, and time in the system, W_s =2 hours.

Now, let's use a simple DES model with two arrival flows, one random, E(4) hours, and another one with scheduled six patients, as indicated on Figure 5.

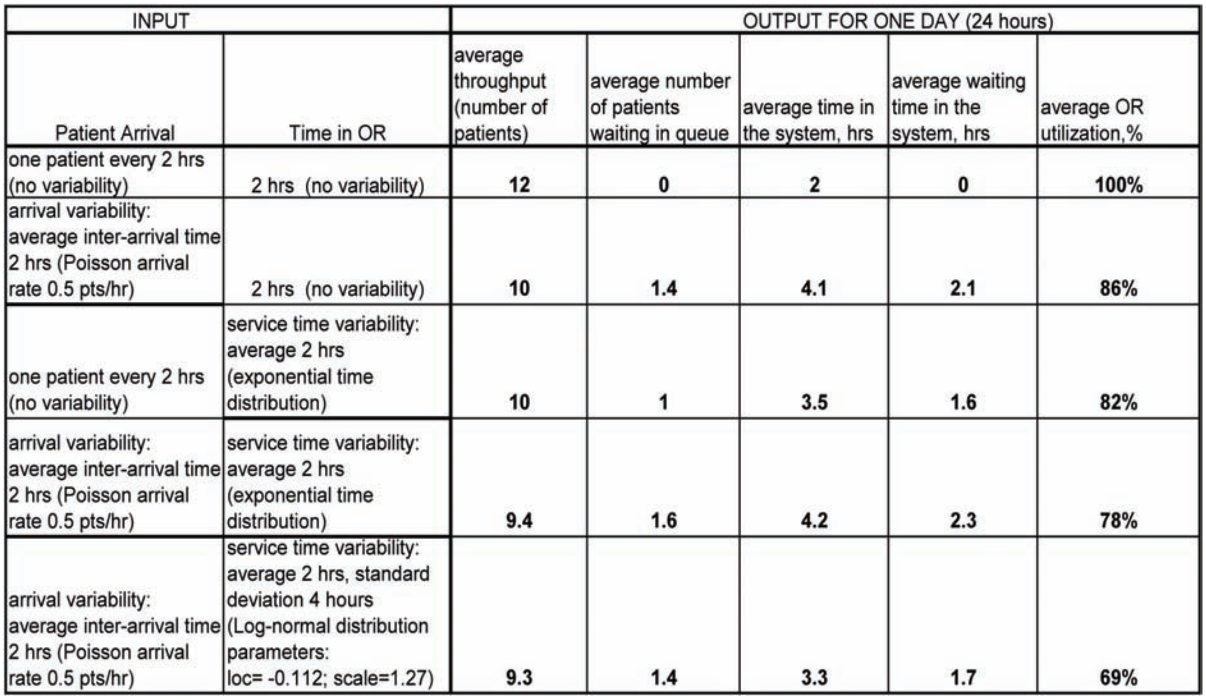
Simulation length was 24 hours. The average number of patients in the queue was L_q = 0.3, waiting time in the queue W_q=0.33 hours, time in the system, W_s =0.55 hours.

Notice how badly QA model over-estimated the time: almost by a factor of 3 for waiting time in the queue, and almost by a factor of 4 for the time in the system !

Thus, QA models cannot account accurately enough for arrival variability that is lower than Poisson variability.

There are some approximate QA formulas that include a coefficient of variation of service time distribution but only for one server (Green, 2006).

Figure 6. Five DES scenarios with consecutively added variability. Simulation performed for 24 hours period



INPUT		OUTPUT FOR ONE DAY (24 hours)				
Patient Arrival	Time in OR	average throughput (number of patients)	average number of patients waiting in queue	average time in the system, hrs	average waiting time in the system, hrs	average OR utilization,%
one patient every 2 hrs (no variability)	2 hrs (no variability)	**12**	**0**	**2**	**0**	**100%**
arrival variability: average inter-arrival time 2 hrs (Poisson arrival rate 0.5 pts/hr)	2 hrs (no variability)	**10**	**1.4**	**4.1**	**2.1**	**86%**
one patient every 2 hrs (no variability)	service time variability: average 2 hrs (exponential time distribution)	**10**	**1**	**3.5**	**1.6**	**82%**
arrival variability: average inter-arrival time 2 hrs (Poisson arrival rate 0.5 pts/hr)	service time variability: average 2 hrs (exponential time distribution)	**9.4**	**1.6**	**4.2**	**2.3**	**78%**
arrival variability: average inter-arrival time 2 hrs (Poisson arrival rate 0.5 pts/hr)	service time variability: average 2 hrs, standard deviation 4 hours (Log-normal distribution parameters: loc= -0.112; scale=1.27)	**9.3**	**1.4**	**3.3**	**1.7**	**69%**

Effect of Added Variability on Process Flow and Delay

Let's now demonstrate how additional arrival variability, service time variability, and/or both would affect the throughput and waiting time in the system. We will be using a simple DES model similar to the model presented on Figure 1.

We consider five scenarios with consecutively added step-by-step patient flow variability:

- Scenario 1. No variability at all. Each patient arrives exactly every 2 hours. Service time (surgery) is exactly 2 hours.
- Scenario 2. There is arrival variability, i.e. a Poisson flow with the average arrival rate 0.5 pts/hr (average inter-arrival time is 2 hours, E(2) hrs). No service time variability, it is exactly 2 hours.
- Scenario 3. No arrival variability. There is a service time variability with the average service time 2 hours, E(2) hours.
- Scenario 4. There are both types of variability. Poisson arrival with the average arrival rate 0.5 patients per hour (average inter-arrival time 2 hours), and service time variability with the average service time 2 hours, E(2)
- Scenario 5. Poisson arrival variability with the average arrival rate 0.5 patients per hour (average inter-arrival time 2 hours). Service time variability is log-normally distributed with the distribution mean value 2 hours and standard deviation 4 hours (these values correspond to the log-normal parameters: location= -0.112 and scale=1.27).

Results for 24 hours simulation time are summarized in Figure 6. It follows from this table that as the variability steps are added to the process, patient throughput decreases, an overall waiting time increases and utilization decreases.

At the same time, the variability distribution should not be characterized only by a single parameter, such as its coefficient of variation (CV). The overall shape of the variability distribution also plays a big role. For example, the coefficient of variation for the lognormal distribution service time (CV=4/2=2) is greater than that for exponential distribution (CV=1). Nonetheless, this did not result in increase of the wait time, as this would follow from an approximated queuing formula (Allen, 1978; Green, 2006). Only DES can accurately account for the effect of the distribution shape and skewness.

ICU Waiting Time

Analysis of ICU waiting time considered in section 2.1.4 using QA could be done using the same model as in the previous section (Figure 1). We simply use capacity 5 or 10, accordingly. Let's start with the exponential distribution of the length of stay with the average 2.5 days to compare with QA results (section 2.1.4).

Let's also use the average inter-arrival time as 1 day or 0.5 days, accordingly.

The following steady-state DES waiting times were obtained: 0.43 hours for 10 beds ICU and 2.94 for 5 beds ICU, accordingly. These are practically the same results as for QA (section 2.1.4).

Now, let's see how different distributions with the same average length of stay affect the waiting time. Recall, that QA cannot answer such practically important questions at all, and it is valid only for exponential distribution or, at best, for distributions with coefficient of variation close to 1 (Green, 2006).

For example, the triangle distribution limited between 2 days and 3 days with the average 2.5 days results in:

- for 10 beds ICU average waiting time is 0.27 hours while for 5 beds unit it is 1.72 hours. Notice, how significantly different these values are from the exponential length of stay with the same average.

Similarly, for the lognormal distribution with the same average 2.5 days and standard deviation, say, 2 days, we get:

- for 10 beds ICU average waiting time is 0.35 hours while for 5 beds unit it is 2.46 hours.

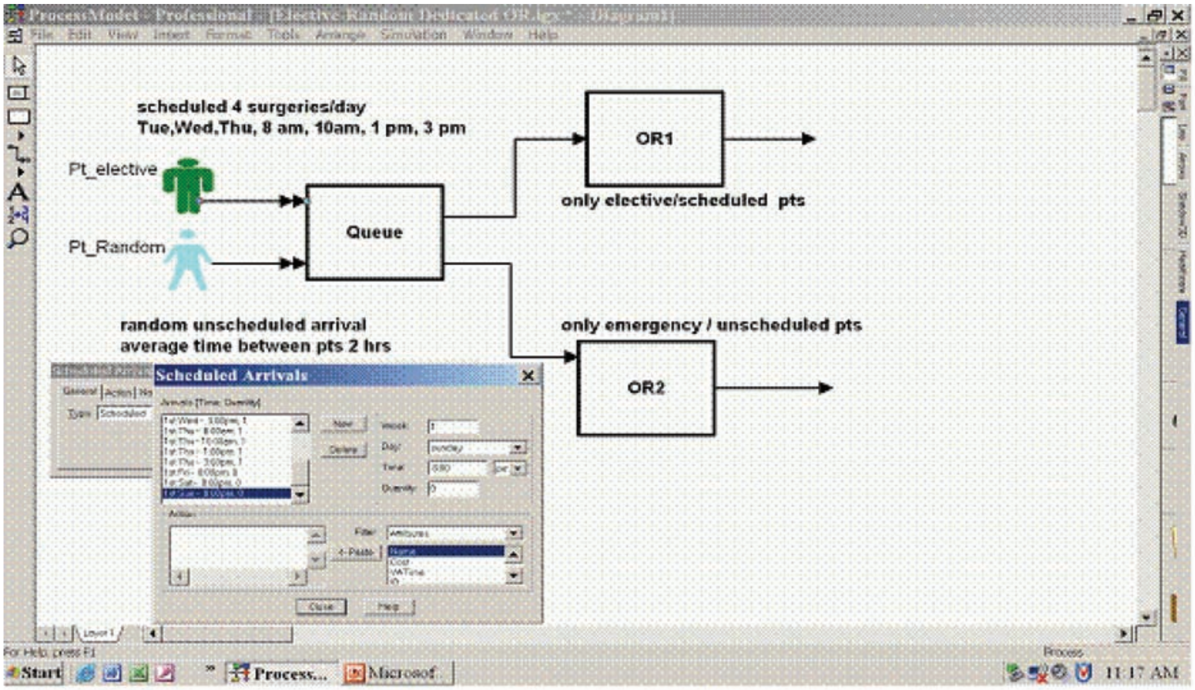
Thus, QA is severely limited in what it cannot account for different distributions of service time and always produces the same result if the same average is used regardless of the effect of different distributions with the same average.

Emergency and Elective Surgeries: Dedicated OR vs. Combined Service OR

In this section we will discuss the use of a simple DES model to address an issue that caused a controversy in literature on healthcare improvement. If patient flow into operating rooms consists of both elective (scheduled) and emergency (random) surgeries, is it more efficient to reserve dedicated operating rooms (OR) separately for elective and emergency surgeries, or to perform both types of surgeries in any available OR?

Haraden et al (2003) recommends that hospitals that want to improve patient flow should designate separate ORs for scheduled and unscheduled (emergency) surgeries. The authors state that in this arrangement '…Since the vast majority of surgeries is scheduled, most of the OR space should be so assigned. Utilization of the scheduled rooms becomes predictable, and wait times for unscheduled surgery become manageable'. The authors imply that this statement is self-evident,

Figure 7. Emergency and Elective surgeries: dedicated OR vs. combined service OR



and provide no quantitative analysis or any other justification for this recommendation.

On the other hand, Wullink et al (2007) built DES model of OR suite for large Erasmus Medical Center hospital (Rotterdam, The Netherlands) to quantitatively test scenarios of using dedicated ORs for emergency and elective surgeries vs. combined use of all ORs for both types of surgeries. These authors concluded that based on DES model results '…Emergency patients are operated upon more efficiently on elective ORs instead of a dedicated emergency ORs. The results of this study led to closing of the emergency OR in this hospital'.

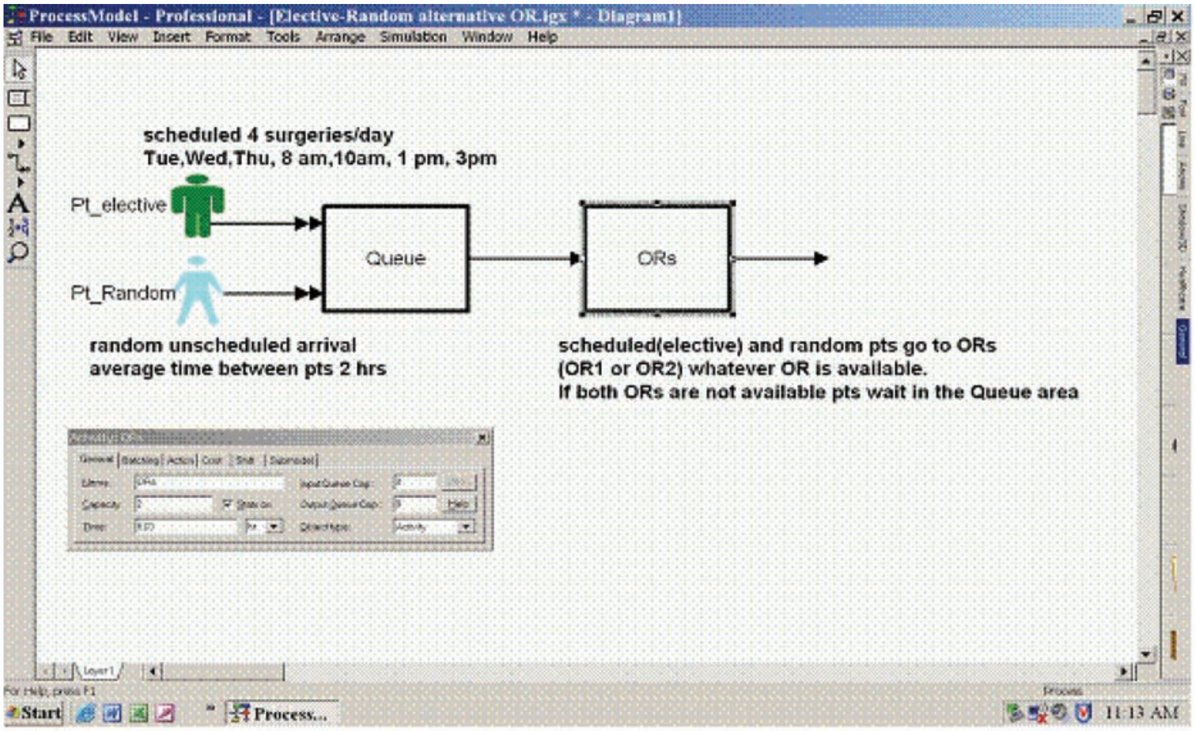
In contrast to the unsupported recommendation of Haraden et al (2003), Wullink et al (2007) presented specific data analysis to support their conclusions: combined use of all ORs for both types of surgery results in reduction of average waiting time for emergency surgery from 74 min to 8 min.

In this section we present a simple generic DES model to address the same issue and verify literature results. For simplicity, we consider an OR suite with two rooms, OR1 and OR2. Patient flow includes both emergency (random) and scheduled patients.

Let's first consider the situation when the majority of surgeries are emergency (random) ones. We assume a Poisson emergency patient arrival with the average inter-arrival time 2 hours, i.e. E(2) hours (Poisson arrival rate 0.5 pts/hr).

Four elective surgeries are assumed to be scheduled three days a week on Tuesday, Wednesday and Thursday at 8 am, 10 am, 1 pm and 3 pm. Both emergency and elective surgery duration is assumed to be random with the average value 2 hours, i.e. E(2) hours. (Wullink et al, 2007 used mean case duration 2.4 hours for elective and 2.1 hours for emergency surgeries)

Figure 8. Emergency and Elective surgeries: dedicated OR vs. combined service OR



scheduled 4 surgeries/day
Tue,Wed,Thu, 8 am,10am, 1 pm, 3pm

random unscheduled arrival
average time between pts 2 hrs

scheduled(elective) and random pts go to ORs
(OR1 or OR2) whatever OR is available.
If both ORs are not available pts wait in the Queue area

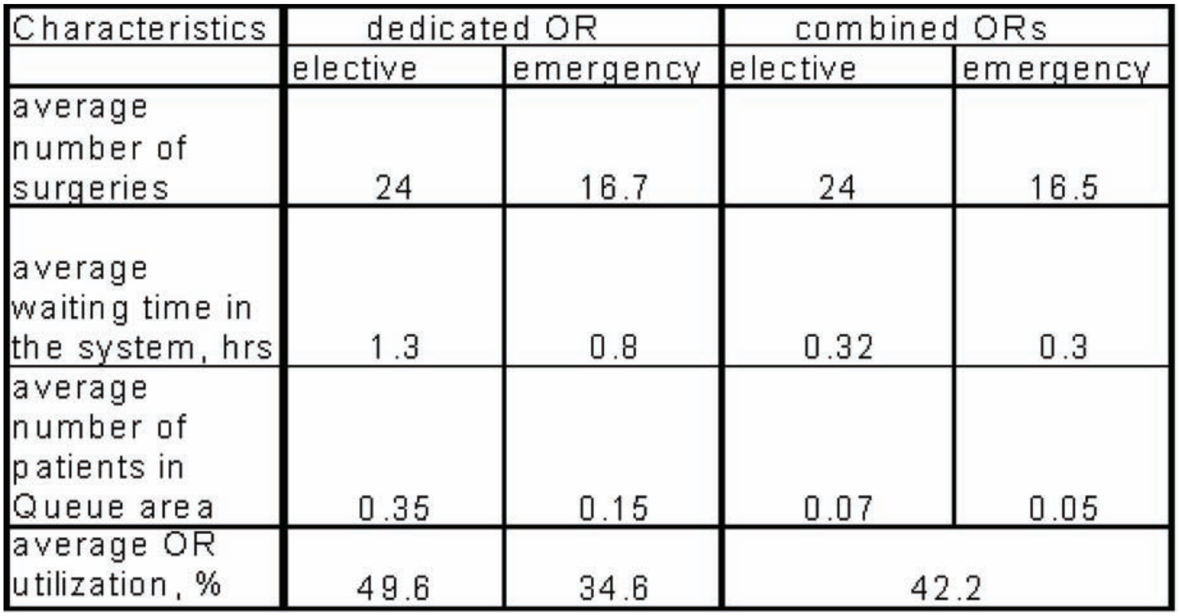
Figure 9. Simulation results: dedicated ORs vs. combined ORs. Most surgeries are emergency ones. Simulation performed for 4 days (96 hours) time period

Characteristics	dedicated OR		combined ORs	
	elective	emergency	elective	emergency
average number of surgeries	12	41.3	12	47.3
average waiting time in system, hrs	0.7	7.1	1.3	1.06
average number of patients in queue area	0.1	3.76	0.16	0.59
average OR utilization, %	24.2	85.8	62.7	

Using these arrival and service time data, let's consider two scenarios.

Scenario 1: two ORs, one dedicated only for elective surgeries (OR1), and another dedicated only for emergency surgeries (OR2), as shown on Figure 7 If the dedicated OR is not available, then the new patient waits in the Queue area until the corresponding dedicated OR becomes available.

Figure 10. Simulation results: dedicated ORs vs. combined ORs. Most surgeries are elective. Simulation performed for 4 days (96 hours) time period



Characteristics	dedicated OR		combined ORs	
	elective	emergency	elective	emergency
average number of surgeries	24	16.7	24	16.5
average waiting time in the system, hrs	1.3	0.8	0.32	0.3
average number of patients in Queue area	0.35	0.15	0.07	0.05
average OR utilization, %	49.6	34.6	42.2	

Scenario 2: also two ORs. However both emergency and elective patients go to any available OR, as indicated on Figure 8. If both ORs are not available, then the new patient waits in the Queue area until one of ORs becomes available.

Scenario 1 model layout: two ORs, one dedicated only for elective surgeries (OR1), and another dedicated only for emergency surgeries (OR2). Scheduled arrival pattern is indicated on the panel.

Simulation was run for 4 days (96 hours) Monday to Thursday (on Friday there were no scheduled elective surgeries) using 300 replications. DES results for these two scenarios are given in Figure 9.

Examination of the results is instructive. While the number of elective surgeries is the same for both scenarios, the number of performed emergency surgeries is higher for combined OR scenario. The average waiting time for elective surgery increases about 2 times for the combined OR scenario (from 0.7 to 1.3 hours); however, the average waiting time for emergency surgery drops dramatically from about 7 hours down to 1 hour ! (Compare this dramatic drop with Wullink et al (2007) result). The average number of patients waiting for emergency surgery is significantly lower for combined OR scenario. Dedicated elective OR is under-utilized (~24%) while dedicated emergency OR is highly utilized (~85%), resulting in a significant increase in waiting time for emergency surgeries. OR utilization in the combined OR scenario is a rather healthy 63%.

Scenario 2 model layout: two ORs. Both emergency and elective patients go to any available OR. Information of the panel indicates capacity of ORs (2) and the average surgery (service) time E(2) hr

Now, let's consider the situation when the majority of surgeries are elective.

We have the same two scenarios with two ORs (dedicated and combined) with the average surgery duration 2 hours, E(2) hours.

However this time 6 daily elective surgeries are scheduled Monday to Thursday (no Fridays) at 7 am, 9 am, 11 am, 1 pm, 3 pm, 5 pm. Emergency (random) surgeries are less frequent with the average inter-arrival time 6 hours, E(6), i.e. Poisson arrival rate about 0.167 patients per hour.

Simulation results for 96 hours (4 days), 300 replications are given in Figure 10.

Notice that in this case the average waiting time for combined ORs drops about 3 to 4 times both for emergency and elective patients, as well as the average number of patients in the Queue area.

Overall, these DES results support the conclusions of Wullink et al (2007) that performing emergency surgeries in the combined OR scenario is more effective than in the reserved dedicated emergency OR. These authors provided a detailed instructive discussion on why dedicated OR scenario performs worse especially for emergency surgeries, while intuitively it seems that it should perform better, like Haraden et al (2003) assumed.

Wullink et al (2007) pointed out that besides reserving OR capacity for emergency surgeries arrivals, ORs need to reserve capacity to cope with the variability of surgery duration. In the combined OR scenario, reservation might be shared to increase the flexibility for dealing with unexpected long case duration and emergency surgery, whereas the dedicated scenario does not offer the opportunity to use the overflow principle (compare this with two simplified scenarios considered earlier in section 2.1.1 using QA model).

On top of that, a dedicated OR scenario may cause queuing of emergency surgeries themselves because of their random arrival time. If emergency surgeries were allocated to all available ORs (combined scenario), then it would be possible to perform them simultaneously reducing thereby a waiting time.

Wullink et al (2007) acknowledge that '… interrupting the execution of the elective surgical case schedule for emergency patients may delay elective cases. However, inpatients are typically admitted to a ward before they are brought to the OR. Although delay due to emergency arrivals may cause inconvenience for patients, it does not disturb processes in the OR'.

As DES modeling indicates, delay in scheduled cases in the combined ORs (if the majority of surgeries are emergency) is usually not too dramatic (e.g. from 0.7 to 1 hour), while reduction of waiting time for emergency surgeries is very substantial (from 74 min to 8 min according to Wullink's DES model, or from about 7 hours to 1 hour according to our simplified DES model with generic input data described in this section).

If the majority of surgeries are scheduled ones, then there is not much delay in combined ORs at all both for scheduled and emergency surgeries.

Examples presented in Section 2 illustrate a general fundamental principle: the lower variability in the system (both arrival and service), the lower delays (see also Green, 2006). In other words, lowering variability is the key to improving patient flow and to reduce delays and waiting times.

One of the root causes of why intuition usually fails to account for the effect of variability even in very simple systems is a general human tendency to avoid the complications of uncertainty in the decision making by turning it into certainty. Average procedure time or average number of arrived patients is typically treated as if they are fixed values ignoring the variability around these averages. This ignorance often results in erroneous conclusions. DES models, however, naturally handle complex variability using statistical distributions with multiple replications.

DES MODELS: ADVANCED APPLICATIONS

In this section more advanced features of DES models will be presented, such as custom-built action logic to capture fine details of system behavior, conditional and alternate routing types, multiple entities entries, multiple scheduled arrivals and highly skewed service time distributions that accurately reflect real data rather than assuming some hypothetical data distribution.

It will also be demonstrated how a specific problem statement leads to simulating different 'what-if' scenarios to address practically relevant issues for ED and ICU (sections 3.1 and 3.2), as well as interdependencies of patient flow for ED, ICU, OR and floor nursing units (NU) (section 3.3).

DES of Emergency Department Patient Flow: Effect of Patient Length of Stay on ED Ambulance Diversion

Emergency Department (ED) ambulance diversion due to 'no available beds' status has become a common problem in most major hospitals nationwide. A diversion status due to 'no available ED beds' is usually declared when the ED census is close to or at the ED beds capacity limit. ED remains in this status until beds become available when patients are moved out of ED (discharged home, expired, or admitted into the hospital as inpatients). Percent of time when ED is on diversion is one of the important ED patient performance metrics, along with the number of patients in queue in ED waiting room, or ED patient waiting time. ED diversion results in low quality of care, dissatisfaction of patients and staff, and lost revenue for hospitals.

Patients' length of stay (LOS) in ED is one of most significant factors that affect the overall ED throughput and ED diversion (Blasak et al, 2003; Gunal and Pidd, 2006; Garcia et al, 1995; Miller et al, 2003; Simon et al, 2003). There are generally two major groups of patients with different LOS distributions: (i) patients admitted as inpatients into the hospital (OR, ICU, floor nursing units), and (ii) patients stabilized, treated and discharged home. Mayhew and Smith (2008) also recognized a key difference between these two groups.

In order to effectively attack the problem of ED diversion reduction, the LOS of these two groups should be quantitatively linked to ED diversion. Then the target LOS limits can be established based on ED patient flow analysis.

A number of publications are available in which the importance of having ED LOS target was discussed. Kolker (2008) provided a detailed analysis of the literature.

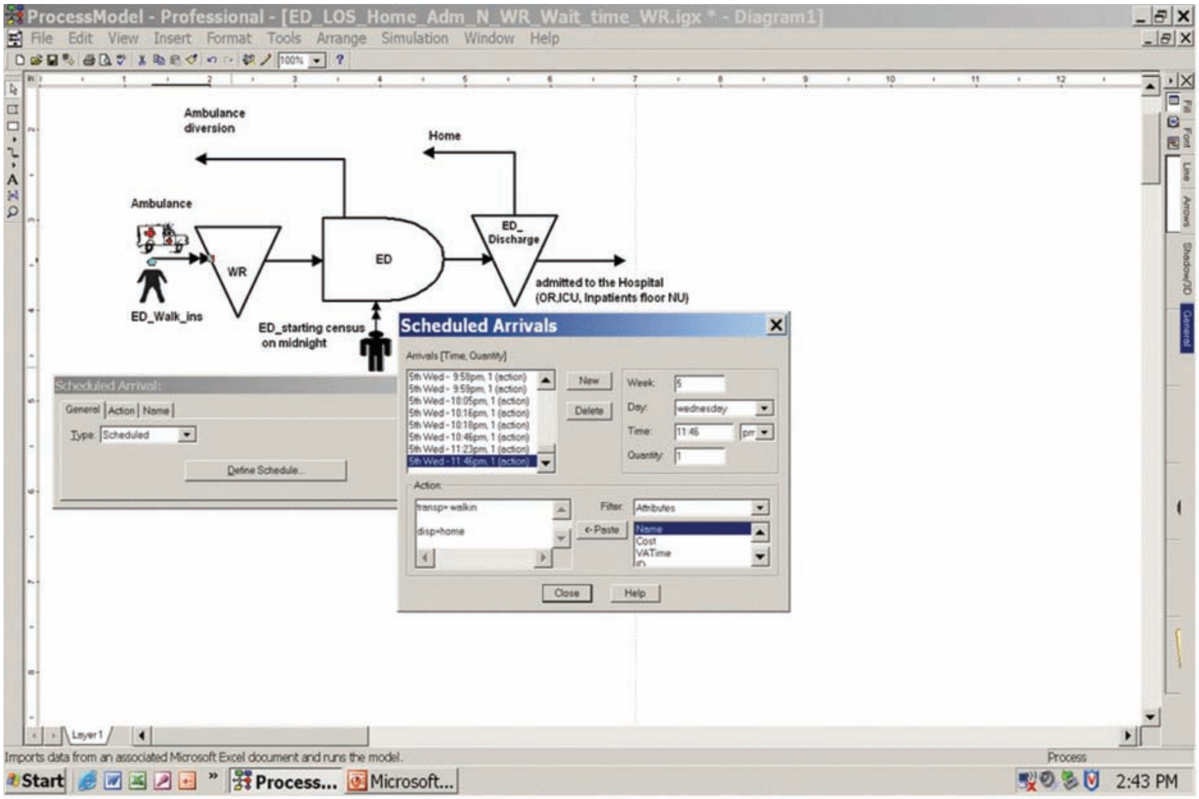
One instructive article published recently by Mayhew and Smith (2008) evaluates the consequences of 4 hours LOS limits mandated by the UK National Health Services for the UK hospitals' Accident &Emergency Departments (A&ED). One of the main conclusions of this work was '… that a target should not only be demanding but that it should also fit with the grain of the work on the ground… Otherwise the target and how to achieve it becomes an end in itself '. Further, '…the current target is so demanding that the integrity of reported performance is open to question'. This work vividly illustrated the negative consequences of the administratively mandated LOS targets that have not been based on the objectives analysis of the patient flow and an A&ED capability to handle it.

Despite a considerable number of publications on the ED patient flow and its variability, there is not much in the literature that could help to answer a practically important question regarding the target patient LOS: what it should be and how to establish it in order to reduce ED diversion to an acceptable low level, or to prevent diversion at all ? Therefore, a methodology that could quantitatively link the patient LOS limits and ED performance metrics would have a considerable practical value.

Description of the ED Patient Flow Model

Kolker (2008) described the entire ED system. It included a fast-track lane, minor care, trauma

Figure 11. Simplified ED structure used to simulate limiting length of stay for patients discharged home and patients admitted to the hospital



Type: Scheduled

Arrivals [Time, Quantity]

5th Wed - 9:58pm, 1 (action)
5th Wed - 9:59pm, 1 (action)
5th Wed - 10:05pm, 1 (action)
5th Wed - 10:16pm, 1 (action)
5th Wed - 10:18pm, 1 (action)
5th Wed - 10:46pm, 1 (action)
5th Wed - 11:23pm, 1 (action)
5th Wed - 11:46pm, 1 (action)

Week: 5
Day: wednesday
Time: 11:46 pm
Quantity: 1

Action:
transp= walkin
disp=home

Filter: Attributes
Name
Cost
VATime
ID

Imports data from an associated Microsoft Excel document and runs the model.

rooms and the main patient beds area. Total ED capacity was 30 beds.

Because the objective of this work was simulating an effect of patient LOS on diversion for the entire ED, the detailed model layout was significantly simplified. A widely recognized guideline in DES modeling is to keep the model as simple as possible while capturing the simulation objectives (Jacobson et al, 2006). This was reiterated by Dearie et al (1976) who stressed the importance of capturing only relevant performance variables when creating a simple but not necessarily the most complete model. Following this guideline, a simplified model is presented on Figure 11.

There are two modes of transportation by which patients arrive into ED indicated on Figure 11: walk-in and ambulance. When ED patients' census hit ED beds capacity limit (total 30 beds), an ambulance was bounced back (diverted), as it is indicated on Figure 11 Ambulance diversion continued until the time when the ED census dropped below the capacity limit. An action logic code was developed that tracked the percentage of time when the census was at the capacity limit. It was reported as percent diversion in the simulation output file.

All simulation runs start at week 1, Monday, at 12 A.M. (midnight). Because ED was not empty at this time, Monday midnight patients' census was used as the simulation initial condition on January 1, 2007: ED was pre-filled by 15 patients.

Each patient in the arrival flow was characterized by its week number, day of week, and admitting time on the record, as indicated on the panel on Figure 11. The following descriptive attributes (also indicated on the panel on Figure 11) were assigned to each patient on the arrival schedule to properly track each patient's routing and statistics in the simulation action logic:

- Mode of transportation: (i) walk-in, (ii) ambulance.
- Disposition: (i) admitted as inpatient, (ii) discharged home

Arrived patients take available free beds reducing ED free capacity.

Discharged patients (released home or admitted as inpatients) moved out of the simulation system according to their disposition conditional routings. The patients' flow 'in and out' of the ED formed a dynamic supply and demand balance.

Total number of patients included in the simulation was 8411 for the two-month period from January 1 to February 28, 2007. This number of patients was representative enough to make results valid for subsequent months and years (Mayhew and Smith (2008) used three months 2002 database to calibrate the queuing model; however, the total number of patients was not given).

Overall Simulation Approach and LOS Distribution Density Functions

The critical element of the dynamics of the supply and demand balance was the time that the patients spent in ED. This time was fitted by a continuous LOS distribution density functions, separately for admitted as inpatients and discharged home patients.

The best fit distributions were identified using the Stat:Fit module built in the simulation package: admitted inpatients best fit LOS was log-logistic, while best fit LOS for patients discharged home was Pearson 6 (Johnson et al, 1994). These distributions were built into the simulation action logic.

Because these LOS distributions represent a combination of many different steps of the patient move through the entire ED process from registration to discharge (including both value-added and non-value-added steps and delays), there is no simple interpretation: these are simply the best analytical fit used to represent actual patient LOS data.

Random numbers drawn from these distributions were used to perform multiple replications in each simulation run. It was identified in 'cold' runs that about 100 replications were needed for each simulation in order to get a stable outcome.

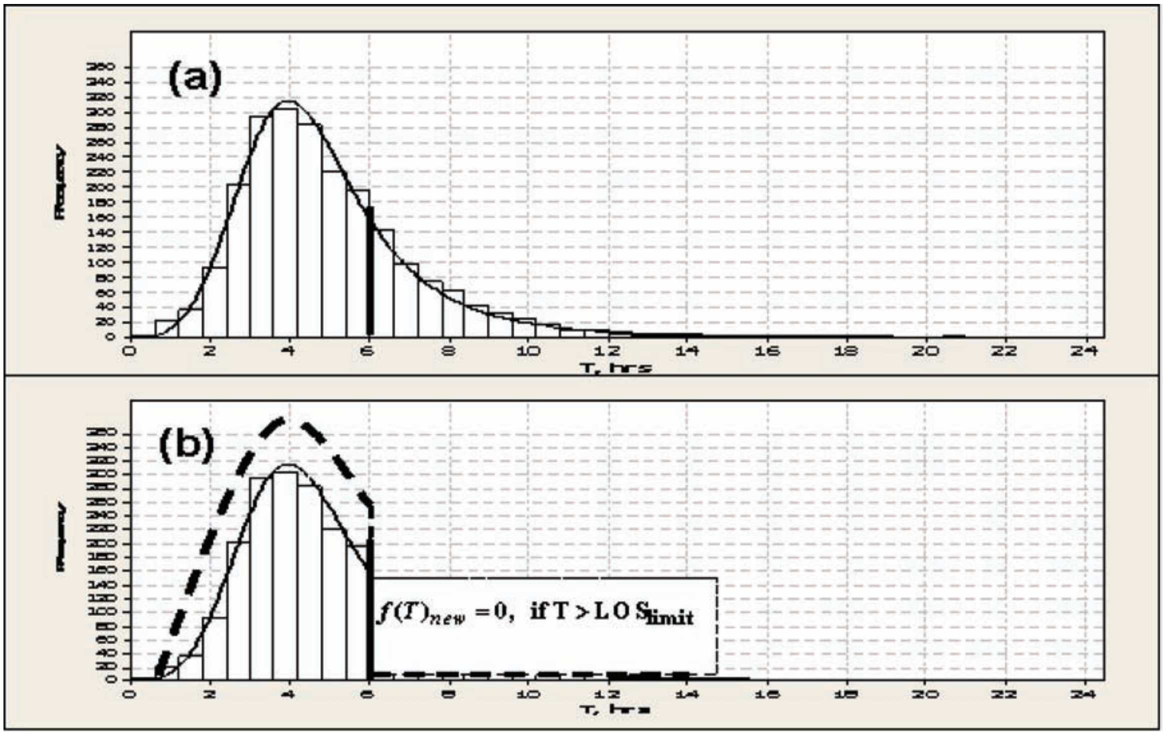
Because the objective was to quantify the effect of the LOS limits (both for discharged home patients and admitted as inpatients) on the percent diversion, the LOS limits were used as two simulation parameters.

An overall simulation approach was based on a full factorial design of experiments (DOE) with two factors (parameters) at six levels, each imposed on the original (baseline) LOS distribution functions. Response function was the simulated percent diversion. Imposing LOS limits (parameters) on original (baseline) LOS distribution functions means that no drawn random LOS value higher than the given limiting value was allowed in the simulation run. Therefore, the original LOS distribution densities should have recalculated for each simulation run as functions of the LOS limits (parameters).

One might be tempted to assume that if a randomly drawn LOS number was higher than the given LOS limit value this number should be made equal to the LOS limit. However, such an approach would result in a highly skewed simulation output because a lot of LOS numbers would be concentrated at the LOS limit value.

Instead, a concept of conditional distribution density should be used. If a random LOS number was in the interval from 0 to LOS_{lim}, this number was used for a simulation replication. However if

Figure 12. Distribution density function and imposed LOS limit



a random LOS number was outside the interval from 0 to LOS $_{\text{lim}}$, this number was not used, and the next random number was generated until it was in the given interval. This procedure generated a new restricted random variable that is conditional to being in the interval from 0 to LOS $_{\text{lim}}$.

Given the original LOS distribution density, $f(T)_{orig}$, and the limiting value,

LOS $_{limit}$, the conditional LOS distribution density function of the new restricted random variable, $f(T)_{new}$ will be

$$f(T)_{new} = \frac{f(T)_{orig}}{\int_0^{LOS_{\text{lim}}} f(T)_{orig} dT}$$, if T is less or equal to LOS

$f(T)_{new} = \mathbf{0}$, if T is greater than LOS $_{\text{lim}}$

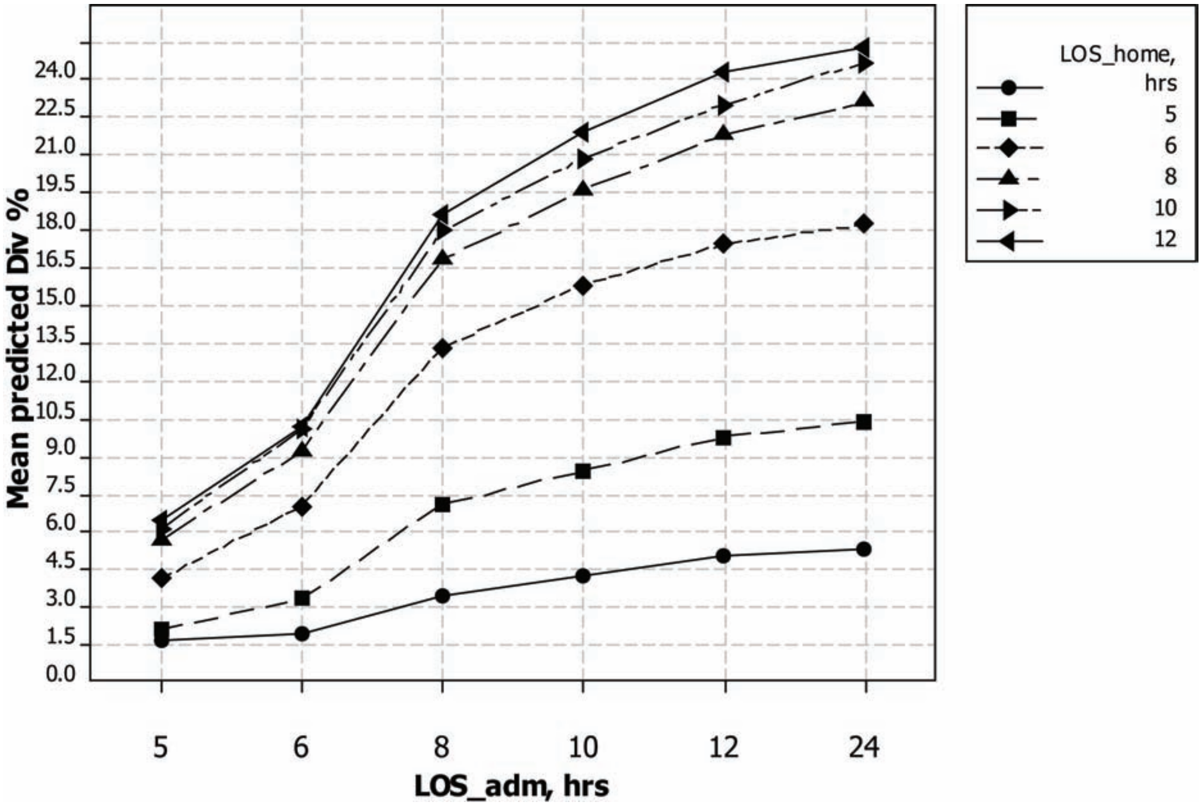
Conditional distribution density $f(T)_{new}$ depicted on Figure 12 (bottom panel, dotted bold line) is a function of both original distribution density and the simulation parameter LOS $_{\text{lim.}}$ (upper integration limit of the denominator integral).

These denominator integrals were preliminary calculated and then approximated by the 3-rd order polynomials that were built in the simulation action logic (Kolker, 2008).

The model's adequacy check was performed by running the simulation of the original baseline patients' arrival. The model's predicted percent diversion (~23.7%) and the reported percent diversion (21.5%) are close enough (in the range of a few percentage points). Thus, the model captures dynamic characteristics of the ED patients' flow adequately enough to mimic the system's behavior, and to compare alternatives ('what-if' scenarios).

Along with the percent diversion calculation, a plot of ED census as a function of time (hours/

Figure 13. Summary plot representing simulated % diversion as a function of two parameters LOS lim (home) and LOS lim (adm)



weeks) was also simulated (Kolker, 2008). This instructive plot visualizes the timing when the ED census hits the capacity limit, and therefore ED diversion had to be declared. The plot also illustrated that at some periods of time (mostly late night time) the ED was actually at a low census.

A full factorial computer design of experiments (DOE) was performed with two factors: LOS $_{lim}$ (home) for discharged home patients and LOS $_{lim}$ (adm) for patients admitted into hospital. Each factor had six levels. Simulated percent diversion was a response function.

A summary of results is presented on Figure 13. It follows from this plot that several combinations of parameters LOS $_{lim}$ (home) and LOS $_{lim}$ (adm) would result in low percent diversion.

For example, if LOS $_{lim}$ (home) stays at 5 hours (low curve) then LOS $_{lim}$ (adm) could be about 6 hours with the practically negligible diversion about 0.5%. Notice that Clifford et al (2008) established the goal for ED LOS 6 hours for inpatients to eliminate ambulance diversion and this metric is considered exceptional if less than 5% of patients exceed this limit. Any other combination of LOS $_{lim}$ (home) and LOS $_{lim}$ (adm) could be taken from the graph to estimate a corresponding expected percent diversion.

Thus, simulation helped to establish a quantitative link between an expected percent diversion and the limiting values of LOS. It has also suggested the reasonable targets for the upper limits LOS $_{lim}$ (home) and LOS $_{lim}$ (adm).

(a) thin solid line: original LOS (top panel). Bold vertical line: imposed LOS limit 6 hrs
(b) re-calculated restricted LOS: bold dotted line

Analysis of the LOS pattern in the study hospital indicated that a significant percentage of ED patients stayed much longer than the LOS targets suggested by the simulation. For example, ~24% patients of a study hospital exceeded LOS $_{\text{lim}}$ (adm) of 6 hours, and ~17% of patients exceeded LOS $_{\text{lim}}$ (home) of 5 hours. These long over-targets LOS for a significant percentage of patients were a root cause of ED closure and ambulance diversion.

Established LOS $_{\text{lim}}$ targets could be used to better manage a daily patient flow. The actual current LOS is being tracked down for each individual patient. If the current LOS for the particular patient at the moment is close to the target limiting LOS $_{\text{lim}}$ a corrective action should be implemented to expedite a move of this patient.

Multiple factors could contribute to the looming delay over the target LOS, such as delayed lab results or X-ray / CT, consulting physician is not available, no beds downstream on hospital floor (ICU) for admitted patients, etc. Analysis and prioritizing the contributing factors to the over the target LOS $_{lim}$ is an important task.

Notice that the average LOS that is frequently reported as one of the ED patient flow performance metric cannot be used to manage a daily patient flow. In order to calculate the average LOS, the data should be collected retrospectively for at least a few dozens patients. Therefore, it would be too late to make corrective actions to expedite a move of the particular patient if the average LOS becomes unusually high (whatever 'high' means). In contrast, if the established upper limiting LOS $_{lim}$ targets were not exceeded for the great majority of patients, it would guarantee a low ED percent diversion, and the average LOS would be much lower than the upper limiting LOS $_{lim}$.

Marshall et al (2005) and de Bruin et al (2007) also discussed the shortcomings of reporting LOS only as averages (the flaw of averages) for the skewed (long tailed) data (see also an illustrative example in section 2.2).

EDs of other hospitals differ by their patient mix, their LOS distribution and bed capacity. However the overall simulation methodology presented here will be the same regardless of a particular hospital ED.

Such a general methodology would be more practically useful for other ED than some predetermined generalized 'one size fits all' target values.

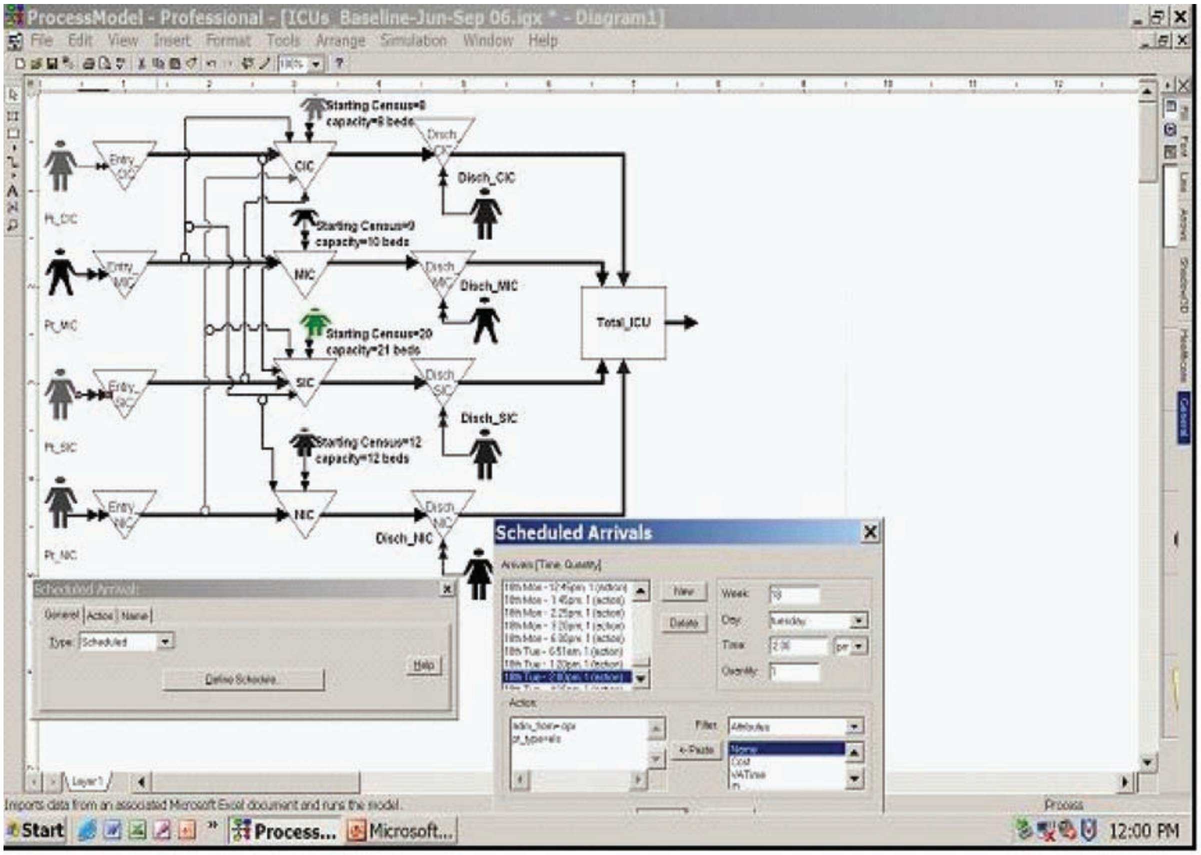
The negative consequences of the 'one size fits all' approach were summarized by Mayhew and Smith, (2008): '…the practicality of a single target fitting all A&ED will come under increasing strain'.

DES of Intensive Care Unit (ICU) Patient Flow: Effect of Daily Load Leveling of Elective Surgeries on ICU Diversion

Intensive Care Unit (ICU) is often needed for the patients' care. Demand for ICU beds comes from emergency, add-on and elective surgeries. Emergency and add-on surgeries are random and cannot be scheduled in advance. Elective surgeries are scheduled ahead of time. However, they are often scheduled for the daily block-time driven mostly by physicians' priorities. (Daily block time is the time in the operating room that is allocated to the surgeon or the group of surgeons on the particular days of the week to perform a particular type of surgical services). Usually elective surgery scheduling does not take into account the competing demand for ICU beds from the emergency and add-on cases.

Because of the limited capacity of the ICU beds, such a disconnection often results in the Emergency Department (ED) closure (diversion) for patients due to no beds in ICU. This is a typical example of a system bottleneck caused by the

Figure 14. DES layout of the ICU patient flow model



interdependency and competing demands between the material (patient) flows in a complex system: the upstream problem (ED closure) is created by the downstream problem (no ICU beds) (see section 3.3).

Usually two types of variability affect the system's patient flow: natural process flow variability and scheduled (artificial) flow variability (Litvak et al, 2001; Litvak and Long, 2000; Haraden et al, 2003).

Patients can be admitted into ICU from the Emergency Department (ED), other local area hospitals, inpatient nursing units, and / or operating rooms (OR). Patients admitted into ICU from ED, other local area hospitals, and inpatient nursing units are primary contributors to the natural random flow variability because the timing of these admissions is not scheduled in advance and is unpredictable.

Admissions into ICU from the OR include emergency, add-on, and elective surgeries. Elective surgeries (cases) are defined as surgeries that could be delayed safely for the patient for at least more than 24 hrs (or usually much longer).

Emergency and add-on surgeries also contribute to the natural process flow variability. Because this type of variability is statistically random, it is beyond hospital control. It cannot be eliminated (or even much reduced). However, some statistical characteristics can be predicted over a long period of time that could help to manage it.

Elective surgeries that require post-operative admission into ICU contribute to the scheduled (artificial) flow variability. Elective surgery scheduling is driven mostly by individual priorities of the surgeons and their availability for other commitments (teaching, research, etc). This variability is usually within the hospital management control, and it could be reduced or eliminated by a proper management of the scheduling system.

It is possible to manage the scheduling of the elective cases in a way to smooth (or to daily load level) overall patient flow variability. A daily load leveling would reduce the chances of excessive peak demand for the system's capacity and, consequently, would reduce its diversion.

There are quite a few publications in which the issues of smoothing surgical schedules and ICU patient flow are discussed. Kolker (2009) provided a detailed analysis of the literature.

Nonetheless, there is not much in the literature that could help a scheduler to directly answer an important question: what maximum number of elective surgeries per day should be scheduled along with the competing demand from emergency surgeries in order to reduce ICU diversion to an acceptable low level, or to prevent diversion at all ?

Therefore, a methodology that could quantitatively link the daily number of elective surgeries and ICU patient flow throughput (or diversion) would have a considerable practical value.

Description of the ICU Patient Flow Model

Layout of the ICU model of the study hospital is represented on Figure 14.

The entire ICU system includes four specialized ICU units: Cardio ICU (CIC), Medical ICU (MIC), Surgical ICU (SIC) and Neurological ICU (NIC). Capacity (the number of beds) of each ICU unit was: CIC=8, MIC=10, SIC=21 and NIC=12. Total ICU capacity was 51 beds.

All simulation runs start at week 1, Monday, at 12 A.M. (midnight). Because ICU was not empty at this time, Monday midnight patients' census was used as the simulation initial conditions: CIC=8, MIC=9, SIC=20 and NIC=12.

Patients admitted into each ICU unit formed an entity arrival flow. The week number, day of the week and admitting time characterize each patient in the arrival flow.

Each discharged patient is also characterized by the week number, day of the week and discharge time.

Patient flow 'in and out' formed a dynamic supply and demand balance (supply of ICU beds and demand for them by patients). If there was no free bed at the time of admission in the particular primary ICU unit, then the patient moved into other ICU units using alternative type routings (depicted by the thin lines between the units, Figure 14).

Patient move followed the following action logic that simulated the established hospital's rules to deal with the overcapacity of the ICU units:
if no beds available in CIC move to SIC

- if no beds available in MIC move to CIC else move to SIC else move to NIC
- if no beds available in NIC move to CIC else SIC

Panel indicates an example of scheduled SIC arrival: week number: 18; Day: Tuesday; Time: 2:00 pm. Patient attributes (bottom of the panel): adm_from = OR (Operating Room); pt_type = els (elective scheduled)

When the patient census of the ICU system hit or exceeded a critical limit, then an ICU diversion was declared due to 'no ICU beds'. The critical limit in the study hospital was defined as the number of occupied beds, which is two beds less than the total capacity, i.e. 49 beds. The two 'extra' beds were left as a buffer in the anticipation of more admissions coming soon.

Diversion status was kept until the time when the ICU census dropped below the critical limit. An action logic code was developed that tracked the percentage of time when the census was at or exceeded the critical limit. It was reported as the percent diversion in the simulation output file.

The following descriptive attributes were assigned to each patient on the arrival schedule to properly track each patient's routing and statistics in the simulation action logic:

- Patient type attribute: elective surgery (els) or emergency surgery (ems).
- Patient 'admitted from' attribute: emergency department (ED), operating room / recovery room (opr), external hospital, rehabilitation, any floor nursing unit.

The total number of admitted patients included into the ICU simulation model was 1847 during the 18 weeks period (about four months worth of data). The total number of elective cases was about 21% of all ICU admission for the 18 week period.

Because elective cases in the study hospital were scheduled by block-time for the same days of the different weeks, the weekly data have been drilled down to analyze their variation for the same days of the different weeks, i.e. from one Monday to another Monday of the following week, from one Tuesday to another Tuesday, and so on.

It follows from these data (Kolker, 2009) that there was a significant variability in the scheduling practice of elective surgeries from one Monday to another Monday, from one Tuesday to another Tuesday, and so on. For example, 8 cases were scheduled on Monday 6/5, 2007 while only 2 cases were scheduled on Monday 6/26, 2007, and only 1 case was scheduled for Monday 9/18, 2007.

A similar picture was observed for other days of week and other ICU units: NIC, MIC, CIC. This highly uneven scheduling practice resulted in straining the ICU system on busy days and underutilizing the system on light days. The overall variability of the schedule was quantified as the standard deviation of the daily number of elective cases over the entire period.

A model adequacy check was performed using the original baseline patient arrival database. The model's predicted percent diversion for the different time periods (from 1 month to 4 months long) was then compared with the actual percent diversion. The later was reported by the ED as the percent of time when the ED was closed to the ambulances due to 'no ICU beds'.

It could be concluded (Kolker, 2009) that the model captures dynamic characteristics of the ICU patient flow adequately enough (within 1 to 2 percent from the actually reported values) to mimic the system's behavior and to compare alternative ('what-if') scenarios.

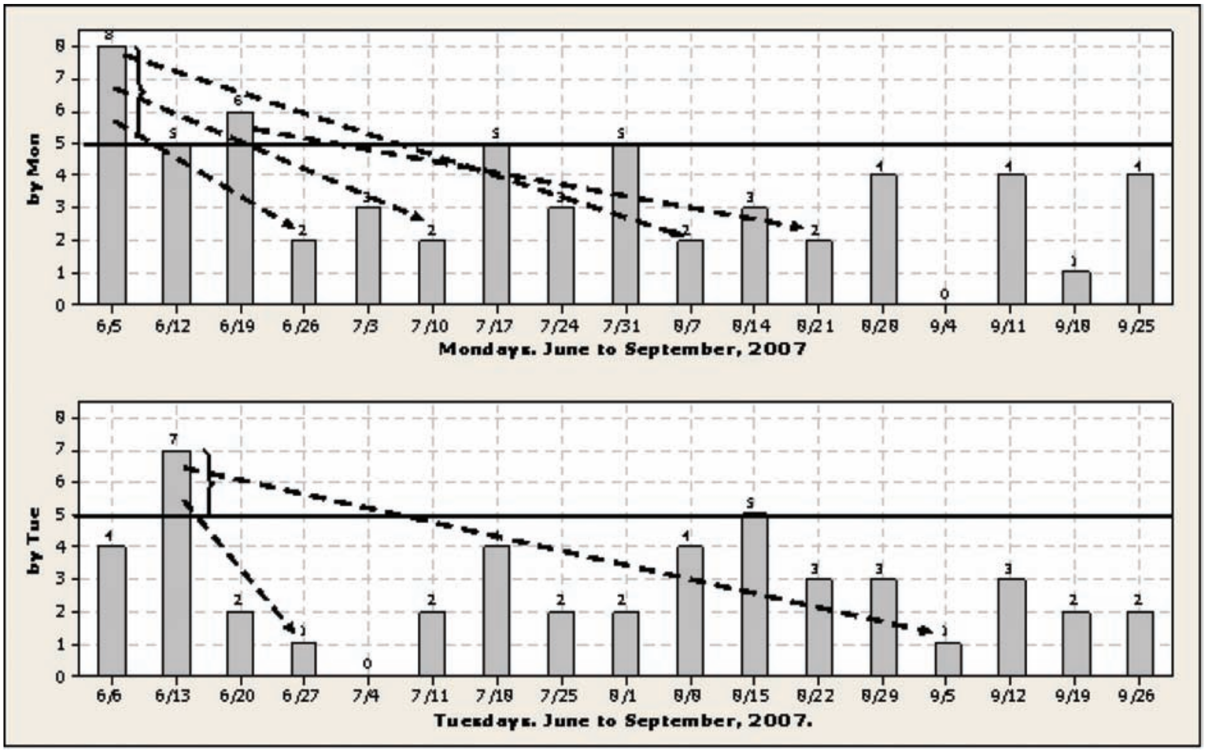
Along with the percent diversion calculation, a plot of ICU census as a function of time (hrs/weeks) was also simulated (Kolker, 2009). The plot visualizes the timing when the ICU census hits or exceeds the critical limit, and therefore ICU diversion had to be declared. The plot also illustrates that at some periods of time the ICU is actually underutilized having low census. These peaks and valleys of the census impose a significant strain on the effectiveness of the ICU operations.

Once the model was checked for its adequacy, it was used with enough confidence to simulate 'what-if' scenarios. The approach was to actively manipulate only the day and time of elective surgeries (leaving all emergency and add-on surgeries timing unchanged). The objective was to quantify the effect of the elective surgeries schedule smoothing (or, equivalently, daily leveling, or daily capping) on the ICU diversion.

The first 'what-if' scenario was: what would the percent diversion be if not more than 5 elective surgeries per day were scheduled for SIC (cap 5 cases) and not more than 4 elective surgeries were scheduled for NIC (cap 4 cases)?

For SIC three 'extra' elective surgery patients were moved from the Monday 6/5 to other Mon-

Figure 15. Diagram of the move of the number of elective surgeries for the daily level (cap) 5 cases (Mondays and Tuesdays shown)



days, such as 6/26, 7/10, and 8/7. One 'extra' elective surgery patient was moved from 6/19 to 8/21.

Similarly, two 'extra' elective surgery patients were moved from Tuesday 6/13 to Tuesdays 6/27 and 9/5, accordingly, as illustrated on Figure 15.

Similar moves were performed for Wednesdays, Thursdays, and Fridays, as well as for NIC. As a result of these moves, new smoother schedules were obtained. Notice that the standard deviations of the new schedules were now much lower than they were for the original schedules (Kolker, 2009).

Simulation runs for the new smoothed schedules resulted in the much-reduced diversion: about ~3.5%. The simulated census clearly indicated that the critical census limit was exceeded less frequently and for a shorter period of time. This is the reason for the reduced diversion compared to the original un-smoothed schedule.

Notice that the total number of elective surgeries remains the same. Not a single surgery was dropped but rather 'extra' surgeries were re-scheduled from the busy days to lighter later days to make the overall schedule for the same time period smoother.

Is it possible to lower diversion further?

The next 'what-if' scenario was: what will the percent diversion be if not more than 4 elective surgeries per day were scheduled, both for SIC and NIC (cap 4 cases)?

A similar move of the 'extra' surgeries from the days in which the daily level of 4 surgeries was exceeded to the later lighter days has resulted in the new schedule that was even smoother than the previous one with the leveling limit of 5 surgeries per day. Standard deviation was reduced by ~40% for Mondays, and ~35% for Tuesdays, Wednesdays, and Thursdays, respectively vs. the baseline original schedule. This should have helped to further reduce diversion. Indeed, the simulation runs demonstrated that the diversion dropped down to the level of ~1.5%.

Is the predicted low ICU diversion ~1.5%, with the SIC and NIC daily leveling of not more than 4 elective surgeries per day an acceptable solution? Technically, it is. However, some 'extra' surgeries would have bumped to more than 2 months apart, e.g. from early June to early August (Figure 15). The problem is that not all patients could wait that long even though the surgery is elective. Also, from the practical standpoint, daily leveling of not more than 4 surgeries per day is sometimes too restrictive.

Therefore a next series of 'what-if' scenarios was considered: is it possible to get a low diversion about ~ 1% by bumping 'extra' cases to the block-time days which are not further than 2 weeks apart (Dexter et al, 1999) ? It was also considered increasing the daily leveling back to 5 elective surgeries per day in order to make the limit less restrictive.

The elective schedule with the additional restriction 'not more than two weeks apart' is less smooth. It has a higher standard deviation (1.59) than the schedule without restriction for which the standard deviation was 1.42. Notice that the original un-smoothed schedule had the highest standard deviation 1.97.

Simulation runs of the 'what-if' scenario corresponding to the restricted 'within two weeks' schedule and SIC daily leveling 5 elective surgeries resulted in ICU diversion of only ~8%. This is a relatively small gain compared to the original baseline un-smoothed schedule with ~10.5% diversion. This small reduction of the diversion was a reflection of a lower smoothness (higher standard deviation) of this schedule. Thus, load leveling to 5 elective surgeries per day with bumped 'extra cases' within 2 weeks apart was not effective enough alone.

In order to reduce the percent diversion back to low single digits while still keeping daily leveling at 5 elective surgeries per day and moving 'extra cases' within two weeks apart, an additional factor was considered. This factor was a more rigorous implementation of ICU admission and discharge criteria. It was suggested that patients with the likely LOS less than 24 hrs were excluded from ICU admission but moved to the regular nursing unit (see section 3.3). This scenario resulted in a significant reduction of ICU diversion, down to about ~ 1%.

There is a trade-off between these two scenarios. From the practical standpoint the higher level-loading elective schedule (5 surgeries per day) would be easier to implement than the lower level-loading one (4 surgeries per day) because the former is less restrictive. However, the former assumes that the ICUs admission criteria/exclusions are rigorously applied while the latter does not require exclusion from the current ICU admission practice.

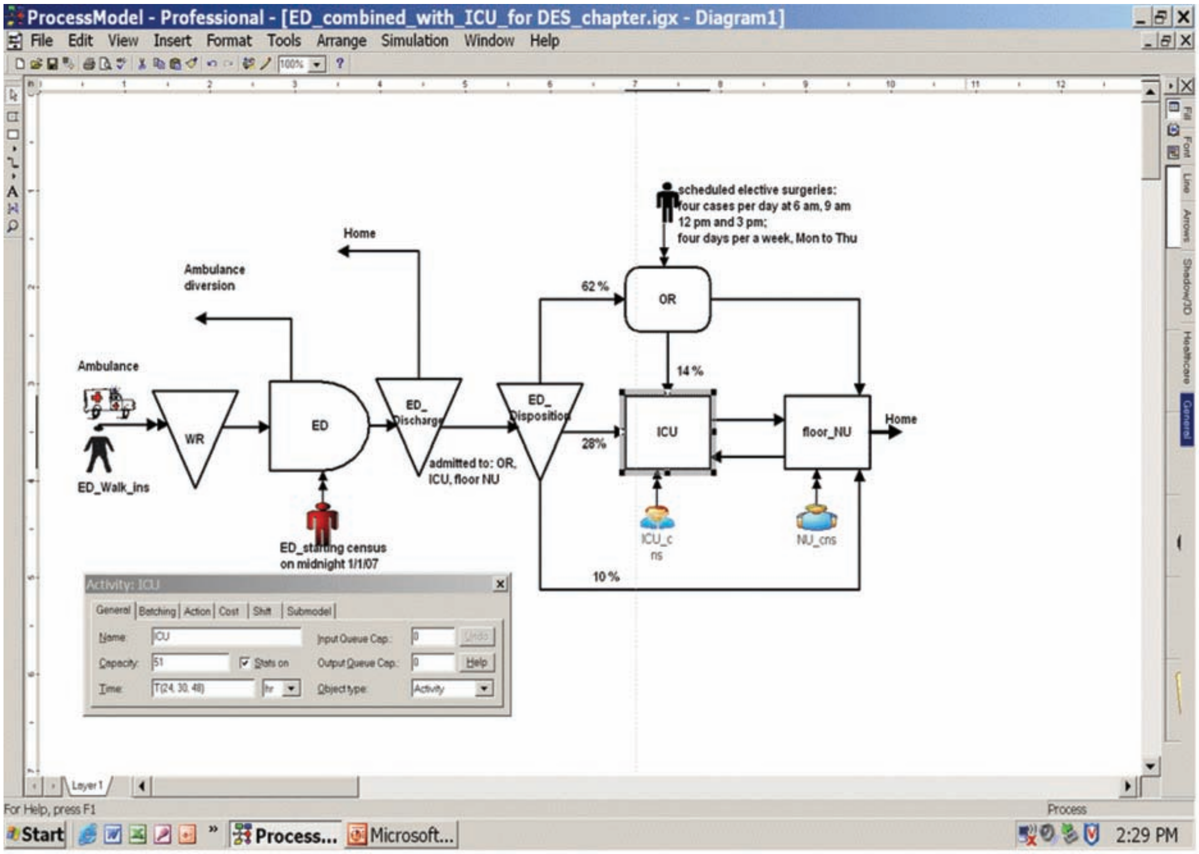
One more valuable application of this DES model could be determining a more appropriate allocation of the number of beds between CIC, SIC, MIC, and NIC units, compared to the current historical allocation.

Once the DES model is validated, it becomes a powerful tool for the hospital operations decision-making.

DES of the Entire Hospital System Patient Flow: Effect of Interdependencies of ED, ICU, Operating Rooms (OR) and Floor Nursing Units (NU)

It was discussed in Introduction that large complex hospital systems or multi-facility clinics are usually deconstructed into smaller subsystems or units. Most published DES models focus on

Figure 16. DES layout of a high-level patient flow map of the entire hospital system



Activity: ICU

General | Batching | Action | Cost | Shift | Submodel

Name: ICU
Capacity: 51 ☑ Stats on
Time: T(24, 30, 48) hr
Input Queue Cap.: 0
Output Queue Cap.: 0
Object type: Activity

the separate analysis of these individual units (Jacobson et al, 2006). However, according to the principles of analysis of complex systems, these separate subsystems (units) should be reconnected back in a way that captures the most important interdependency between them. DES models that capture the interaction of major units in a hospital, and the information that can be obtained from analyzing the system as a whole, can be invaluable to hospital planners and administrators.

This section specifically illustrates a practical application of this system-engineering principle.

DES models of the ED and ICU patient flow have been described separately in details in sections 3.1 and 3.2. It is well known that these subsystems are not stand-alone units but they are closely interdependent, as well as the Operating Rooms (OR) and floor nursing units (NU).

A high-level patient flow map (layout) of the entire hospital system is shown on Figure 16 One output of the ED model for patients admitted into the hospital (ED discharge) now becomes an ICU, OR and NU input through ED disposition. About 62% of admitted patients were taken into operating rooms (OR) for emergency surgery, about 28% of admitted patients moved directly into ICU, and about 10% of patients admitted from ED into floor nursing units.

OR suite size was 12 interchangeable operating rooms used both for ED emergency and scheduled surgeries.. There were four daily scheduled OR admissions at 6 am, 9 am, 12 pm and 3 pm, Monday to Thursday (there were no scheduled surgeries on Fridays and weekends).

The best fit of the emergency surgery duration was found to be a Pearson 6 distribution.

Elective surgery duration depends on surgical service type, such as general surgery, orthopedics, neuro-surgery, etc. For the simplicity of this model, elective surgery duration was weighted by each service percentage. The best fit of the overall elective surgeries duration was found to be a Johnson SB distribution (Johnson et al, 1994).

About 14% of post surgery patients were admitted from OR into ICU (direct ICU admission) while 86% were admitted into floor NU. However some patients (about 4%) were readmitted from floor NU back to ICU (indirect ICU admission from OR).

Patient length of stay (LOS) in NU was assumed to be in the range from 1 day to 10 days with the most likely 5 days represented by a triangle distribution. NU overall capacity was 420 beds. At the simulation start, NU was pre-filled with starting census 380 patients (see also sections 3.1 and 3.2).

Baseline DES resulted in ED diversion about 24%, ICU diversion about 11% (see sections 3.1 and 3.2), and floor NU diversion about 14.6%.

If limiting ED LOS had aggressive targets 5 hours for patients discharged home and 6 hours for patients admitted to the hospital (see section 3.1) then ED diversion became practically negligible (less than 0.5%). However because of interdependencies of patient flows, ICU diversion increased to 12.5% and floor NU diversion remained about the same, 14.9%. Thus, aggressive process improvement in one subsystem (ED) resulted in worsening situation in other interrelated subsystems (mostly, ICU).

If instead of the above aggressive limiting ED LOS a more relaxed target is used, say, LOS not more than 6 hours for discharged home and not more than 10 hours for admitted to the hospital, then simulated ED diversion would become about 7%, ICU diversion is about 11.1%, and floor NU diversion remained practically unchanged, 14.8%. While ED diversion now became worse, it is still better than it was at the baseline level by about a factor of 3. At the same time, this less aggressive ED target LOS did not, at least, make the ICU and floor NU diversion much worse.

Thus, from the entire hospital system standpoint the primary focus of process improvement activities should be on ED, and then on floor NU followed by ICU.

At the same time, ED patient target LOS reduction program should not be too aggressive and it should be closely coordinated with that for floor NU and ICU. Otherwise, even if ED reports a significant progress in its patient LOS reduction program, this progress will not translate into improvement of the overall hospital system patient flow. This illustrates one of the fundamental principles of the Theory of Constraints (Goldratt, 2004).

On the other hand, if ICU policy of declaring diversion is changed from 49 occupied beds to full capacity of 51 occupied beds, then ICU reported diversion will drop down to ~9.6%, leaving unchanged diversions of all other units in the system.

This illustrates that reported performance metric (percent of time at full capacity or some others) depends not only on physical capacity and patient flow variability but also on the hospital administrative policy.

Of course, many other scenarios could be analyzed using DES model to find out how to improve the entire hospital system patient flow rather than each separate hospital department.

PRACTICAL IMPLEMENTATION OF DES RESULTS IN HEALTHCARE: ISSUES AND PERSPECTIVES

As it was already pointed out and supported by extensive literature review (Jun et al, 1999; Jacobson et al, 2006), DES modeling as a methodology of choice in healthcare has been extensively used to quantitatively analyze healthcare delivery processes and operations and to help decision-makers to justify business decisions.

However, for DES to reach its full potential as the key methodology in healthcare, the results of simulation must be practically implemented. Unfortunately, the number of publications that report successful implementation of DES results is much lower than the number of publications that report successful development of DES models. For example, in the survey of two hundred papers reporting the results of DES studies in healthcare, only 16 reports of successful implementations were identified (Jacobson et al, 2006). Fone (2003) found that Operational Research has had limited success in the implementation of results in practice in the healthcare setting. Sachdeva et al (2006) also states that '…Healthcare Operational Research (OR) has had limited success in achieving an adequate level of acceptance by stakeholders, particularly physicians, leading to implementation of results'.

A likelihood of successful implementation or effectiveness of DES project (E) can be related to two major factors:

(i) the likelihood that DES model adequately captures all relevant features of process (system) and properly verified and validated to actual clinical data, i.e. technical quality of the model (TQ), and
(ii) the likelihood of acceptance of the results of the DES study by key stakeholders and decision-makers (A), i.e., $E = TQ * A$.

A similar relationship in which acceptance term (A) also included accountability was presented by Mercy Medical Center (2007).

Most reported DES studies focus on TQ, and the likelihood of developing a good verified and validated DES model is high (although not guaranteed). However, if the likelihood of acceptance of the model results is low (for whatever reason), then the overall success and impact of the DES project measured by effectiveness of its implementation will also be low regardless of technical merits of the DES model itself.

A number of recommendations were developed to increase the likelihood of DES results implementation success. Some of these recommendations include (Jacobson, 2006): the system being simulated actually needs decision, the DES project must be completed before a deadline, data used for simulation are credible, and, most importantly, the key stakeholders and the decision-maker must actively participate in the project.

Lowery (1996) noted that involvement of the upper management in the project is critical for its success. Litvak (2007) argues that if hospital executives are not involved in the process (queuing theory or simulation), the analysts could do their calculations but they would not be used for decision-making.

Carter and Blake (2004) published an interesting summary of their experience in practical implementation of simulation projects. They have used four projects to highlight the practical lessons of applying operations research methodologies in health care: '…Experience suggests that OR techniques can be successfully applied in the health care setting. The secret is to understand the unique nature of the health care business and its impact on models, decision makers, and the development of implementation policies'. Further, '…decision making in hospitals is characterized by multiple players; …incorporating the objectives of all decision makers is vital in this environment'.

Thus, procedure and methodology of applying DES requires decision-makers to work closely with the simulation analyst to provide details of the system, often for the first time. As a result, the decision-makers are likely to gain a new perspective on the relationship between the available resources and the capability of the system (Jacobson et al, 2006).

The experience of the author of this chapter has also shown that at least two main conditions are needed: (i) the stake-holder (project owner) must have a genuine incentive for process improvement and realize that there is no real alternative to DES modeling, and (ii) a dedicated and flexible data analyst must participate in the project. The data analyst must not only have a full access to raw data stored in various data bases but be also qualified enough to convert these data bases into a data file (usually Excel) with the fields that match the fields developed by a simulation specialist who designed the model. Thus, a successful DES project truly takes teamwork by the professionals.

Rakich et al (1991) studied the effect of DES on management development. The authors concluded that conducting a simulation study not only develops decision-making skills, but also forces to recognize the implication of system changes. It was noted that if decision-makers developed their own DES models, implementation occurred much more frequently. Mahachek (1992) noted that one of significant barriers in the implementation of DES is the decision-makers' perception that '… simulation is an additional layer of effort rather than an organizer of all your current efforts'. According to Lowery (1996), DES projects start as a means of documenting assumptions, organizing the decision-making process and identifying potential problem areas. She is quite right when she passionately writes that '…It is amazing how much time is spent in the planning process (especially in meetings) arguing over the differences in opinion, where these differences are due to disagreements over assumptions never actually acknowledged….While disagreements may still ensue over the content of the assumptions, the arguments become focused when the assumptions… are in front of all participants'.

Healthcare has a culture of rigid division of labor. This functional division does not effectively support the methodologies that cross the functional areas, especially if they assume significant changes in traditional relationships (Kopach-Konrad et al, 2007). Furthermore, the role and status of DES professionals in healthcare delivery is not usually well defined and causes sometimes skepticism and fear.

Relatively few health care administrators are equipped to think analytically about how health care delivery should function as a system or to appreciate the relevance of system-engineering methods in healthcare. Even fewer are equipped to work with engineers to apply these tools (Reid et al, 2005). Thus, it is often difficult for many administrators to appreciate the DES approach contributions to the health care delivery process analysis. On the other hand, DES professionals often have little, if any, education in health care delivery. This sometimes results in the lack of clinically relevant factors related to patient care included in DES model, '…which are at the heart of physician decision-making' (Sachdeva et al, 2006).

This underscores the importance of considering social and communication issues in the acceptance and implementation of any socio-technical system (Kopach-Konrad, et al, 2007).

One approach proposed to overcome some of these issues was applied to pediatric ICU (Sachdeva et al, 2006). It includes a combination of 'hard' and 'soft' operations research. The initial simulation model of pediatric ICU patient flow was modified based upon input from the active participation of physicians working in this ICU. During interviews with stakeholders it was acknowledged that there are factors called 'soft' that are difficult to model in an objective unambiguous way. Therefore, soft OR was used to capture concerns that could not be captured using traditional DES methodology. Cognitive mapping was chosen as the soft OR approach. Cognitive maps attempt to capture beliefs, values, and expertise of stakeholders by conducting structured interviews. Cognitive mapping was used for two main purposes: (i) to assist in the identification of issues that were previously not captured using traditional DES models, and (ii) comparing results from the outcomes research, hard and soft OR to enhance greater buy-in and acceptance by the key stakeholders.

The results of cognitive mapping helped not only identify new issues not captured by hard OR but also supported many of the results from hard OR that were counter-intuitive to pre-existing beliefs.

Thus, results from this study support the view that a combination of hard and soft OR allows a greater level of understanding leading to acceptance and willingness to implement DES results. This is consistent with the recommendations of the UK Engineering and Physical Science Research Council (EPSRC) (2004) regarding soft OR and application in healthcare. '…It has always been one of the main characteristics of OR to seek for opportunities to integrate soft and hard methods' (EPRSC, 2004).

CONCLUSION

This chapter covers applications of the most widely used system-engineering methods, such as queuing analytic theory and DES models, to healthcare,. It demonstrates the power of DES models for the analysis of patient flow with variability and subsystem interdependency.

Many health care organizations are making serious strategic decisions such as new construction to expand capacity, merging with other hospitals etc., without using system engineering and, particularly, DES modeling analysis to evaluate an impact of these decisions.

However, DES models and management science principles are widely used in other industries, and demonstrate a great value in providing important insights into operational strategies and practices.

Complex dynamics of delivery of care processes makes them an important area of application of DES modeling and management science methodologies to help identify both trends in capacity needs and the ways to use existing capacity more efficiently.

At the same time, it is acknowledged that one of the major current challenges is a relatively low acceptance of DES results by the medical community and hospital administration. Practical implementation of DES results in health care settings is sometimes rather slow and difficult.

There are various reasons for this situation, both technical and psychological. Some of them have been discussed in section 4.

Nonetheless, more and more healthcare organizations have started to recognize the value and predictive power of system engineering and DES models through concrete and realistic examples. The fast changing landscape of the healthcare industry will help promote the organizational changes needed for adoption improvement recommendations based on DES models. Hopefully this chapter contributes a little toward achieving this goal.

REFERENCES

Abu-Taieh, E., & El Sheikh, A. R. (2007). Commercial Simulation Packages: A Comparative Study. *International Journal of Simulation*, *8*(2), 66–76.

Allen, A. (1978). *Probability, statistics and queuing theory, with computer science applications.* New York: Academic Press

Blasak, R., Armel, W., Starks, D., & Hayduk, M. (2003). The Use of Simulation to Evaluate Hospital Operations between the ED and Medical Telemetry Unit. In S. Chick, et al (Ed.), *Proceedings of the 2003 Winter Simulation Conference* (pp. 1887-1893). Washington, DC: IEEE.

Carter, M. (2002). Health Care Management, Diagnosis: Mismanagement of Resources. *Operation Research / Management Science (OR/MS) . Today*, *29*(2), 26–32.

Carter, M., & Blake, J. (2004). Using simulation in an acute-care hospital: easier said than done. In M. Brandeau, F. Sainfort, &W. Pierskala, (Eds.), *Operations Research and Health Care. A Handbook of Methods and Applications*, (pp.192-215). Boston: Kluwer Academic Publisher.

Clifford, J., Gaehde, S., Marinello, J., Andrews, M., & Stephens, C. (2008). *Improving Inpatient and Emergency Department Flow for Veterans. Improvement report.* Institute for Healthcare Improvement. Retrieved from http://www.IHI.org/ihi

D'Alesandro, J. (2008). *Queuing Theory Misplaced in Hospitals*. Management News from the Front, Process Improvement. PHLO. Posted Feb 19, 2008 at http://phlo.typepad.com

de Bruin, A., van Rossum, A., Visser, M., & Koole, G. (2007). Modeling the Emergency cardiac inpatient flow: an application of queuing theory. *Health Care Management Science*, *10*, 125–137. doi:10.1007/s10729-007-9009-8

Dearie, J., & Warfield, T. (1976, July 12-14). The development and use of a simulation model of an outpatient clinic. *Proceedings of the 1976 Summer computer Simulation Conference*, Simulation Council, Washington, DC, (pp. 554-558).

Dexter, F., Macario, A., Traub, R., Hopwood, M., & Lubarsky, D. (1999). An Operating Room Scheduling Strategy to Maximize the Use of Operating Room Block Time: Computer Simulation of Patient Scheduling and Survey of Patients' Preferences for Surgical Waiting Time. *Anesthesia and Analgesia*, *89*, 7–20. doi:10.1097/00000539-199907000-00003

Engineering and Physical Sciences Research Council (EPSRC). (2004). *Review of Research Status of Operational Research (OR) in the UK,* Swindon, UK. Retrieved from www.epsrc.ac.uk

Fone, D., Hollinghurst, S., & Temple, M. (2003). Systematic review of the use and value of computer simulation modeling in population health and health care delivery. *Journal of Public Health Medicine*, *25*(4), 325–335. doi:10.1093/pubmed/fdg075

Gallivan, S., Utley, M., Treasure, T., & Valencia, O. (2002). Booked inpatient admissions and hospital capacity: mathematical modeling study. *British Medical Journal*, *324*, 280–282. doi:10.1136/bmj.324.7332.280

Garcia, M., Centeno, M., Rivera, C., & DeCario, N. (1995). Reducing Time in an Emergency Room via a Fast-track. In C. Alexopoulos, et al (Ed.), *Proceedings of the 1995 Winter Simulation Conference,* (pp. 1048-1053). Washington, DC: IEEE.

Goldratt, E., & Cox, J. (2004). *The Goal* (3rd Ed., p. 384). Great Barrington, MA: North River Press.

Green, L. (2004). *Capacity Planning and Management in Hospitals*. In M. Brandeau., F. Sainfort, W. Pierskala, (Eds.), *Operations Research and Health Care. A Handbook of Methods and Applications*, (pp.15-41). Boston: Kluwer Academic Publisher.

Green, L. (2006). Queuing Analysis in Healthcare. In R. Hall, (Ed.), *Patient Flow: Reducing Delay in Healthcare Delivery* (pp. 281-307). New York: Springer.

Green, L., Kolesar, P., & Soares, J. (2001). Improving the SIPP approach for staffing service systems that have cyclic demands. *Operations Research*, *49*, 549–564. doi:10.1287/opre.49.4.549.11228

Green, L., Kolesar, P., & Svoronos, A. (1991). Some effects of non-stationarity on multi- server Markovian queuing Systems. *Operations Research*, *39*, 502–511. doi:10.1287/opre.39.3.502

Green, L., Soares, J., Giglio, J., & Green, R. (2006). Using Queuing Theory to Increase the Effectiveness of Emergency Department Provider Staffing. *Academic Emergency Medicine*, *13*, 61–68. doi:10.1111/j.1553-2712.2006.tb00985.x

Gunal, M., & Pidd, M. (2006). Understanding Accident and Emergency Department Performance using Simulation. In L. Perrone, et al (Ed.) *Proceedings of the 2006 Winter Simulation Conference* (pp. 446-452). Washington, DC: IEEE.

Hall, R. (1990). *Queuing methods for Service and Manufacturing.* Upper Saddle River, NJ: Prentice Hall.

Haraden, C., Nolan, T., & Litvak, E. (2003). *Optimizing Patient Flow: Moving Patients Smoothly Through Acute Care Setting* [White papers 2]. Institute for Healthcare Improvement Innovation Series, Cambridge, MA

Harrison, G., Shafer, A., & Mackay, M. (2005). Modeling Variability in Hospital Bed Occupancy. *Health Care Management Science*, *8*, 325–334. doi:10.1007/s10729-005-4142-8

Hillier, F., & Yu, O. (1981). *Queuing Tables and Graphs* (pp.1-231). New-York: Elsevier, Hlupic, V., (2000). Simulation Software: A Survey of Academic and Industrial Users. *International Journal of Simulation*, *1*(1), 1–11.

IHI - Institute for Healthcare Improvement. (2008). Boston, MA: Author. Retrieved from http://www.ihi.org/IHI/Programs/ConferencesAndSeminars/ApplyingQueuingTheorytoHealthCareJune2008.htm

Ingolfsson, A., & Gallop, F. (2003). *Queuing ToolPak 4.0*. Retrieved from http://www.bus.ualberta.ca/aingolfsson/QTP/

Jacobson, H., Hall, S., & Swisher, J. (2006). Discreet-Event Simulation of Health Care Systems. In R. Hall, (Ed.), *Patient Flow: Reducing Delay in Healthcare Delivery*, (pp. 210-252). New York: Springer.

Johnson, N. Kotz., S., & Balakrishnan, N., (1994). *Continuous Univariate Distributions* (Vol.1). New York: John Wiley & Sons.

... *Journal of Medical Systems*, *31*(6), 543–546. doi:10.1007/s10916-007-9096-6

Jun, J., Jacobson, H., & Swisher, J. (1999). Application of DES in health-care clinics: A survey. *The Journal of the Operational Research Society*, *50*(2), 109–123.

Kolker, A. (2008). Process Modeling of Emergency Department Patient Flow: Effect of patient Length of Stay on ED diversion. *Journal of Medical Systems, 32*(5), 389-401. doi: http://dx.doi.org/10.1007/s10916-008-9144-x

Kolker, A. (2009). Process Modeling of ICU Patient Flow: Effect of Daily Load Leveling of Elective Surgeries on ICU Diversion. *Journal of Medical Systems.* 33(1), 27-40. Doi: http://dx.doi.org/10.1007/s10916-008-9161-9

Kopach-Konrad, R., Lawley, M., Criswell, M., Hasan, I., Chakraborty, S., Pekny, J., & Doebbeling, B. (2007). Applying Systems Engineering Principles in Improving Health Care Delivery. *Journal of General Internal Medicine*, *22*(3), 431–437. doi:10.1007/s11606-007-0292-3

Lawrence, J., Pasternak, B., & Pasternak, B. A. (2002). *Applied Management Science: Modeling, Spreadsheet Analysis, and Communication for Decision Making*. Hoboken, NJ: John Wiley & Sons.

Lefcowitz, M. (2007, February 26). *Why does process improvement fail?* Builder-AU by Developers for developers. Retrieved from www.builderau.com.au/strategy/projectmanagement/

Litvak, E. (2007). A new Rx for crowded hospitals: Math. Operation management expert brings queuing theory to health care. *American College of Physicians-Internal Medicine-Doctors for Adults,* December 2007, ACP Hospitalist.

Litvak, E., & Long, M. (2000). Cost and Quality under managed care: Irreconcilable Differences? *The American Journal of Managed Care*, *6*(3), 305–312.

Litvak, E., Long, M., Cooper, A., & McManus, M. (2001). Emergency Department Diversion: Causes and Solutions. *Academic Emergency Medicine*, *8*(11), 1108–1110.

Lowery, J. (1996). Introduction to Simulation in Healthcare. In J. Charness, D. Morrice, (Ed.) *Proceedings of the 1996 Winter Simulation Conference,* (pp. 78-84).

Mahachek, A. (1992). An Introduction to patient flow simulation for health care managers. *Journal of the Society for Health Systems*, *3*(3), 73–81.

Marshall, A., Vasilakis, C., & El-Darzi, E. (2005). Length of stay-based Patient Flow Models: Recent Developments and Future Directions. *Health Care Management Science*, *8*, 213–220. doi:10.1007/s10729-005-2012-z

Mayhew, L., & Smith, D. (2008). Using queuing theory to analyze the Government's 4-h completion time target in Accident and Emergency departments. *Health Care Management Science*, *11*, 11–21. doi:10.1007/s10729-007-9033-8

McManus, M., Long, M., Cooper, A., & Litvak, E. (2004). Queuing Theory Accurately Models the Need for Critical Care Resources. *Anesthesiology*, *100*(5), 1271–1276. doi:10.1097/00000542-200405000-00032

McManus, M., Long, M., Cooper, A., Mandell, J., Berwick, D., Pagano, M., & Litvak, E. (2003). Variability in Surgical Caseload and Access to Intensive Care Services. *Anesthesiology*, *98*(6), 1491–1496. doi:10.1097/00000542-200306000-00029

Mercy Medical Center. (2007). *Creating a Culture of Improvement.* Presented at the Iowa Healthcare Collaborative Lean Conference, Des Moines, IA, August 22. Retrieved from www.ihconline.org/toolkits/LeanInHealthcare/IHALeanConfCultureImprovement.pdf

Miller, M., Ferrin, D., & Szymanski, J. (2003). Simulating Six Sigma Improvement Ideas for a Hospital Emergency Department. In S. Chick, et al (Ed.) *Proceedings of the 2003 Winter Simulation Conference* (pp. 1926-1929). Washington, DC: IEEE.

Nikoukaran, J. (1999). Software selection for simulation in manufacturing: A review. *Simulation Practice and Theory*, *7*(1), 1–14. doi:10.1016/S0928-4869(98)00022-6

Rakich, J., Kuzdrall, P., Klafehn, K., & Krigline, A. (1991). Simulation in the hospital setting: Implications for managerial decision making and management development. *Journal of Management Development*, *10*(4), 31–37. doi:10.1108/02621719110005069

Reid, P., Compton, W., Grossman, J., & Fanjiang, G. (2005). *Building a better delivery system: A new engineering / Healthcare partnership.* Washington, DC: Committee on Engineering and the Health Care System, Institute of Medicine and National Academy of Engineering, National Academy Press.

Ryan, J. (2005). *Building a better delivery system: A new engineering / Healthcare partnership. System Engineering: Opportunities for Health Care* (pp.141-142). Washington, DC: Committee on Engineering and the Health Care System, Institute of Medicine and National Academy of Engineering, National Academy Press.

Sachdeva, R., Williams, T., Quigley, J., (2006). Mixing methodologies to enhance the implementation of healthcare operational research. *Journal of the Operational Research Society, advance online publication, September 6*, 1 - 9

Seelen, L., Tijms, H., & Van Hoorn, M. (1985). *Tables for multi-server queues* (pp. 1-449). New-York: Elsevier, Simon, S., Armel, W., (2003). The Use of Simulation to Reduce the Length of Stay in an Emergency Department. In S. Chick, et al (Ed.) *Proceedings of the 2003 Winter Simulation Conference* (pp. 1907-1911). Washington, DC: IEEE

Swain, J., 2007. Biennial Survey of discreet-event simulation software tools. *OR/MS Today, 34*(5), October.

Weber, D. O. (2006). Queue Fever: Part 1 and Part 2. *Hospitals & Health Networks, Health Forum*. Retrieved from http://www.IHI.org

Wullink, G., Van Houdenhoven, M., Hans, E., van Oostrum, J., van der Lans, M., Kazemier, G., (2007). Closing Emergency Operating Rooms Improves Efficiency.

KEY TERMS AND DEFINITIONS

Operations Research: The discipline of applying mathematical models of complex systems with random variability aimed at developing justified operational business decisions

Management Science: A quantitative methodology for assigning (managing) available material assets and human resources to achieve the operational goals of the system based on operations research.

Non-Linear System: A system that exhibits a mutual interdependency of components and for which a small change in the input parameter(s) can result in a large change of the system output

Discrete Event Simulation: One of the most powerful methodologies of using computer models of the real systems to analyze their performance by tracking system changes (events) at discrete moments of time

Queuing Theory: Mathematical methods for analyzing the properties of waiting lines (queues) in simple systems without interdependency. Typically uses analytic formulas that must meet some rather stringent assumptions to be valid.

Simulation Package (also known as a simulation environment): A software with user interface used for building and processing discrete event simulation models

Flow Bottleneck / Constraint: A resource (material or human) whose capacity is less than or equal to demand for its use.

This work was previously published in Handbook of Research on Discrete Event Simulation Environments: Technologies and Applications, edited by E. Abu-Taieh and A. El Sheikh, pp. 443-483, copyright 2010 by Information Science Reference (an imprint of IGI Global).

Chapter 7.13

Towards Process-of-Care Aware Emergency Department Information Systems:

A Clustering Approach to Activity Views Elicitation

Andrzej S. Ceglowski
Monash University, Australia

Leonid Churilov
The University of Melbourne, Australia

ABSTRACT

The critical role of emergency departments (EDs) as the first point of contact for ill and injured patients has presented significant challenges for the elicitation of detailed process models. Patient complexity has limited the ability of ED information systems (EDIS) in prediction of patient treatment and patient movement. This article formulates a novel approach to building EDIS Activity Views that paves the way for EDIS that can predict patient workflow. The resulting Activity View pertains to "what is being done," rather than "what experts think is being done." The approach is based on analysis of data that is routinely recorded during patient treatment. The practical significance of the proposed approach is clinically acceptable, verifiable, and statistically valid process-oriented clusters of ED activities that can be used for targeted process elicitation, thus informing the design of EDIS. Its theoretical significance is in providing the new "middle ground" between existing "soft" and "computational" process elicitation methods.

INTRODUCTION

Information system (IS) design principles call for requirements definition as an intermediate stage in the design and development of IS (Mertins, Bernus, & Schmidt, 1998). The requirements definition is a document that outlines all the needs that users require of the prospective system. The requirements definition is designed to allow for the translation of the physical needs of a process into an automated environment. Programmers should be able to work from this document without going back to the users for clarification. The requirements definition can thus "be compared to a schematic of a plan or a diagram of how a technical device works" (Langer, 2008).

The requirements definition commonly takes the organisation from a functional view of activities (who, in which department, does what) to a process-oriented view of operations (what happens, when, and where). This shift from functional data structuring to process event recording is best described in process models. Process models are formalised representations of the activities enacted by a human or a machine that are considered important to the achievement of the objective of the process (Dumas, van der Aalst, & ter Hofstede, 2005). The process models provide a structured framework for IS specification and design, one example is ARIS, a widely used reference architecture and methodology (Scheer, 1999), and allow configuration of the IS to support or control the flow of work in the operational process (Rozinat & van der Aalst, 2008). Comprehensive process models combine different views (Poulymenopoulou, Malamateniou, & Vassilacopoulos, 2003; Seltsikas, 2001) that describe:

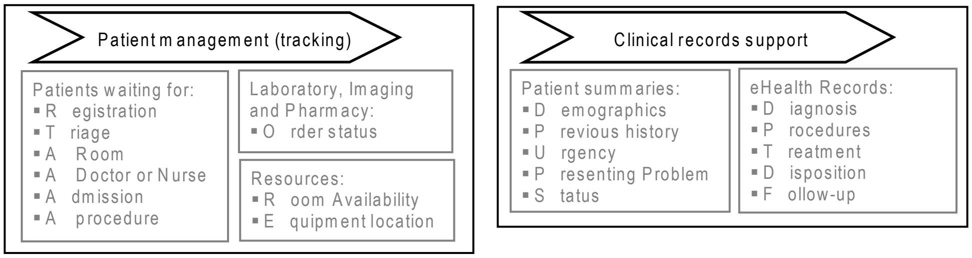
1. what activities are being performed within a process and their interactions (an activity view);
2. what data are relevant as inputs to, or outputs from these activities (data and output views);
3. who performs each activity and where it is performed (an organisational or resource view); and
4. when and how the process activities are being performed (a control view).

Information systems designed for hospital emergency departments (ED), also known as emergency rooms (ER) or accident and emergency departments (A&E), are commonly called emergency department information systems (EDIS). EDIS as they exist today mainly address two aspects of ED operations: (i) providing for tracking of patients and (ii) making patient information available to clinicians and administrators (Figure 1).

The first function, having patient information available online, promotes efficiency of operations through enhanced data entry capabilities, transferability between hospital departments and locations, and potential for bedside update of patient records. Electronic health records have wide reaching implications for EDIS design that are being addressed through various electronic health record initiatives (e.g., OpenEHR in Australia; GEHR in Europe; and HL7 in the USA).

The second function of existing EDIS relates to patient flow management. Most systems provide a list of patients awaiting treatment along with presenting problem, urgency, and disposition. This allows clinicians to select patients for treatment and to see when test results are available. Many systems can provide tracking while patients are in the ED. Patient tracking is passive with the system

Figure 1. Current EDIS deal with patient management retrospectively. There is an absence of information about the pathways future treatment might take and likelihood of patient admission.



reporting the location of patients in an effort to assist with efficient use of resources.

Unfortunately, existing EDIS do not have predictive functions. This limits their capacity to provide prediction of workflow (where patients will go next) and optimisation of throughput (by minimising queues within the system) and resource use (by making sure that resources are aware of the impending need). In this article, we argue that existing EDIS are unable to provide such benefits because every workflow is instantiated with every patient presentation (or "instance"). By this, we mean that the EDIS sees every patient presentation as a unique instance that will follow an undefined sequence of activities and use unknown resources—there are no "template" processes programmed into the EDIS that might be followed, even if the treatment is highly reproducible. In making EDIS "process aware," the system is able to apply process templates to patients and so is capable of predicting the pathway that a patient might follow through the ED, what resources might be required, and what the overall state of the ED might be at any time. Process awareness does not imply only that the system designers considered processes when they specified the system requirements, but rather that the systems allow for explicit definition of the process logic, execution, and monitoring.

If EDIS are going to progress beyond the limitations of existing systems, then work flows need to be defined so that patient instances can be linked to specific treatments. Once this is achieved, it will be possible to build higher level understanding of ED operations. This understanding will allow decision support functions such as prediction of resource need, optimisation of bed use, and warning of impending blockage.

The principles of IS design described in the opening paragraphs clearly indicated that the ability to logically represent the groups of activities that occur in the course of patient treatment within ED through a clear and comprehensive *activity view* constitutes a necessary (although not sufficient) condition for moving EDIS to a process aware basis.

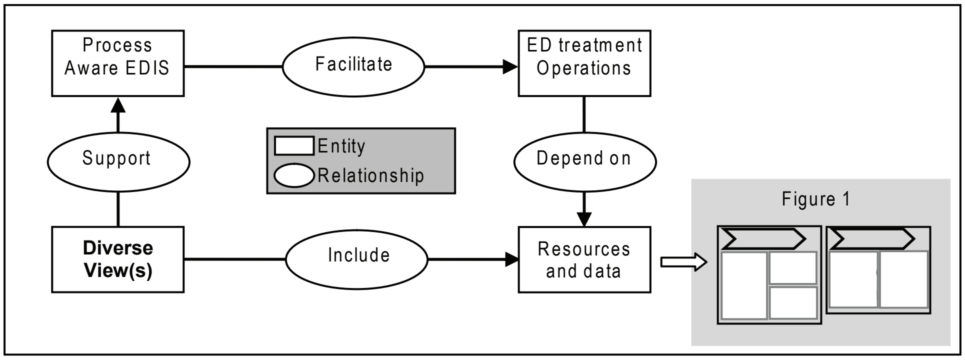
The *objective* of this article is to: (i) describe an activity view that supports the requirements definition of process aware systems and (ii) provide a method for the development of this activity view.

The search for clusters of activities within existing ED patient data records represents a new middle ground between "soft" (or ethnographic) methods for the elicitation of process models (Bustard, Oakes, & He, 1999) and "hard" methods such as workflow (or process) mining (Business Process Management Center, 2003) that arrive directly at process models from data analysis. The article's contribution to practice lies in the potential to design process aware EDIS since the activity view developed in this article fits with standard IS design methodologies. The formulation in this article of an activity view for EDIS design is new because of the lack of existing of comprehensive process models for patient treatment in EDs (Djorhan & Churilov, 2003).

Background: Context and Motivation for Process Aware EDIS

EDIS focus on patient management and data retrieval and storage (Amouh, Gemo, Macq, et al., 2005). Patient management aspects of EDIS have functions that prioritise patients according to their urgency, allocate beds and rooms, and register occurrence of key events such as nurse and doctor assessments and patient departure. EDIS data management revolves around the transport and storage of electronic patient records and the ordering and reporting of pathology tests and imaging investigations. Supplementary hardware such as wireless devices can track patients and enhance the gathering of data for both patient and data management (Amouh et al., 2005). The systems do not forecast patient flow and resource use, nor do they facilitate exchange of information with outside organisations. EDIS functionality

Figure 2. Process aware EDIS are supported by diverse views: organisational, data, control, activity and output views. Existing EDIS tend to be derived solely from listings organisational (resource) and data views and so are only able to encompass a part of ED operations.



supports resource allocation and patient selection for treatment based on priority (Aronsky, Jones, Lanaghan et al., 2007, gives an example of this), but it fails to coordinate patient movement and patient treatment (for instance, there is no tracking of patients sent for X-rays, estimation of the time they will take at the X-ray location, nor booking of space at the next resource, such as the plaster cast room, that they might require once their X-rays have been assessed.).

An extreme view of an “ideal” process aware EDIS would be one that is able to incorporate every step in patient care in which human hand-offs are automated, each step in patient treatment automatically logged and tracked, and timing and sequencing of steps analysed for performance evaluation. Human interactions with networked electronic devices such as personal computers, CT scanners, lab systems, telephones, IV pumps, and wireless patient tracking tags would be linked to the EDIS for automation of process control. Order entering by physicians, bar-coding of medication by nurses, patient registration by clerks, and surgery scheduling for surgeons should be linked and coordinated automatically. Overall, the EDIS should be able to sequence, monitor, track, alert, and reroute any step in each of the patient care processes (Rucker, 2003).

This extreme view, while attractive to proponents of workflow systems (systems that automatically direct work throughout a process), is unlikely to be achieved in the real world. The ED environment is simply too complex, too many decisions need to be made by clinicians based on patient observations that are impossible to include in any IS, and patient variation is too vast to be included in a single configurable workflow. However, this extreme view can guide thinking towards EDIS that support real processes and provide avenues for decision support while remaining sufficiently flexible to sustain the unique treatment needs of individual patients. This is impossible without understanding the interaction of activities involved in the processes, as depicted in the explicit process aware EDIS/activity view relationship presented in Figure 2.

Thus, *the research problem* addressed in this article is to how to elicit an activities view for an EDIS. The following sections will discuss (i) the methods available for elicitation of activity views and (ii) the work that has been done to group ED treatment processes.

THE ELICITATION OF ACTIVITY VIEWS AND VIEWS OF ED ACTIVITIES

Activity View Elicitation

The most common way in which activities are elicited is through interviews with experts and people who perform the work (Earl, 1994; Kotonya & Sommerville, 1998; Weerakkody & Currie, 2003). This is frequently termed an *ethnographic approach* (Schuler & Namioka, 1993). As a technique for building the Activity View, it is prone to subjective views of the work that may be distorted according to social dynamics unrelated to the work (Rennecker, 2004) and may encounter situations where the interviewees are unable to provide generalized pictures of the work (Gospodarevskaya, Churilov, & Wallace, 2005). EDs appear to fall into the latter class.

Process mining (van der Aalst et al., 2003) is a purely computational technique that is able to extract feasible "as is" process models directly from workflow data without resorting to interviews. It has its roots in a data mining idea that associations between variables in a relation can be counted and granted some level of confidence (Agrawal, Imielinski, & Swami, 1993). Combination of this concept with inference algorithms (Angluin & Smith, 1983) provided a way in which time-series data could be mined (Cook & Wolf, 1998) to retrospectively build a picture of sequences of events in software (Agrawal, Gunopulos, & Leymann, 1998). This idea has been extended so that the branches, loops, and joins common in most processes may be inferred from event logs (de Medeiros, van der Aalst, & Weijters, 2003).

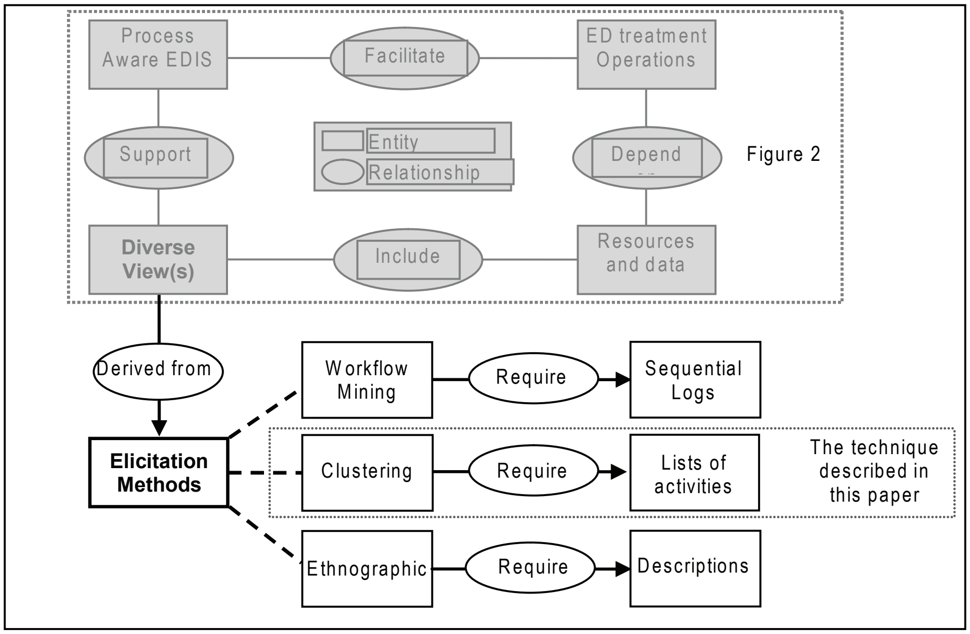
Process mining requires access to a log that records the sequence of defined tasks in workflow for a large number of cases. Such data is readily accessible for most work that takes place within or on computer systems, as evidenced by business activity management software tools for the analysis of logged data such as ARIS-Process Performance Manager (IDS-Scheer, 2004). Process mining provides an excellent solution to process elucidation in situations where workflow is fully automated ("mature" information system applications) but little process elicitation help is available for less mature "case handling" applications where process is undefined or much of the work is performed by an expert who initiates activities based on the particulars of each job (van der Aalst et al., 2003).

Detailed event logs are seldom available for activities that take place outside computer systems. Fortunately, "computer external" activities are often logged in databases for billing and other purposes. Such information may be captured in batches after the activities have been completed but lack information about sequence or timing of events. The existence of these nonsequential "activity logs" provides an avenue for the identification of patterns of activity. Activity logs of this sort are commonly associated with ill-defined processes where experts make complex decisions while performing the work (such as hospital EDs). The binary "event" logs do not have the detail necessary for process mining and the mere volume of data is likely to make the logs inscrutable to traditional data analysis techniques (past efforts in this regard are discussed in the next section), but they do provide an avenue for the identification of patterns of activity if non-traditional methods are used. The use of these logs in clustering of activities falls between the "soft" ethnographic and "hard" process mining that were introduced above (depicted in Figure 3). The clustering "compromise" approach will be described later in this article, but it is first necessary to describe existing views of ED activities in order show to current understanding of ED processes.

Existing Views of ED Activities

There are well over a thousand diagnoses listed in the Victorian Emergency Data Set guidelines

Figure 3. An extension of Figure 2, showing that elicitation is achieved through social and technical elicitation extremes. The middle ground is explored in this paper.



(2007), and many other governments have a similar proliferation of diagnoses. It is not feasible to incorporate separate activity views for every one of these diagnoses in a requirements definition because this will probably lead to a situation where overhead costs for the control systems surpass the benefit of efficient coordination of every variant (Becker, Kugeler, & Rosemann, 2003). Simplification is necessary to reduce the large number of diagnoses and permutations of treatment to a number suitable for cost effective implementation in an IS. Some grouping of the activities involved in patient treatment is needed in order to reduce the complexity of the requirements definition. Without this grouping, it is difficult to conceive systems that can indicate what the next step in patient care may be, where it should take place, and who should be responsible for it.

Groupings and simplifications have been attempted many times in the past. Analysts have used output data such as "the time treatment takes," and input data such as "the complexity of presentation" to group patients (for example, Hoffenberg, Hill, & Houry, 2001; Walley, 2003). These approaches address the activities related to patient movement (whether patients are likely to be admitted to hospital or not, or whether they may be treated in a chair, rather than a bed, for example) but not the detailed activities involved in patient treatment.

Patient movements have been analysed in simulation studies (Brailsford, Churilov, & Liew, 2003; Mahapatra, Koelling, Patvivatsiri et al., 2003; Sinreich & Marmor, 2004), but the models, in keeping with the philosophy of discrete event simulation, tend to imitate the physical movement of patients through the ED, rather than the treatment provided to patients. The studies result in recommendations on how to reduce wait or facilitate throughput but they fail to provide insight into the management of patients in accord with their treatment requirements.

Clinicians have tried to get a simplified picture of ED operations by grouping patient "cases," characteristically according to combinations of age, urgency of complaint, diagnosis, time in

ED, and outcome of visit linked to cost (Bond, Baggoley, Erwich-Nijhout et al., 1998; Cameron, Baraff, & Sekhon, 1990; Jelinek, 1995). These clinical classification schemes have failed to group patients by similarity of treatment because they have used the use of cost as an objective function. Low and high cost attributes trade off, so dissimilar patients end up in similar groups.

Clinical guidelines (Clinical Pathways) exist that detail every aspect of patient treatment and act as checklists for common chronic ailments (for example, the Action plan for anaphylaxis available at http://www.medicalobserver.com.au/clinicalguidelines. Porter, Cai, Gribbons et al. (2004) provide an example of decision support for a single treatment). Clinical Pathways provide a notion of a sequence of prescribed activities involved in patient treatment that would be ideal for a process aware EDIS. Unfortunately, they only cover a small number of narrow treatments so they do not provide the variety of ED treatments that would need to be included for predictive decision support. A different approach is needed to unravel the complexity of patient treatment in EDs. Such an approach is described in the following sections.

METHOD DESCRIPTION: FROM CLINICAL PROCEDURES TO AN ACTIVITY VIEW FOR A PROCESS AWARE EDIS

Mertins et al. (1998) suggest that it is possible to build information systems from a subset of the organisational, data, control, activity, and output views (defined as aspects of process models in the Introduction). This approach is apparent in the design of most existing EDIS, where the data and organisational views are well represented (for exampl, the linking of Figure 1 to the resources and data component in Figure 2), but the activity view is less well represented or not present at all (Rucker, 2003). The resulting EDIS' cannot be process aware because treatment activities have not been functionally related in the activity view, treatment objectives are not available for the processes, and supporting applications (bedside monitoring, for instance) cannot be integrated into the process. Elucidation of the activity view is necessary to allow coordination of the resources, communication, and technology associated with treatment.

Since the activity view is, in its simplest form, a collection of objects such as activities, objectives, and software applications, clinical procedures that are manually recorded (as described at the end of the previous section) may be used to provide a library of activities. Even though there is a wide range of patients and presentations, much of the patient treatment related work in EDs is based on application of a short list of medical procedures such as patient observation, administration of drugs, and laboratory and imaging investigations. Just 62 procedures are used for reporting ED treatment in Victoria, Australia (Metropolitan Health and Aged Care Services Division of the Victorian State Government, 2007). Thirty six procedures account for 99% of all procedures in Victorian hospitals. Almost 17% are classed as "Other," which includes observation of patients by medical staff; 6% are "No procedures"; some 10% are drug administrationl; and over 9% X-ray imaging. Other significant procedures are venipuncture, intravenous catheter access in preparation for infusion of fluid or drugs, and echocardiogram diagnostics (figures derived from Victorian Emergency Medical database for 2002).

An activity view that simply lists all these procedures would result in processes models based on a vast number of possible permutations of causal linkages between all procedures. Individual procedures could have associated objectives but it would be difficult to understand how the objectives were related to each other. Some form of simplification is necessary to advance the activity view beyond this primitive.

The grouping of procedures into treatment specific clusters is a way of providing this simplification—procedures are logically linked as activities within treatments. While the grouping of activities in this way does not provide a true process view (the activities are not sequenced), it significantly reduces the number of permutations in order to provide a simplified view of ED operations. It is this simplified view that has eluded designers of ED information systems up to now. Each group of activities, or treatment cluster, may be scrutinised to determine the most likely (or most desirable) sequence of activities.

The grouping of procedures for this activity view may be achieved through nonparametric clustering. One nonparametric technique is self organising mapping (SOM) (Kohonen, 1995). The SOM is a grouping technique that is algorithm driven and relies on data rather than domain-specific expertise. The objectives of the technique are to minimise diversity within groups and to maximise differences between groups. The technique generally employs large datasets, works well with many input variables, and produces arbitrarily complex models unlimited by human comprehension (Kennedy, Lee, Van Roy et al., 1998).

Self organising maps provide a visual understanding of patterns in data through a two dimensional representation of all variables. Records that have similar characteristics are adjacent in the map, and dissimilar records are situated at a distance determined by degree of dissimilarity. Viscovery SOMine, the software tool used in this analysis, employs a variant of Kohonen's Batch-SOM (Kohonen, 1995), enhanced with a scaling technique for speeding up the learning process (Eudaptics Software Gmbh, 1999).

The concept of providing a simplified activity view of treatment through the grouping of procedures is illustrated in the next section.

VALIDATION THROUGH EXAMPLE: CLUSTERING CLINICAL PROCEDURES TO BUILD AN ACTIVITY VIEW

Victorian Emergency Medical Data (VEMD) made up of de-identified records of all ED presentations across 31 anonymous hospital campuses was obtained and five similar-sized campuses (by number of records) were selected for analysis and comparison. Each record contained demographic particulars and details of the visit such as "apparent severity of complaint," "key time points," and "disposition," plus all medical procedures performed, but cost data was not available.

All cases where patients underwent more than one procedure were included for analysis. This was generally around 60% of all patient presentations. The 13 least-used procedures were omitted from the analyses, as was the "NONE" procedure. These exclusions totalled less than 1% of procedures in cases where patients had more than one procedure. Random samples of approximately 10,000 cases having Departure Status "Discharged home" were extracted. Where there were less than 10,000 cases with this departure status at a campus, all cases were included for analysis.

The data was saved into a tab delimited format. Each record had 50 fields—a record identifier and 49 procedures coded as "0" for "not performed" to 1,2,3...16 for repeated applications. The procedure data was sparse, but the number of records gave some assurance that patterns of recurring groups of procedures could be found. Self organising mapping was applied to the data using the same clustering settings. These settings included:

- The initial map height that gave the initial number of vertical nodes in the two dimensional representation of the data (the number of horizontal nodes was automatically set from the map ratio);

- A scaling factor that specified the increase in horizontal number of nodes as the clustering algorithm progressed through each growth step (the vertical number of nodes was adjusted according to the desired map ratio);
- The influence radius of the neighbourhood interaction of the intermediate maps (the reach of the Gaussian neighbourhood function). A high intermediate tension "averages" the data distribution, while a low tension allows adaptation to display finer features.
- The number of iterations and the Wegstein factor (a convergence parameter in the batch SOM algorithm comparable to the momentum factor as it is commonly used in supervised neural network algorithms).

Between 13 and 27 clusters were identified across the five data sets. The clusters were validated through a range of internal measures of cluster quality. These measures were analogous to traditional indicators of cluster quality such as the Rand Statistic, Jaccard Coefficient, and the Folkes and Mallows Index; however, they operated on two dimensions, rather than the single figure of the traditional measures. Maps that displayed the frequency of records across two dimensional cluster space, the quantisation error, the proximity of nodes to neighbours, and curvature of the map through n-dimensional space were scrutinised to ensure that the spread of clusters was even, the clustering error within reasonable limits, and the cluster shapes regular.

This clustering of procedures into prototype "workflows" was verified through discussions with a specialist in emergency medicine and found to be clinically sensible. It was concluded that the clusters reflected "as is" core ED treatments. Similar sets of procedures were apparent in clusters across campuses. Typical prototype workflows that were common across multiple campuses are (figures in brackets indicate likelihood of procedure):

- 12 Lead ECG (1.0), with Peripheral IV catheter and Venipuncture (0.6);
- 12 Lead ECG and ECG monitoring (1.0), with Venipuncture (0.9);
- Peripheral IV catheter and IV drug infusion (1.0), with Venipuncture (0.7);
- Suture, Steri-strip, glue (1.0) with Dressing (between 0.6 and 0.9);
- Plaster of Paris (1.0) and X-ray (0.9) with Drug administration (around 0.5);
- Splint (1.0), X-Ray (0.8) with Drug administration (between 0.2 and 0.6);

These clusters each comprise between 2% and 9% of patients and add up to between 20% and 30% of patients. In addition to these widespread clusters, there are typically two to three large clusters at each campus that provide for some 25% of presentations. These large clusters often include drug administration, venipuncture and full ward test (urine) or 12 Lead ECG, but the proportions differ between campuses. It is important to note that these clusters represent "core treatment" activities within the EDs. These treatments employ resources most frequently

The truncated example in Table 1 indicates that the patient was likely to be experiencing breathing difficulties (possibly an asthma attack) and might have been classed as urgent or nonurgent (note that this is in direct contrast to previous studies, which have segmented patients by urgency—a patient movement, rather than patient treatment orientation). Nebulised medication was provided to all patients. This treatment was supported with X-rays, drugs, venipuncture, electrocardiogram, peripheral intravenous catheter, and full ward tests. Two campuses also indicated that intravenous injections were commonly recorded in this group. The numbers in Table 1 may be considered to represent the likelihood between 0 and 1 of patients in that cluster undergoing the procedure.

In the example given in Table 2, it can be seen that there is much agreement across campuses re-

Table 1. Nebulised medication procedures across three hospital campuses, A, B, and C

	Campus	**A**	**B**	**C**
Procedure Description	% Patients	2.9%	2.4%	3.6%
Nebulised Medication	NEB	1.00	1.00	1.00
X-ray	XRAY	0.43	0.26	0.47
Oral/ sublingual/ topical/ rectal drug administration	DRUG	0.81	0.89	0.80
Venipuncture	VB	0.28	0.21	0.29
12 Lead ECG	ECG	0.16	0.14	0.15
Peripheral intravenous catheter (IV access)	IV	0.28	0.22	0.24
Full ward test - urine	FWT	0.06	0.09	0.06
Intravenous infusion	IVS	0.13		0.12

garding the reporting of "head injury observation" (HIO), despite the varying percentage of patients (second column of the table). The campus in the last row displays anomalous random blood glucose (RBG) and Spirometry (SPR) that may indicate different patient and treatment profiles.

Similar studies were carried out for admitted as well as discharged patients and core treatments identified that overlapped the above and expanded to reflect the treatment accorded to patients who were later admitted to hospital. The studies were reinforced with text mining exercises that compared patient reason for presentation with their treatment and through simulation of treatment activities. It was also found that the nonexclusive nature of the core treatments (i.e., one procedure might be used in multiple core treatments) that arose for the clustering technique made the technique far superior (in defining treatments that were clinically realistic) to other methods that were attempted such as association mining and CART.

This section set out to describe the realisation of the idea that a simplified activities view could be developed if procedures involved in patient treatment were clustered into process-oriented groups. Distinct clusters of procedures were identified in the treatment of patients at a number of EDs. The grouping was validated and verified and considered a reasonable "as is" simplification of ED activities into core treatments (Ceglowski, Churilov, & Wassertheil, 2007, describes simulation of ED operations based on treatment clusters). The implications of these findings are discussed in the next section.

DISCUSSION: HOW CLUSTERED ACTIVITIES SUPPORT SYSTEMS DESIGN

In providing core treatments, the previous section has expanded the simple activity view of individual procedures to one with grouped procedures in a handful of frequently applied core treatments. The simplification reduced the number of objects from 62 procedures to around 20 core treatments. This reduction in complexity facilitates the association of activities with other aspects of the activities view such as process goals because each core treatment represents a process-oriented class of treatment.

The primary benefit of identifying prototype workflows and linking them to patient attributes has been the potential for predictive decision support. Certain core treatments take longer than others take and have a higher rate of hospital admission associated with them. When many patients requiring such long duration treatments reside in the ED concurrently, then throughput slows and

Table 2. Head injury observation across five campuses

Campus	% Patients	HIO	XRAY	IV	IVI	VB	DRS	SUT	ECG	FWT	INF	DRUG	CT	IVS	RBG	SPR
A	2.3%	1.0	0.4	0.5	0.0	0.4	0.1	0.1	0.3	0.2	0.2	0.5	0.1	0.3	0.2	0.0
B	0.9%	1.0	0.4	0.4	0.1	0.3	0.2	0.2	0.1	0.3	0.1	0.5	0.1	0.2	0.1	0.0
C	4.2%	1.0	0.5	0.4	0.0	0.5	0.1	0.0	0.4	0.1	0.2	0.6	0.2	0.2	0.0	0.0
D	3.4%	1.0	0.3	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
E	0.6%	1.0	0.4	0.3	0.0	0.4	0.2	0.1	0.3	0.3	0.1	0.4	0.2	0.1	0.5	0.5

Key: HIO = Head Injury Observation; XRAY = X-ray examination; IV = Peripheral intravenous catheter; IVI =IV drug infusion; VB = Venipuncture; DRS = Dressing; SUT = Suture, sterstrip, glue; ECG = 12 lead Electrocardiogram; FWT = Full Ward Test of urine; INF = Infusion of fluid (not blood); DRUG = Oral, sublingual, topical, rectal drug administration; CT = Computerised tomography scan; IVS = Intravenous drip; RBG = Test of Random Blood Glucose; SPR = Spirometry

the ED becomes prone to blockage—regardless of its capacity. By linking patient presentation to core treatments and the time they take, it is possible to update prediction of potential blockage as each new patient presents at the ED.

An extension of this high level prediction is the potential for prediction of future workflow requirements. Having patient presentation linked to their most likely future treatment allows their future workflow to be mapped and planned for, so handoffs can be identified, responsibilities indicated, and resources specified. In this way the organisational, data, and output views may be linked to core treatments.

The core treatments add knowledge about common treatment activities that can be further explored using various techniques, such as ethnographic studies or additional data investigations. The control view can be structured once sequencing and mapping of cause-effect linkages has been done (possibly through expert clinical input) because the roles and responsibilities may be identified and linked to each activity within the treatment. This moves EDIS towards process aware systems that can not only coordinate patient treatment and movement, but predict them, too.

The clustering technique may further be extended through use of techniques such as association mining to provide more detailed segmentations of the groups and better understanding of the business rules, especially if the data is linked to attributes such as urgency, age, and whether the patient was admitted or not. The insights provided by such investigations give rise to another, more refined, activity view where patient attributes may be causally linked to treatment activities, making prediction of patient routings feasible.

CONCLUSION

This article indicated that existing EDIS suffer from inadequate understanding of patient treatment processes that manifest as EDIS that are unable to predict future patient treatment and patient movement needs. It was noted that development of an activities view would assist movement towards process aware, predictive EDIS. A suggestion was made that clinical procedures recorded for other purposes could be used to populate the activity view, but simplification was necessary in order to reduce the number of possible process models that could be deduced. A method for simplification was described that resulted in procedures being grouped in clinically acceptable core treatments that covered 99% of ED treatment operations.

The utility of these core treatments in providing an activity view was discussed.

This article has described a route to take existing EDIS (which deal primarily with the management of historic data such as patient records and the queue of patients awaiting treatment) to event-based systems that can "look forward" to predict what pathways patients might take through the ED. EDIS that are capable of managing workflows (predicting the work to be performed at each successive stage of treatment) facilitate:

- Logistics management, by "booking" resources for when patients will need them;
- Predictive reporting, by linking presentation problem and severity with likely length of stay, probably treatment, and whether a patient might be admitted to a ward; and
- Management decision support, through the ability to assimilate the status of patients in the ED with the new presentations awaiting treatment.

Clustering represents an additional tool in the elicitation of process models for EDIS design. It is one that is not limited in breadth in the way that ethnographic studies often have to be—all history (as it exists) can be included in the analysis. Nor does clustering have the requirement of workflow mining that detailed logs exist—simple activity records will suffice to provide a working activities view to supplement existing organisational, data, and input views for EDIS design. Transforming such a supplementation into a truly integrated process aware EDIS design presents a challenging direction for future research.

REFERENCES

Agrawal, R., Gunopulos, D., & Leymann, F. (1998). Mining process models from workflow logs. In *Sixth International Conference on Extending Database Technology,* Valencia, Spain.

Agrawal, R., Imielinski, T., & Swami, A. (1993). Mining association rules between sets of items in large databases. In *ACM SIGMOD Conference on Management of Data*, Washington, DC.

Amouh, T., Gemo, M., Macq, B., et al. (2005). Versatile clinical information system design for emergency departments. *IEEE Transactions on Information Technology in Biomedicine, 9*(2), 174-183.

Angluin, D., & Smith, C.H. (1983). Inductive inference: Theory and methods. *Computing Surveys, 15*(3), 237-269.

Aronsky, D., Jones, I., Lanaghan, K., et al. (2007). Supporting patient care in the emergency department with a computerized whiteboard system. *Journal of the American Medical Informatics Association*.

Becker, J., Kugeler, M., & Rosemann, M. (2003). *Process management: A guide for the design of business processes*. Berlin, Heidelberg, New York: Springer.

Bond, M., Baggoley, C., Erwich-Nijhout, M., et al. (1998). Urgency, disposition and age groups: A casemix model for emergency departments. *Emergency Medicine Australasia, 10*(2), 103-110.

Brailsford, S., Churilov, L., & Liew, S.K. (2003). Treating ailing emergency departments with simulation: An integrated perspective. In *International Conference on Health Sciences Simulation.* Orlando, FL: The Society for Modeling and Simulation International.

Business Process Management (BPM) Center. (2003). *Process mining.* Retrieved May 24, 2008, from http://tmitwww.tm.tue.nl/research/processmining/

Bustard, D., Oakes, W.R., & He, Z. (1999). Models to promote effective system change. In *IEEE International Conference on Software Maintenance* (ICSM '99).

Cameron, J., Baraff, L., & Sekhon, R. (1990). Case-mix classification for emergency departments. *Medical Care, 28,* 146-158.

Ceglowski, A., Churilov, L., & Wassertheil, J. (2007). Combining data mining and discrete event simulation for a value-added view of a hospital emergency department. *Journal of the Operational Research Society, 58*(2), 246-254.

Cook, J.E., & Wolf, A.L. (1998). Discovering models of software processes from event-based data. *ACM Transactions on Software Engineering and Methodology, 7*(3), 215-249.

de Medeiros, A.K.A., van der Aalst, W.M.P., & Weijters, A.J.M.M. (2003). Workflow mining: Current status and future directions. In R. Meersman, Z. Tari, & D.C. Schmidt (Eds.), *On the move to meaningful Internet systems 2003: CoopIS, DOA, and ODBASE* (pp. 389-406). Berlin, Heidelberg: Springer-Verlag.

Djorhan, V., & Churilov, L. (2003). Business interactions in an acute emergency department in Australia: A clinical process modeling perspective. In *the 6th Pacific Asia Conference on Information Systems (PACIS 2002).* Tokyo, Japan: The Japan Society for Management Information (JASMIN).

Dumas, M., van der Aalst, W., & ter Hofstede, A. (2005). *Process-aware information systems: Bridging people and software through process technology*. Hoboken, NJ: Wiley-Interscience.

Earl, M.J. (1994). The new and the old of business process redesign. *The Journal of Strategic Information Systems, 3*(1), 5-22.

Eudaptics Software Gmbh. (1999). *Viscovery SOMine.* Wien: Eudaptics Software Gmbh.

Gospodarevskaya, E., Churilov, L., & Wallace, L. (2005). *Modeling the patient care process of an acute care ward in a public hospital: A methodological perspective*. Hawaii: HICSS.

Hoffenberg, S., Hill, M.B., & Houry, D. (2001). Does sharing process differences reduce patient length of stay in the emergency department? *Annals of Emergency Medicine, 38*(5), 533-540.

IDS-Scheer. (2004). ARIS process performance manager. Retrieved May 24, 2008, from http://www.ids-scheer.com

Jelinek, G.A. (1995). *Casemix classification of patients attending hospital emergency departments in Perth, Western Australia: Development and evaluation of an urgency-based casemix system.* Perth, Australia: University of Western Australia.

Kennedy, R., Lee, Y., Van Roy, B., et al. (1998). *Solving data mining problems through pattern recognition*. Prentice Hall.

Kohonen, T. (1995). *Self-organizing maps*. Berlin, Germany: Springer.

Kotonya, G., & Sommerville, I. (1998). *Requirements engineering: Processes and techniques*. New York: John Wiley.

Langer, A.M. (2008). Analysis and design of information systems. London: Springer (pp. 418; p. 249 illus.).

Mahapatra, S., Koelling, C.P., Patvivatsiri, L., et al. (2003). Pairing emergency severity index 5-level triage data with computer aided system design to improve emergency department access and throughput. In *The 2003 Winter Simulation Conference.* New Orleans, LA: INFORMS.

Mertins, K., Bernus, P., & Schmidt, G. (1998). *Handbook on architectures of information systems*. Berlin, Germany: Springer.

Metropolitan Health and Aged Care Services Division of the Victorian State Government. (2007). Victorian emergency minimum dataset (VEMD). Retrieved May 24, 2008, from http://www.health.vic.gov.au/hdss/vemd/2004-05/manual/index.htm

Porter, S.C., Cai, Z., Gribbons, W., et al. (2004). The asthma kiosk: A patient-centered technology for collaborative decision support in the emergency department. *Journal of the American Medical Informatics Association, 11,* 458-467.

Poulymenopoulou, M., Malamateniou, F., & Vassilacopoulos, G. (2003). Specifying workflow process requirements for an emergency medical service. *Journal of Medical Systems, 27*(4), 325-335.

Rennecker, J. (2004). Updating ethnography to investigate contemporary organisational forms. In M.E. Whitman & A.B. Woszczynski (Eds.), *The handbook of information systems research* (pp. xi, 349). Hershey, PA: IGI Global.

Rozinat, A., & van der Aalst, W.M.P. (2008). Conformance checking of processes based on monitoring real behavior. *Information Systems Frontiers, 33*(1), 64-95.

Rucker, D. (2003). *Finally, a tool to re-engineer health care: The workflow engine*. San Francisco, CA: Montgomery Research, Inc.

Scheer, A.W. (1999). *Business process frameworks*. Berlin, Germany: Springer.

Schuler, D., & Namioka, A. (1993). *Participatory design: Principles and practices*. Hillsdale, NJ: L. Erlbaum Associates.

Seltsikas, P. (2001). Organizing the information management process in process-based organizations. In *34th Hawaii Int. Conf. Syst. Sci.,* Hawaii.

Sinreich, D., & Marmor, Y. (2004). A STAFFING emergency. *Industrial Engineering, 36*(6).

van der Aalst, W.M.P., ter Hofstede, A.H.M., & Weske, M. (2003). Business process management: A survey. In *Business Process Management (BPM2003)* (pp. 1-12). Berlin, Germany: Springer-Verlag.

van der Aalst, W.M.P., van Dongena, B.F., Herbst, J., et al. (2003). Workflow mining: A survey of issues and approaches. *Data & Knowledge Engineering, 47*(2), 237-267.

Walley, P. (2003). Designing the accident and emergency system: Lessons from manufacturing. *Emerg Med J, 20*(2), 126-130.

Weerakkody, V., & Currie, W. (2003). Integrating business process reengineering with information systems development: Issues and implications. In W.M.P. van der Aalst, A. H.M. ter Hofstede, & M. Weske (Eds.), *Business process management (BPM2003)* (pp. 302-320). Berlin, Germany: Springer-Verlag.

This work was previously published in International Journal of Healthcare Information Systems and Informatics, Vol. 3, Issue 4, edited by J. Tan, pp. 1-16, copyright 2008 by IGI Publishing (an imprint of IGI Global).

Chapter 7.14

Predicting Voluntary Participation in a Public Health Program Using a Neural Network

George E. Heilman
Winston-Salem State University, USA

Monica Cain
Winston-Salem State University, USA

Russell S. Morton
Winston-Salem State University, USA

ABSTRACT

Researchers increasingly use Artificial Neural Networks (ANNs) to predict outcomes across a broad range of applications. They frequently find the predictive power of ANNs to be as good as or better than conventional discrete choice models. This article demonstrates the use of an ANN to model a consumer's choice to participate in North Carolina's Maternity Care Coordination (MCC) program, a state sponsored voluntary public health service initiative. Maternal and infant Medicaid claims data and birth certificate data were collected for 59,999 births in North Carolina during the years 2000-2002. Part of this sample was used to train and test an ANN that predicts voluntary enrollment in MCC. When tested against a hold-out production sample, the ANN model correctly predicted 99.69% of those choosing to participate and 100% of those choosing not to participate in the MCC program.

INTRODUCTION

Information technology (IT) plays a pervasive role throughout the health care industry. In addition to providing the data storage and data processing capabilities needed to support the business management, customer relations management, human resource management and office automations requirements of health care organizations, IT also is used increasingly to support decision making functions.

Most decision support methodologies rely on the mathematical modeling of historical data. Many of these systems, such as the widely accepted Acute Physiology and Chronic Health Evaluation (APACHE) system, are based on binary LOGIT regression estimations or other statistical analysis techniques. This type of modeling requires the specification of *a priori* functional relationships between dependent and independent variables based on assumptions such as correct model specification, error-free measurement of independent variables, and normally distributed, heteroscedastistic, independent, zero-mean residuals. It is more likely, however, that health care decisions will depend on a variety of factors involving complex, hidden interrelationships of both socio-demographic and health related characteristics.

To address issues of nonlinearity and complex relationships in study data, many modelers have turned to other methods of analysis that fall under the broader categorization of "artificial intelligence" (AI). AI, which attempts to give computers human-like reasoning capabilities, includes techniques such at expert systems, fuzzy systems, genetic algorithms, case-based reasoning and a variety of classifier systems like the Artificial Neural Network (ANN) used in this study.

Because of advantages like ease of optimization, prediction accuracy, easy knowledge dissemination, workload reduction and decision support, Artificial Neural Networks have been widely accepted and used for more than a decade in the health care arena (Lisboa & Taktak, 2006). When used in medical applications, ANNs are known to provide decision support assistance that can produce highly accurate results (Kaur & Wasan, 2006). Several studies show ANNs offering better predictive performance than other modeling alternatives (Alkan, Koklukaya, & Subasi, 2005; Alpsan, Towsey, Ozdamar, Tsoi, & Ghista, 1995; Goss & Vozikis, 2002). Examples of medical applications of an ANN include the analysis of trauma data (Chesney et al., 2006; Eftekhar et al., 2005) and the diagnoses of cancer (Lisboa & Taktak, 2006), diabetes (Kuar & Wasan, 2006), gastrointestinal hemorrhage (Das et al., 2003), and myocardial infarction (Baxt, 1991; Baxt, Shofer, Sites, & Hllander, 2002).

While medical diagnosis is probably the most common health care application for Artificial Neural Networks, they also have been used successfully in other health care service areas. Examples include identifying individuals at risk for high medical costs (Crawford, Fuhr, Clarke, Hubbs, 2005), identifying sources of future high cost treatments within a given health plan population (Kudyba, Hamar, & Gandy, 2006), evaluating if patient debt is likely to be repaid (Zurada & Lonial, 2005), and predicting nursing staff levels (Seomun, Chang, Lee, Kim, & Park, 2006).

ANNs are generally well accepted and frequently used in the health care industry, but one sector that does not seem to have taken advantage of this technology is public health care services. While facing the expected pressures for professionalism and quality service, public health care also faces the additional burdens of budgetary restrictions and legislative oversight. As a result, public health care, like other sectors of health care, is intensifying its focus on the enhancement of operating efficiency through effective resource allocation. One way to enhance efficiency is to more accurately identify resource demands. Because Artificial Neural Networks excel at identifying relationships in historical data for purposes of classification and prediction, it follows that using an ANN to predict participation in a public health program should improve predictive capability, reduce inefficient resource allocation, and decrease variability in treatment processes (Kudyba et al., 2006). North Carolina's Maternity Care Coordination (MCC) program represents one such public health care initiative.

The Maternity Care Coordination program attempts to coordinate prenatal care for eligible Medicaid clients. MCC provides counseling, referrals, and resource assistance for women considered to be at high risk for poor birth outcomes. Participation in the program, however, is voluntary. The goal of this study is to develop an artificial neural network that can predict Medicaid women's voluntary enrollment in the MCC program.

MATERNITY CARE COORDINATION: ENHANCING PRENATAL CARE

States have attempted to address the issue of poor neonatal outcomes by incorporating comprehensive, coordinated prenatal care programs into their Medicaid plans. These prenatal care programs are enhanced beyond the scope of the traditional medical model to include services such as health education, psychosocial risk assessment, enrollment in WIC (the Special Supplemental Food Program for Women, Infants, and Children), and other types of health promotion interventions. Unfortunately, attempts to evaluate the effectiveness of comprehensive prenatal care coordination have had mixed results (Buescher, Roth, & Williams, 1991; Clarke, Miller, & Mahan, 1993; Herman & Berendes, 1996; Korenbrot, Gill, & Patterson, 1995; Nason & Alexander, 2002; Schulman, Sheriff, & Momany, 1997).

The North Carolina Maternity Care Coordination program (MCC) is an example of an early prenatal care coordination program, and is the focus of this study. MCC has the objective of reducing barriers to Medicaid clients' use of health and social services. The program is geared toward helping eligible women receive nutritional care, psychosocial counseling, and other resource assistance. For example, women in MCC are encouraged to seek eligible services such as transportation, housing assistance, and job training. Counseling may include social and emotional support, stress reduction methods, and coaching in healthy behaviors. Referral for WIC enrollment is emphasized, and most women enrolled in MCC receive nutritional counseling through WIC (Buescher & Horton, 2002).

Medicaid women who are perceived to be at very high risk for a poor birth outcome are most likely to be referred to the MCC program by their physician. Participation in MCC is, however, voluntary and thus at the discretion of the Medicaid-enrolled woman. If she chooses to participate in MCC, she will have access to expanded prenatal care; if she chooses not to participate, she will receive the standard package of care available through the state's Medicaid program.

Various observable maternal medical and socioeconomic risks may influence a pregnant woman's decision to participate in an enhanced prenatal care program and may even be the same risk factors that prompted the health care provider to recommend the program in the first place. In actuality, however, it may be the unobserved relationships among these factors that influence her final decision to participate in an enhanced prenatal care program.

A variety of complex, hidden personal factors may not be reflected in the medical or intake records. These may include health or domestic issues that the woman is not willing to reveal or able to discern. For example, a woman at higher risk for a poor birth outcome may be facing stressors in the local environment such as violence, use of alcohol or illicit drug activity in the community. These factors may influence her choice to participate, even while remaining unobserved by the health care provider. In this study we test whether neural network learning is able to model complex nonlinear patterns between the predictor variables and the choice to participate in MCC.

STUDY DATA

This study uses data developed by the North Carolina State Center for Health Statistics (SCHS) called the Composite Linked Birth File. The Composite Linked Birth File is comprised of the linkage of a unique birth certificate record to any Medicaid-paid infant claims records, MCC and

WIC enrollment records, or infant death certificate record. The data include a census of all births in the state of North Carolina in the years 2000-2002. The total number of North Carolina resident live births was 120,247 in 2000, 118,112 in 2001, and 117,307 in 2002. Among these, Medicaid-paid births based on the infant's Medicaid status numbered 49,188 in 2000, 51,720 in 2001, and 48,883 in 2002. Births to women enrolled in the Maternity Care Coordination program were 24,694 in 2000, 24,328 in 2001, and 19,637 in 2002. Thus, approximately 50 percent of North Carolina Medicaid women who delivered during the study period were enrolled in the MCC program.

The sample includes only Medicaid births to white and African-American women aged 15-45 years. Three selection criteria were established to address issues of bias in the sample selection. First, women who enrolled in the MCC program after 32 weeks gestation are not included, thereby excluding late joiners. Second, only live singleton births are included. And third, births to women who received no prenatal care are excluded. In addition to the selection criteria described above, records with missing data for any study variables are excluded. The remaining observations are 137,249 Medicaid births, including 57,635 births to women participating in the MCC program for years 2000-2002. We randomly selected 60,000 observations for use in the study's data sample.

METHODOLOGY

Predictor Variables

The state of North Carolina collects up to 300 pieces of maternal and infant information for each birth included in the Composite Linked Birth File. We selected 19 variables that previously have been identified as important in predicting if a woman is at risk for a high risk pregnancy and, therefore, more likely to participate in the MCC program (Paneth, 1995; Schwethelm, Margolis, Miller, & Smith, 1989). These predictor variables fall into three general categories: 1) location, 2) overall health, and 3) pregnancy-related health.

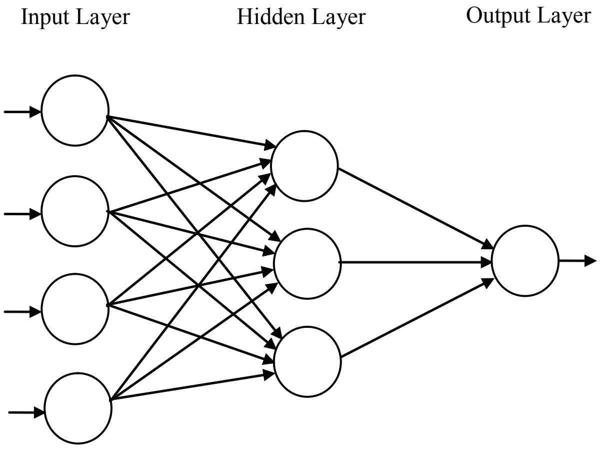
Specifically, the predictor variables include mother's zip code (MOMZIP), county of residence (COUNTY), mother's age (MOMAGE), mother's race (MOMRACE), last year of mother's schooling (MOMEDUC), marital status (MSTATUS), self-reported tobacco use (TOBACCO), self-reported alcohol use (ALCOHOL), the month prenatal care began (MMPNCBEG), presence of medical risk factor(s) (MEDRISK), and a previous death of a live newborn (PREVDETH). The input variables include several other dummy variables (0 or 1) indicating the presence of specific medical conditions such as anemia (ANEMIA), cardiac problems (CARDIAC), diabetes (DIABETES), chronic hypertension (HYPERCH), pregnancy-related hypertension (HYPERPR), eclampsia (ECLAMPSIA), preterm birth or small for gestation age in a previous pregnancy (SGA), and renal disease (RENAL). MCC is the outcome variable, where 1 indicates that the woman chooses to participate in the MCC program and 0 indicates the choice not to participate in the program.

Artificial Neural Network Model

Backpropagation network learning is a commonly used algorithm that has been proven to be a reliable tool for general classification applications (Alspan et al., 1995; Hornik, Stinchcombe, & White, 1989; Medsker & Liebowitz, 1994; White, 1990). For this study, the NeuroShell2 software package was used to define and test a three layer, feed forward, back propagation Artificial Neural Network model.

Figure 1 shows a simple propagation network of the type used in this study. In the diagram, the circles are neurons (mathematical processing units) and the lines connecting the neurons are numeric weights. The models are typically composed of: 1) a layer of input neurons, wherein each input neuron represents one predictor variable, 2)

Figure 1. Diagram of a simple propagation artificial neural network



one or more hidden layers of weighting neurons, and 3) an output layer containing a neuron for each dependent variable to be predicted. Our neural network model includes an input layer with 19 neurons, one hidden layer containing 100 neurons, and an output layer containing one neuron to predict MCC participation.

During the training phase of network development, the ANN must be trained to predict actual output values based a correctly described set of weighted connections in the input and hidden layers. In the beginning the weight values are randomly set, the input values of the first case in the training set are presented to the network's input layer, and the calculated output of each neuron is fed forward through the network until an output value is derived. Next, the computed output value is compared to the actual value of the output variable in the training case. The error value (the squared difference between actual and calculate output) is then propagated backward through the network and small adjustments are made to the weights so that, in the future, the network will come closer to calculating the correct output value. This process is repeated for each case in the training set, and the training set is processed over and over while the weights are continually tweaked.

Periodically, a holdout (test) set of cases is run against the network to determine if the predictive power of the network is still improving. The network will never learn an exact predictive function, but it will slowly approach one. The purpose of the test set is to make sure that the network is not over trained in recognizing relationships within its training set at the expense of loosing its predictive power with new data.

The original sample used in this study consisted of 60,000 observations. This number is a limitation of the NeuroShell2 software. After the sample was selected one observation was found to have a 4-digit zip code and was dropped, leaving a total of 59,999 observations. Table 1 presents the descriptive statistics for the variables used in the analysis.

Seventy percent (70%) of the observations (42,000 patterns) were used to train the network and twenty percent (20%) of the observations (12,000 patterns) were used as a test set to evaluate model training. Ten percent (10%) of the observations (5,999 patterns) were used as a production set to validate the trained model. The neural network software randomly selected the observations for each of these three data sets.

Training continued through 35 epochs of the training set. The model's weights were evaluated against the test set every 200 events. After 62,000

Table 1. Descriptive statistics for variables

Variable	Min. Value	Max. Value	Mean	Std.Dev.
Zip Code	22717	65109		
County	0	100		
Mother's age	15	45	23.57821	5.350374
Mother's Race 1= white 2= African American	1	2	1.361606	0.480470
Mother's years of schooling	0	16	11.42652	5.421363
Marital Status 1=married 2= single	1	2	1.600160	0.489869
TOBACCO 1=yes 2 = no	1	2	1.793197	0.527171
ALCOHOL 1=yes 2 = no	1	2	1.867	0.347672
Dummy Variables 0=no; 1=yes				
MMPNCBEG	0	9	2.808147	1.577052
MEDRISK	0	1	0.123819	0.329377
PREVDETH	0	1	0.018384	0.134335
ANEMIA	0	1	0.027617	0.163875
CARDIAC	0	1	0.003533	0.059338
DIABETES	0	1	0.024734	0.155314
HYPERCH	0	1	0.008467	0.091626
HYPERPR	0	1	0.050718	0.219422
ECLAMPSI	0	1	0.004917	0.069948
SGA	0	1	0.012284	0.110149
RENAL	0	1	0.003217	0.056625
MCC	0	1	0.429857	0.495060

events had been processed with no changes to the weight structure, training was stopped. Finally, the production set was processed through the trained model to produce the network's predictions for each pattern in the production file.

RESULTS

NeuroShell2 provides a number of statistical tools to assess the predictive ability of the network model. Table 2 presents a summary of their values. Following the table is a narrative description of the statistics.

The coefficient of multiple determination, R^2, compares the accuracy of the model to a

Table 2. Production set assessment statistics

Output	5999 patterns processed
R2	0.9917
correlation coefficient r	0.9960
r2	0.9920
Mean Squared Error	0.002
Mean Absolute Error	0.012
Min. Absolute Error	0
Max. Absolute Error	0.846
Percent within 5%	41.357
Percent within 5% to 10%	0.100
Percent within 10% to 20%	0.017
Percent within 20% to 30%	0.183
Percent over 30%	0.783

benchmark model consisting of the mean of all the samples. An R^2 value of 1 indicates a perfect fit, near 1 indicates a very good fit, and near or below zero indicates a very poor fit.

The square of the correlation coefficient, r^2, provides a measure of the strength of the relationship between the actual and predicted outputs. An r^2 closer to 1 indicates a strong linear relationship, while an r2 closer to 0 indicates no linear relationship.

Min Absolute Error is the minimum absolute value of (actual - predicted) for all patterns in the production set. Max Absolute Error is the maximum absolute value of (actual - predicted) for all patterns. Mean Absolute Error is the mean of the absolute value of (actual - predicted) for all patterns. Mean Squared Error is the mean of $(\text{actual - predicted})^2$ for all patterns.

NeuroShell2 also lists the percent of network predictions that differ from the actual answers within a range of specified percentages. When an actual answer is 0, a percentage difference cannot be calculated. As a result, the total computed percentages may not total 100%.

The 5999 patterns in the production set included observations for 3453 women who rejected participation in MCC and 2545 women who chose to participate in MCC. The model correctly predicted all 3453 nonparticipants (100%) and 2537 of 2545 participants (99.69%).

CONCLUSION

States face increasing pressure to limit growth in their Medicaid budgets while still meeting the health care needs of vulnerable populations. Thus, predicting the number of eligible recipients of public health care services becomes a significant challenge for program managers, especially when participation is voluntary. To meet this challenge, the use of predictive models has become much more important in an ever-widening variety of public health programs. Conventional prediction methods, which excel at identifying causal effects and linear relationships among variables, require *a priori* model specification and may not be able to detect underlying complex relationships among predictor variables. When prediction accuracy is more important than assessing causal effects, Artificial Neural Networks offer the user a powerful prediction tool without the need to understand all the subtle relationships that may exist within the target population. Additionally, significant advances in computer hardware and software technology have made Artificial Neural Networks an increasingly powerful, available, affordable, useful and user-friendly tool. Public health care resource allocation and planning can be greatly enhanced by the predictive power of ANNs, particularly in terms of voluntary program participation.

This study develops an Artificial Neural Network to predict voluntary enrollment by Medicaid women in North Carolina's Maternity Care Coordination (MCC) program for enhanced prenatal care. Observations from 59,999 randomly selected Medicaid births from the years 2000-2002 were used in the development and testing of the ANN. The model contained 19 predictor variables related to location, overall health, and pregnancy-related health to predict voluntary participation in the enhanced prenatal care program. The model correctly predicted the mother's choice to participate in MCC over 99% of the time.

Using the superior predictive power of Neural Networks, managers can make better funding, staffing, and other resource allocation decisions based on timely, correct predictions of program participation. Neural Network models can be updated as new information is obtained and retrained to recognize new relationships among predictor variables that may result from evolving changes in participant characteristics or program modifications.

This research path may be extended in many directions. Because so little research has been published on the use of Artificial Neural Networks in the prediction of voluntary participation in public health care programs, one obvious extension is to expand the study of ANNs in the prediction of voluntary participation in other types of health care programs. Other extensions of the study could also be made to predict voluntary program participation in other areas outside of health services, such as education, child care, utility subsidies, and transportation.

REFERENCES

Alkan, A., Koklukaya, E., & Subasi, A. (2005). Automatic seizure detection in EEG using logistic regression and artificial neural network. *Journal of Neuroscience Methods, 148*(2), 167-176.

Alpsan, D., Towsey, M., Ozdamar, O., Tsoi, A.C., & Ghista, D.N. (1995). Efficacy of modified backpropogation and optimization methods on a real-world medical application. *Neural Networks*, *8*(6), 945-962.

Baxt, W.G. (1991). Use of an artificial neural network for the diagnosis of myocardial infarction. *Annals of Internal Medicine*, *115*(11), 843-848.

Baxt, W.G., Shofer, F.S., Sites, F.D., & Hollander, J.E. (2002). A neural computational aid to the diagnosis of acute myocardial infarction. *Annals of Emergency Medicine*, *39*(4), 366-373.

Buescher, P.A. & Horton, S.J. (2002). Prenatal WIC participation in relation to low birth weight and Medicaid infant costs in North Carolina-An update. *Center for Health Informatics and Statistics Studies*, *122*, 1-9.

Buescher, P.A., Roth, M.S., & Williams, D. (1991). An evaluation of the impact of maternity care coordination on Medicaid birth outcomes in North Carolina. *American Journal of Public Health*, *81*(12), 1625-1629.

Chesney, T., Penny, K., Oakley, P., Davis, S., Maffulli, N., & Templeton, J. (2006). Data mining medical information: Should artificial neural networks be used to analyze trauma audit data. *International Journal of Healthcare Information Systems and Informatics*, *1*(2), 51-64.

Clarke, L.L., Miller, M.K., & Mahan, C.S. (1993). The effectiveness of Florida's improved pregnancy outcome program. *Journal of Health Care for the Poor and Underserved*, *4*(2), 117-132.

Crawford, A.G., Fuhr, J.P., Clarke, J., & Hubbs, B. (2005). Comparative effectiveness of total population versus disease-specific neural network models in predicting medical costs. Disease Management, *8*(5), 277-287.

Das, A., Ben-Menachem, T., Cooper, G.S., Chak, A., Sivak, M.V. Jr., Gonet, J.A., & Wong, R.C. (2003). Predicition of outcome in acute lower-gastrointestinal hemorrhage based on and artificial neural network: Internal and external validation of a predictive model. *Lancet*, *362*(9392), 1261-1266.

Eftekhar, B., Mohammad, K., Ardebili, H.E., Ghodsi, M., & Keabchi, E. (2005). Comparison of artificial neural network and logistic regression models for prediction of mortality in head trauma based on clinical data. BMC Medical Informatics and Decision Making, *5*(3), 1-8.

Goss, E., & Vozikis, G.S. (2002). Improving health care organizational management through neural network learning. *Health Care Management Science*, *5*(3), 221-227.

Herman, A.A., & Berendes, H.W. (1996). The evaluation of the effectiveness of a community-based enriched model of prenatal intervention project in the District of Columbia. *Health Services Research*, *33*(5), 609-621.

Hornik, K., Stinchcombe, M., & White, H. (1989). Multilayer feedforward networks are universal approximations. *Neural Networks*, *2*(5), 359-366.

Kaur, H., & Wasan, S.K. (2006). Empirical study on applications in data mining techniques in health care. *Journal of Computer Science*, *2*(2), 194-200.

Korenbrot, C.C, Gill, A., & Patterson, E. (1995). Evaluation of California's statewide implementation of enhanced perinatal services as Medicaid benefits. *Public Health Report*, *110*(2), 125-133.

Kudyba, S., Hamar, G.H., & Gandy, W.M. (2006). Utilising neural network applications to enhance efficiency in the health care industry: Predicting populations of future chronic illness. *International Journal of Business Intelligence and Data Mining*, *1*(4), 371-383.

Lisboa, P.J. & Taktak, A.F.G. (2006). The use of artificial neural networks in decision support in cancer: A systematic review. Neural Networks, *19*, 408-415.

Medsker, L., & Liebowitz, J. (1994). *Design and development of expert systems and neural networks*. New York: McMillan.

Nason, C.S., Alexander, G.R., Pass, M.A., & Bolland, J.M. (2001). An evaluation of a Medicaid managed maternity program: The impact of comprehensive care coordination on utilization and pregnancy outcome. *Journal of Health and Human Resources Administration*, *24*(3/4), 493-521.

Paneth, N.S. (1995). The problem of low birth weight. *The Future of Children: Low Birth Weight*, *5*(1), 21-34.

Schulman, E. F., Sheriff, D.J., & Momany, E. (1997). Primary case management and birth outcomes in the Iowa Medicaid program. *American Journal of Public Health*, *87*(1), 80-84.

Schwethelm, B., Margolis, L.H., Miller, C., & Smith, S. (1989). Risk status and pregnancy outcome among Medicaid recipients. *American Journal of Preventative Medicine*, *5*(3), 157-163.

Seomun, G., Chang, S.O., Lee, S.J., Kim, I.A., & Park, S. (2006). A prediction model for patient classification according to nursing need: Using data mining techniques. In H. Park, P. Murray, & C. Delaney (Ed.), *Consumer-centered computer-supported care for healthy people* (p. 899). Fairfax, VA: IOS Press.

Subasi, A., & Ercelebi, E. (2005). Classification of EEG signals using neural network and logistic regression. *Computer Methods and Programs in Biomedicine*, *78*(2), 87-99.

White, H. (1990). Connectionist nonparametric regression: Multilayer feedforward networks can learn arbitrary mappings. *Neural Networks*, *5*(6), 535-549.

Zurada,J., & Lonial, S. (2005). Comparison of the performance of several data mining methods for bad debt recovery in the health care industry. *The Journal of Applied Business Research*, *21*(2), 37-53.

This work was previously published in International Journal of Healthcare Information Systems and Informatics, Vol. 3, Issue 2, edited by J. Tan, pp. 1-11, copyright 2008 by IGI Publishing (an imprint of IGI Global).

Chapter 7.15

An Exploration of Demographic Inconsistencies in Healthcare Information Environments

Larbi Esmahi
Athabasca University, Canada

James W. Edwards
Agfa Healthcare, Canada

Elarbi Badidi
United Arab Emirates University, UAE

INTRODUCTION

Healthcare providers typically use technology in a ubiquitous manner. They choose to rely upon the task-specific capabilities of a specific system, rather than the integration of all systems in the solution space. A typical example of this would be the advancement of ultrasound technologies for 3-D modeling. Whilst the capabilities of the imaging solutions are highly beneficial to the individual's unique needs for healthcare, the integration of this system into a greater solution, or system-of-systems, is often overlooked (Maier, 1998; Maier, 2005). As such, the demographic data accompanying the information may be in a format inconsistent with the requirements for the electronic medical record. Workflow Management Systems attempt to simplify and control the primary data entry methods to the data environment (Choennia, Bakkera, & Baetsa, 2003; Graeber, 1997). However, the design of these systems focuses on an interpretation layer to gather data from varying input sources, including voice and text. There is no guarantee that this information will propagate throughout the system-of-systems, as required. Common information protocols such as Digital Imaging and Communications in Medicine (DICOM) (NEMA, 2004) and Health Level Seven (HL7.org, 2006) provide a framework by which medical data is communicated. However, these standard protocols are subject to interpretation that allows for a high degree of variance in the presentation of data. This creates problems of data redundancy, and confuses the authoritative provisioning of data with referential copies.

The electronic healthcare record (EHR) is a merged presentation of the information obtained through various systems in the healthcare enterprise

(Hasselbring, Peterson, Smits, & Spanjers, 2000). Imaging and demographic data contribute to the contents. Additionally, the physician comments, markup, and modality reports also contribute to the record. These individual pieces of the EHR are drawn from many disparate systems throughout the enterprise. The record information system (RIS) or alternatively a health information system (HIS) will be the primary demographic repository for patient information. As such, this text and contextual information will be used as the primary data source for downstream comparison. The Picture Archive and Communication System (PACS) will be used as a repository for imaging data (Miltchenko, Pianykh, & D'Antonio, 2002).

As the global economy and global business practices increase, individuals tend to be more transient. Their medical histories are an important precursor to successful health care provisioning. Contingent upon this medical history record is the successful integration of data from varied sources, including the mobile patient's information. This information must be portable, presentable, and independent of the initial data program from which it was obtained. By far, the greatest concern relates to data inconsistency and subsequent inaccuracy in an environment of disparate systems.

In the next section of this article, we will discuss the Health Level Seven communication protocol. In the third section, we will discuss the protocol DICOM. The application of these protocols into solutions for healthcare information repositories is presented in the fourth section, where both PACS and RIS systems are discussed. The problem of Data Disparity that causes inconsistencies in the intersystem communications will be discussed in the fifth section. The design of the XML Bus solution will be presented in the sixth section. The successes and shortcomings of this design are discussed in the conclusion.

HEALTH LEVEL SEVEN

The HL7 protocol provides an information standard for communicating patients and sites level information into and out of a health information system within the system-of-systems model (HL7 Canada, 2002; HL7.org, 2006; Neotool, 2007). HL7 allows for a loosely framed communication standard between medical IT systems. Without the provisioning of this ANSI standard, interoperability between systems was performed in an ad hoc manner.

The HL7 standard is based on the concept of events referred to as triggers (HL7, 2006, 2007). Each of these triggers fires a process that effects some particular communication of information. For example, the relocation of a patient to a new hospital would require the dissemination of information concerning that location throughout the healthcare system-of-systems. This event would be one of such triggers. A trigger may relate to a single record, as in this example, or it may relate to multiple records. A patient may have a name change due to marriage. This would require an update to all existing records in the information system to ensure data consistency.

Each trigger is composed of segments. The segment is a variable length field separated by a discernable character, such as a comma or pipe. In a manner similar to comma separated values (CSV) files, data can be delineated and also referenced externally though API functions. The content of each segment shall contain ASCII characters. The HL7 committee defines the acceptable character set as "The ASCII displayable character set (hexadecimal values between 20 and 7E, inclusive) is the default character set unless modified in the MSH header segment" (HL7, 2006). The HL7 trigger is represented in Table 1.

Each field may contain multiple subfields, delimited by a caret character. In the case of a name, |*DOE^JOHN^^^^*| the content between the two pipe symbols is the field of data, whereas the data *DOE* and *JOHN* are considered subfields.

Table 1. Sample HL7 trigger (Interfaceware, 2006)

```
MSH|^~\&|EPIC|EPICADT|SMS|SMSADT|199912271408|CHARRIS|ADT^A04|1817457|D|2.3|
EVN|A04|199912271408|||CHARRIS
PID||0493575^^^2^ID 1|454721||DOE^JOHN^^^^|DOE^JOHN^^^^|19480203|M||B|254
E238ST^^EUCLID^OH^44123^USA||(216)731-4359|||M|NON|400003403~1129086|999-|
NK1||CONROY^MARI^^^^|SPO||(216)731-4359||EC|||||||||||||||||||||||||||
PV1||O|168 ~219~C~PMA^^^^^^^^^^||||277^ALLEN FADZL^BONNIE^^^^||||||||||
    ||2688684|||||||||||||||||||||||||199912271408||||||002376853
```

The MSH is the message header segment, providing basic instructions on the contents within the trigger message.

This example also makes reference to three other key items: the *PID* that is the patient identifier, the EVN identifying that an event is included in this message, and the PV1 filed, which is followed by information about the patient's stay at the hospital.

One of the important contents within this message is the event type. As per the example, the message type provided is A04. HL7 defines many different message types, each with unique content. There are 51 defined Admission, Discharge or Transfer (ADT) events for HL7 in the V2.5 standard. The following table (Table 2) describes some of these events.

Without elaborating further on some of the many messages available to the HL7, it becomes clear that many distinct attributes are communicated in this protocol. Static entities such as Patient ID, Accession number, and event dates are provided in the same framework as dynamic information, such as location. The messaging protocol is also intended to communicate changes in state, through the provisioning of state-in-time attributes that have an expectation of permanence (Evola, 1997). These attributes, such as Patient ID, may have referential integrity for a site perspective. However, in the conglomerate or regional model of healthcare, that identifier now becomes nonreferential from a global viewpoint, and as such, introduces disparity at a higher system-of-systems level.

Table 2. HL7 message types

Message Type	Definition
Admit/visit notification (event A01)	Assign a bed to an admitted patient
Transfer a patient (event A02)	Patient changes their physical location
Discharge/end visit (event A03)	Patient leaves the facility
Register a patient (event A04)	Patient is brought into the facility, but not given a bed
Pre-admit a patient (event A05)	Patient is not admitted (In the facility), but demographic information is registered in the information system prior to their arrival for procedure.
Change an outpatient to an inpatient (event A06)	If a patients status changes, normally due to severity, they will be given a new location at the facility
Change an inpatient to an outpatient (event A07)	As per A06, defines a state change in the patient location.
Update patient information (event A08)	Represents a change to any of the demographic information related to a patient. This may be name, address, or other field.
Patient departing tracking (event A09)	Patient in transit outbound
Patient arriving - tracking (event A10)	Patient in transit inbound

DICOM

DICOM exists as an information distribution mechanism for medical devices (Ratib, Ligier, Rosset, Staub, Logean, & Girard, 2000). It is important to note that DICOM can be viewed as a technical protocol for layer seven communications or a solution to information exchange.

The DICOM protocol was developed in a joint effort between the American College of Radiology (ACR) and the National Electrical Manufacturers Association (NEMA, 2004). The protocol was introduced as a hardware interface, a minimum set of software commands, and a consistent set of data formats for communication between medical devices. This standard was intended to provide a framework to an emerging technology, medical information technology, allowing the sharing of data amongst Picture Archive Communication Systems and compliant sources.

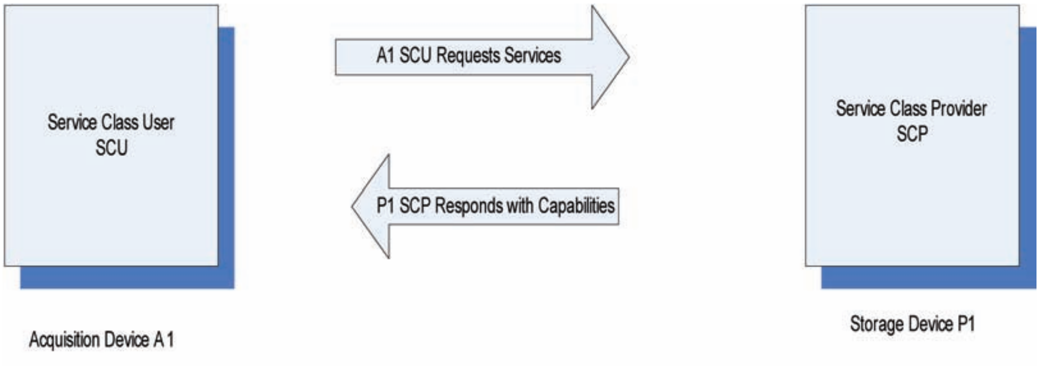
The DICOM protocol is used by a multitude of devices within the hospital enterprise for information transfer, sharing, and coordination (Jung, 2005). Some of the systems that rely on the protocol include modalities (Ultrasound, X-ray, CR, CT, and so on), Picture Archive Communication Systems, Film Printers, and Digitizers (media conversion systems) (Iacucci, Nielsen, & Berge, 2002). Although the implementation of the protocol is proprietary for each manufacturer, the standards as provided by the NEMA organization assist in ensuring general interoperability and definition of expectation for each DICOM function.

The first layer of protocol discussion relates to the negotiation of capabilities between the acquisition device and the subsequent receiver. Two concise roles are defined within DICOM to elucidate the responsibilities of each participant in the information exchange: the Service Class User (SCU) and the Service Class Provider (SCP). The SCU is the requestor of services for the purposes of information storage. In essence, it has information, and solicits a predefined receiver to accept this information. The SCU negotiates the acceptance of the sender's data, typically in one or more ways (Revet, 1997).

The storage transmission starts with a request from the SCU. The SCU identifies itself and asks for a specific function, through a composite request. The request consists of an object and an associated action. For example, a C-STORE message may consist of a request for data storage, and a subsequent object, such as an ultrasound image. The SCP, or storage provider, accepts the association request from the resource, assuming the storage host trusts it.

As illustrated in Figure 1, the bidirectional request-response behavior is typical of the DICOM protocol. The SCP not only accepts the initial request, but also responds with a list of capabilities for that request. The response consists of a list of Service Object-Pair (SOP) classes, reflective of the

Figure 1. SCU-SCP communications



storage ability of the SCP system. Also included in this request-response exchange is the choice of transfer syntax used for communication. Since there is a multiplicity of available syntaxes in the DICOM standard, some systems require the presence of an explicit value representation in the message. Others rely on an implicit understanding between data dictionary implementations, as provided partly by the DICOM standard, and partly by the SCP developer (McCormick, 2006).

DICOM data is broken into six major groups: File, Study, Acquisition, Image, Object, and Presentation. Each of these groups is well defined in terms of permissible content by the DICOM committee, as published in the DICOM standards and Supplements. Seven major groups are used to categorize DICOM Data elements. Group 0002 identifies file level attributes. Group 0008 identifies attributes relating to the study. Group 0010 identifies the patient attributes. Group 0018 relates to the acquisition of specific attributes related to the image. Group 0020 contains object level information, including the hierarchal relationship attributes that allow the linking of this image or object to the other objects in the series, study, and patient. Group 0028 elements provide display information crucial to the proper visual presentation of the image. Medical software uses this information to apply default settings. Group of Private Data Elements (odd numbered groups), allow the vendor to include information that can be used in a proprietary manner (i.e., to display the images, in case that vendor's system is part of the total System-of-Systems solution).

In summary, the DICOM protocol allows not only for the communication of patient, study, series, and image level information, it also defines the mechanism by which that information may be exchanged (Kolesnikov, 1997; Kolesnikov, Kelle, & Kauranne, 1997). This data is the primary source for study information as it related to the patient.

PACS AND RIS

PACS systems are built as a central repository for DICOM information (Gell, 2000). They are typically deployed as a means of replacing typical film based media. Through the implementation of the Storage Class User (SCU) and Storage Class Provider (SCP) mechanisms defined in DICOM, the PACS system receives images for later retrieval. PACS provides an electronic means of long-term storage. This storage serves as the integrated lifecycle management mechanism for a continued inbound stream of data (Miltchenko et al., 2002). The PACS is also the recipient of messages from the RIS. These messages represent unique events, such as a patient name change. Upon reception of such events, the PACS system is expected to start a process that will eventually update the demographic data using the previous name to the new patient name. The PACS answer to subsequent queries related to the updated patient records is subject to the proper interpretation of the data, as identified through the use of explicit data types, as well as the data dictionary. In fact, the use of DICOM data dictionaries allow for explicit metadata definition of data streams received. In the case of PACS, data dictionaries assist in defining the understanding of data content, both by type and content (Kennedy, Seibert, & Hughes, 2000).

Health Information Systems (HIS) organize demographic records for the purpose of centrally collecting a repository of electronic information. Radiology Information Systems (RIS) build upon this purpose for the radiology patient by scheduling orders. As information repositories, these systems (HIS and RIS) are constantly updated with both new and changing information. RIS systems can also provide worklists to modalities containing patient names and other demographic information of importance. In order for modalities to communicate outwards to information systems, they rely upon the DICOM protocol (Miltchenko et al., 2002; Tornhola, 2004). This may require the HIS system to accept DICOM events. Alternatively, data translation systems occasionally transform DICOM messages to the appropriate HL7 data construct, normally understood by the HIS system. The DICOM standard assists PACS implementations in providing a referential target, but only provides DICOM consistency of the data that is independent of the RIS. The RIS always relies on the HL7 protocol and its messaging mechanism for informing the PACS of changes, as well as receiving events from DICOM devices.

The messaging mechanism between different systems offers the translation medium that serves to both interpret and re-represent the data. However, the interpretation is based on an understanding of the message context inbound. This is a highly subjective interpretation. Resultantly, events and interpretation can result in inconsistency in this messaging based approach.

CAUSES FOR DATA DISPARITY IN THE SYSTEM-OF-SYSTEMS APPROACH

As discussed in the previous sections, the event and messaging framework used in the health enterprise system does not warrant the consistency between different instances or parts of the patient records. In this section, we will examine some of the events that may end with data disparity in the health enterprise system.

Data Silos in Healthcare Information Systems

Protocols such as DICOM and HL7 exist for the purposes of exchanging information within the PACS and RIS information silos in the hospital enterprise. These protocols ensure data confidence for downstream systems, but are not designed to provide referential data cross system in the system-of-systems model. These protocols provide a framework by which medical data is communicated, but are subject to strict programmatic interpretation. System implementations interpret the protocol standards in unique ways, allowing for a high degree of variance in the presentation of data from multiple independent data sources. This creates problems of data redundancy, inaccuracy, and confuses the authoritative provisioning of data with referential copies. By far the greatest concern relates to data inconsistency and subsequent inaccuracy in an environment of disparate systems. Unique data keys used for data alignment or referential integrity may be drawn from human assumptions that are faulty.

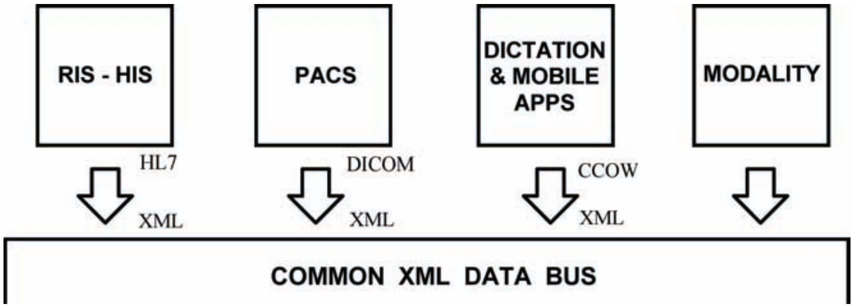
Inconsistent Record Identifier for the Patient's Data

Name change: In the system-of-systems, the patient name is always used as a key or part of the key for querying the patient data. Patients sometime change their names, especially after a marriage or divorce. When such an event occurs, demographic references strongly tied to that person's medical history will need to be changed or updated in order to insure the continuous access to relevant historical data.

In order to synchronize a patient's name throughout the system-of-systems enterprise, an HL7 N-event entitled "Patient Update" needs to occur. This type of event will ensure that all records containing "patient name" are updated to reference "the new patient name."

Legacy system for scanning film and paper data: Many of the enterprise records for patients in the hospital exist on documents. Admission, discharge, and transfer records may exist solely on nonelectronic medium. These information sources must be manually updated each time an event occurs, such as a patient name change. More information exists in the way of medical film. Not only is the image data present, but often the demographic information for the patient is burnt into the film.

Figure 2. XML data bus



OCR technologies can be helpful in dealing with the shear volume of ADT records for the patients. However, the electronically introduced data will need to be reconciled with the existing HER records.

Data Inconsistency Generated by Automatic Triggers or Cascading Events

Study cancel: On a less frequent basis, patient examinations are not conducted. This could be due to a myriad of causes, including patient absenteeism, acquisition device failure, as well as general infrastructure failure. In any of these events, a decision is made to cancel the acquisition of data relevant to the patient. In these cancellation scenarios, an N-event message is then scheduled. However, when the message is received by the PACS system, the study or appropriate identifier may not be present, as defined in the N-Event. This may be caused if the study acquisition has not yet begun. Also, the billing system may not receive the correct event-message. As such, we have an event-ordering problem.

Study split or merges: Data flow allows for the division and recombination in the process of medical diagnosis. A patient may have had a very long CT exam that extends into body parts outside the area of expertise for the radiologist. As such, it may be beneficial, both medically and financially, to split the study into two distinct studies for the patient. The inverse may also occur, resulting in a study merge. Study or series acquisition may be interrupted for one or more reasons, including equipment failure, resource contention, or multiple system acquisition. In any of these events, two or more distinct studies may need to be merged into a single study record.

A question arises regarding the synchronization of data between these models. It is unclear whether one or more IS records in this environment would exist for each study. As such, we encountered a many-to-one disagreement. Billing systems would need to be correctly informed that only one, albeit larger, procedure was performed. Also, only one read or transcription should have occurred in this model.

Data Exchange and Transfer of Patient Records

In some medical situations, a patient will need to be relocated from one hospital environment to another. In this dataflow scenario, the patient's records may be imported to the new environment. Alternatively, a new record may be created at the newest site. Also, the imaging data is sometime transmitted to the DICOM SCP of the receiving site's PACS. The transmitted and imported data needs then to be reconciled against the new site's information system in order to correlate records to demographic data, so that any patient movement or other procedures can be referenced to the same patient.

Character Set Translation and Legacy Systems Tagging

ISO_IR disagreement and database character translation: ISO character sets refer to the specific procedure for mapping a sequence of bytes to a sequence of characters. The DICOM standard includes a specific tag necessary to identify the character set used in the header. This is of extreme importance to the demographic consistency of the data interpretation and action throughout the enterprise.

By way of example, consider a query for all patients whose last name starts with Ł (from ISO 8859-2, decimal 163). If the system were not capable of understanding this character, perhaps through a limited understanding of only ISO_8859-1, then this character would escape the query, possibly with undesirable results. Worst yet, any patient name update including the character Ł would also be problematic.

Private DICOM tagging: Many modality vendors choose to include proprietary information in the DICOM header of the images and objects they transmit. This information is only of use to a system that is programmed to take advantage of it. It allows for a tighter sub-system-of-system model, but at the expense of the greater solution.

Time Synchronization

Time is a critical component to a successful diagnosis. All members of the health enterprise solution normally have their own time keeping facility. However, in the system-of-systems, the use of time stamps is critical to insure the coordination of transactions and order of precedence. These time stamps should be synchronized within the whole system-of-systems.

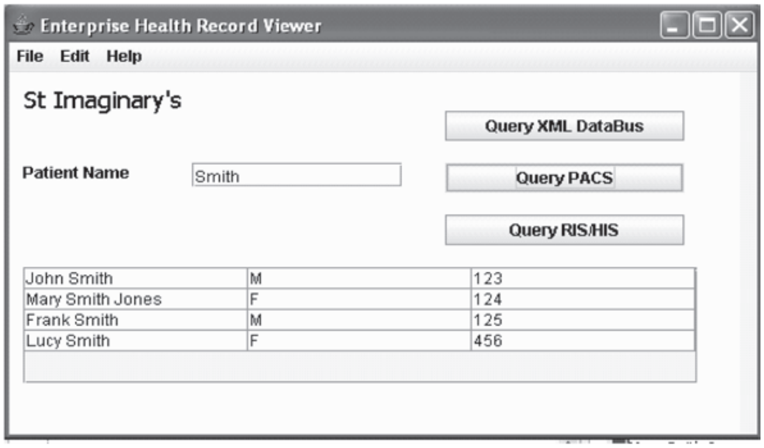
Other Technical Issues

Data reintroduction for disaster recovery purposes: In the event of system failure, one or more entities within the system-of-systems will need to be repopulated with original data. Upon completion of this, a synchronization effort will need to occur between it and one of more members within the environment. This activity requires coordination of the various information systems within the hospital enterprise.

Table 3. Excerpt from DCM2XML.jar output

```
    <?xml version=“1.0” encoding=“UTF-8”?>
    <dicomfile>
    <filemetainfo>
    <attr tag=“00020000” vr=“UL” pos=“132” name=“Group Length” vm=“1” len=“4”>196</attr>
    <attr tag=“00020001” vr=“OB” pos=“144” name=“File Meta Information Version” vm=“1” len=“2”>1\0</attr>
    <attr tag=“00020013” vr=“SH” pos=“290” name=“Implementation Version Name” vm=“1” len=“16”>eFilm/efDICOMLib</attr>
    <attr tag=“00020016” vr=“AE” pos=“314” name=“Source Application Entity Title” vm=“1” len=“18”> &#19;</attr>
    </filemetainfo>
    <dataset>
    <attr tag=“00080005” vr=“CS” pos=“340” name=“Specific Character Set” vm=“1” len=“10”>ISO_IR 100</attr>
    <attr tag=“00080008” vr=“CS” pos=“358” name=“Image Type” vm=“2” len=“16”>DERIVED\PRIMARY </attr>
    <attr tag=“00080012” vr=“DA” pos=“382” name=“Instance Creation Date” vm=“1” len=“8”>20010109</attr>
    <attr tag=“00080013” vr=“TM” pos=“398” name=“Instance Creation Time” vm=“1” len=“6”>095618</attr>
    <attr tag=“00080016” vr=“UI” pos=“412” name=“SOP Class UID” vm=“1” len=“26”>1.2.840.10008.5.1.4.1.1.1</attr>
   <attr tag=“00080018” vr=“UI” pos=“446” name=“SOP Instance UID” vm=“1” len=“40”>1.3.51.5145.5142.20010109.1105627.1.0.1
</attr>
```

Figure 3. Enterprise healthcare record viewer prototype



St Imaginary's

Patient Name: Smith

John Smith	M	123
Mary Smith Jones	F	124
Frank Smith	M	125
Lucy Smith	F	456

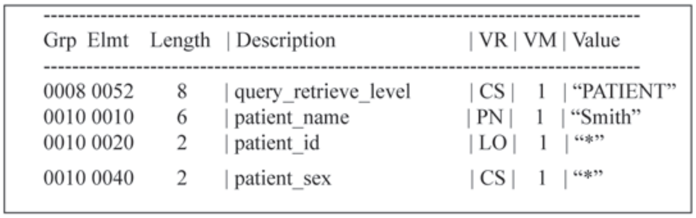
RIS feed interruption: The RIS messaging mechanism is a necessary prerequisite in the system-of-systems for data continuity. Upon failure of any RIS system in this environment, the update events will not properly register for all receiving systems in the enterprise, resulting in an environmental data inconsistency.

AN XML BUS FOR RESOLVING SOME OF THE DATA DISPARITY ISSUES

One of the prevalent issues in message-oriented systems is defining one or more protocols by which messages can be processed. Adherence to standards, bridging between protocols and configurations all raise issues in a multiple systems environment. In the healthcare enterprise, the interdependency of systems for successful patient care only serves to exasperate the situation. XML and semantic Web technology presents a great potential for solving some of the disparity issues (Heitmann, 2002; Pianykh, Castañeda-Zuniga, W. D., D'Antonio, & Tyler, 2001a; Pianykh, Miltchenko, & Castaneda-Zuniga, 2001b; Tornhola, 2004). In this section, we present a solution based on the use of an XML bus for data transfer. Figure 2 presents the XML bus design from a dataflow perspective.

The data bus would allow for a common data conduit. The connection to this conduit would be accomplished through adapters that provide common data typing. Each connection into the data bus would require an adapter that allows for consistent conversion from source protocol to XML.

Figure 4. DICOM response from EHR application C_Find



```
----------------------------------------------------------------------------------
Grp  Elmt   Length  | Description               | VR | VM | Value
----------------------------------------------------------------------------------
0008 0052     8     | query_retrieve_level      | CS |  1 | "PATIENT"
0010 0010     6     | patient_name              | PN |  1 | "Smith"
0010 0020     2     | patient_id                | LO |  1 | "*"

0010 0040     2     | patient_sex               | CS |  1 | "*"
```

DICOM to XML Conversion

The adapter, as shown in the arrow in Figure 2, is a translation engine that understands both XML and the healthcare-specific protocol, in this case, DICOM. Using open source tools such as DCM4CHE, conversion of DICOM to XML is readily possible.

The following code is a truncated output of the dcm2xml.jar transformation performed on a sample DICOM file.

HL7 to XML Conversion

Version 3.0 of the HL7 standard is a pure XML implementation (Heitmann, 2002). As such, the major concern relates not to the transformation of the trigger, but to the interpretation. This is somewhat addressed in the Reference Information Model of HL7 3.0. In versions prior to 3.0, a methodology is necessary to interpret the trigger events as XML. The HL7 organization has devised rules in order to properly encode the HL7 triggers in XML. These rules would enable an adapter framework to implement commonality of meaning across the data bus, as shown in Figure 2.

Modality to XML Data Bus Adapter

There is commonality between the DICOM to XML Adapter, and the Modality to XML adapter. Both use DICOM as a protocol for communication, and as such, may rely partially on the implementation details for each other. Modalities also have unique features, such as Modality Performed Procedure Steps (MPPS), which must also be taken care of in any successful implementation (Noumeir, 2005). The modality adapter must be able to communicate these specific events directly to the data bus. Any subsequent queries upon the data bus would then be able to accurately provide procedure start and procedure end dates and times through the Modality to XML adapter shown in Figure 2. (see also Table 3)

Context to XML

Many applications rely on the Clinical Context Object Workgroup (CCOW) for interoperability notification. This standard and an extension of the HL7 framework allows singular CCOW-aware applications to interact with other CCOW-aware applications for the purposes of information sharing (Grimson, Stephens, Jung, Grimson, Berry, & Pardon, 2001). This standard is extremely beneficial in the system-of-systems approach, as it represents a common notification mechanism for changes in status. It also has value in voice dictation systems as a means of coercing dictation information into the patient framework through the identification of common attributes, such as patient name and study instance-unique identifiers.

Proof of Concept

The following interface provides a rudimentary proof of concept for the Enterprise Healthcare Record Viewer application. The intent of this application is not to commit a full implementation, but rather to provide a framework by which further research may be committed. (see Figure 3)

The EHR interface provides three query mechanisms. The XML Data Bus function performs a direct SQL query to the data repository, as stored through a future XML to SQL transformation. The second interface queries the PACS SCP through a standard C_FIND. Figure 4, an excerpt of the DICOM conversation ensuing from that query, details the Group and Element data transferred.

The last query mechanism queries the RIS system. Connectivity to the RIS is accomplished through an HL7 Query message.

CONCLUSION

Medical information systems exist as information silos within the global health enterprise, making the task of designing an effective and accurate Enterprise Health Record Viewer very difficult. Each healthcare enterprise system in the system-of-systems acts as a referential entity for the information it contains, but only for the specific domain for which it is specialized. For each system in the enterprise, downstream distributed applications typically rely on the one specific data silo as a means of identifying and enacting decisions within an application framework. Whilst this ensures one to one consistency of data between the application and a centralized data repository, it does not ensure consistency within the enterprise.

In the enterprise health record, two systems were found to be of importance. Radiological clients communicated primarily with a PACS system via DICOM as a means of obtaining study level data for patients. Radiology workstations communicated with RIS systems via HL7 in order to record patient-level attributes. Data consistency was often accomplished through the implementation of translation systems converting one protocol to another. In fact, protocols such as DICOM, CCOW, and HL7 exist as standards for information sharing, but the exact implementation of message conversion from one standard to another is often an area of information redundancy. Data conversion solutions were also viewed as a possible cause for information loss or inaccuracy due to the incongruity in frameworks between the systems and their protocols. In the translation and representation between systems in the enterprise, data conversion is not always possible. Enterprise inconsistencies also exist as a direct result of data workflow. HIMMS and IHE are leading the way in standardization of data consistency and authority in the healthcare enterprise by defining information pathways and messaging content within the medical information environment.

The development of an Enterprise Record Viewer illuminated the necessity for authority of data. Although protocol translation was seen as a contributing factor to inconsistencies, the production of a solution became reoriented around the creation of a central authority in order to ensure consistency. This hierarchal approach avoided the concern over data consistency in the enterprise by creating another independent silo for data display. Connectivity to the RIS and PACS systems allowed the viewer to query independently of the XML Data Bus in order to allow alternative means of exploring data that may not have been messaged properly.

The production of the framework for the XML data bus is representative of a methodology or approach for an Electronic Healthcare Record. Further effort is necessary to expand upon this singular solution to resolve the data disparity issues driven by the system-of-systems approach in the hospital enterprise. The XML data bus design provides a framework for solving some of the identified causes for data disparity. Patient name changes are addressed through the transmission of this data to the bus. All queries can then be programmed to query via the bus. Similarly, patient moves and study cancellation messages can be communicated into the bus for dissemination and subsequent query. While the bus design alleviates these areas by creating a singular entry point for enterprise systems, other causes for data inconsistency cannot be solely addressed through the XML data bus design. Consistencies in data dictionaries, ISO_IR disagreement and private DICOM tagging practices require future research. These areas may benefit from an assessment of the W3C semantic Web design. Another concern remains with data movement and event ordering. Issues such as time synchronization and RIS message repetition may benefit from an asynchronous transactional approach as implemented through the use of a message queuing. Legacy film based scanning practices would benefit from an examination of form based workflow technologies, and would integrate more readily into an XML construct such as the proposed XML data bus.

Future implementations are recommended to focus on the remote user's requirements as a means of both centralizing data, and also on providing a readily accessible, consistent, and lightweight viewpoint to data. This latter objective will facilitate a successful adoption through the consistent presentation of patient demographic data. As Scotland, England, Estonia, Canada and others begin the process of providing centralized socialized healthcare through the amalgamation and adoption of countrywide healthcare solutions, Enterprise Healthcare Record Viewers and identification of data authorities inside the system-of-systems healthcare enterprise will become critical to the successful provisioning of healthcare to patients.

REFERENCES

Choennia, S., Bakkera, R., & Baetsa, W. (2003). On the evaluation of workflow systems in business processes. *The Electronic Journal of Information Systems Evaluation, 6*(2), Paper 5. Retrieved February 12, 2008, from http://www.ejise.com/volume6-issue2/issue2-art5.htm

Evola, R. L. (1997). *Patient administration*. Article 3, in Health Level Seven, Version 2.3. Retrieved February 12, 2008, from http://www.dmi.columbia.edu/resources/hl7doc/hl72.3/ch3.pdf

Gell, G. (2000, February 15). PACS-Graz, 1985-2000: from a scientific pilot to a state-wide multimedia radiological information system. In G. J. Blaine, & E. L. Siegel (Eds.), *Proceedings of the SPIE, "Medical Imaging 2000: PACS Design and Evaluation: Engineering and Clinical Issues"* (Vol. 3980, pp. 19–28). San Diego, CA.

Graeber, S. (1997). The impact of workflow management systems on the design of hospital information systems. *The American Medical Informatics Association Annual Fall Symposium*. Retrieved February 12, 2008, from http://www.amia.org/pubs/symposia/D004101.PDF

Grimson, J., Stephens, G., Jung, B., Grimson, W., Berry, D., & Pardon, S. (2001). Sharing health-care records over the Internet. *IEEE Internet Computing, 5*(3), 49–58. doi:10.1109/4236.935177

HL7. (2006). *HL7 ANSI-approved standards*. Retrieved February 12, 2008, from http://www.hl7.org/documentcenter/public/faq/ansi_approved.htm

HL7. (2007). *HL7 EHR system functional model release 1.* Retrieved February 12, 2008, from http://ftp2.ansi.org/download/free_download.asp?document=ANSI%2FHL7+EHR%2C+R1%2D2007

HL7 Canada. (2002). *Guidebook for HL7 development projects in Canada*. Retrieved February 12, 2008, from http://sl.infoway-inforoute.ca/downloads/hl7can_Guidebook_v1_0.pdf

HL7.org. (2006). *What is HL7?* Retrieved February 12, 2008, from http://www.hl7.org/about/hl7about.htm

Hasselbring, W., Peterson, R., Smits, M., & Spanjers, R. (2000). *Strategic information management for a Dutch university hospital.* Retrieved February 12, 2008, from http://citeseer.ist.psu.edu/720240.html

Heitmann, K. U. (2002). *XML encoding rules of HL7 v2 messages - v2.xml.* Retrieved February 12, 2008, from http://www.hl7.org/Special/committees/xml/drafts/v2xml1mlbb.pdf

Hollingsworth, D. (1995, January 19). Workflow management coalition. *The Workflow Reference Model. Document Number TC00-1003, Issue 1.1.* Retrieved February 12, 2008, from http://www.wfmc.org/standards/docs/tc003v11.pdf

Iacucci, E., Nielsen, P., & Berge, I. (2002, August). Bootstrapping the electronic patient record infrastructure. In K. Bødker, M. Kühn Pedersen,

J. Nørbjerg, J. Simonsen, & M. Thanning Vendelø (Eds.), *Proceedings of the 25th Information Systems Research Seminar in Scandinavia (IRIS 25), "New Ways of Working in IS"*. Bautahøj, Denmark. Retrieved February 12, 2008, from http://heim.ifi.uio.no/~pnielsen/PHD/IaNiBe.doc

Interfaceware. (2006). *HL7 message sample.* Retrieved February 12, 2008, from http://www.interfaceware.com/manual/ch-2-3-1-2.html

Jung, B. (2005, June 23–24). DICOM-X - seamless integration of medical images into the EHR. In A. Tsymbal, & P. Cunningham (Eds.), *The 18th IEEE International Symposium on Computer-Based Medical Systems: Computer Based Medical Systems (CBMS)* (pp. 203–207). Trinity College, Dublin, Ireland.

Kennedy, R. L., Seibert, J. A., & Hughes, C. J. (2000, February 15). Legacy system integration using Web technology. In G. J. Blaine, & E. L. Siegel (Eds.), *Proceedings of the SPIE, "Medical Imaging 2000: PACS Design and Evaluation: Engineering and Clinical Issues"* (Vol. 3980, pp. 231–234). San Diego, CA.

Kolesnikov, A. (1997). *EUROMED DICOM WWW gateway*. Retrieved February 12, 2008, from http://cs.joensuu.fi/~koles/projects/wwwdcm/demo.html

Kolesnikov, A., Kelle, O., & Kauranne, T. (1997, May 22). Remote medical analysis with Web technology. In B. Ramin, & P. Karttunen (Eds.), *Proceedings of the Finnish Symposium on Signal Processing - FINSIG'97*, (pp. 87–96). Pori, Finland.

Maier, M. W. (1998). Architecting principles for systems-of-systems. *Systems Engineering*, *1*(4), 267–284. doi:10.1002/(SICI)1520-6858(1998)1:4<267::AID-SYS3>3.0.CO;2-D

Maier, M. W. (2005). Research challenges for systems-of-systems. *IEEE International Conference on Systems, Man and Cybernetics, 4*, 3149–3154

McCormick, P. (2006). *DICOM and databases.* White Paper. Retrieved February 12, 2008, from http://icmit.mit.edu/dicomdb.html

Miltchenko, M. V., Pianykh, O. S., & D'Antonio, M. G. (2002, December 1–6). Using universal PACS: The globally accessible medical imaging system. *RSNA 2002 Annual Meeting.* Chicago, IL. InfoRAD section. Retrieved February 12, 2008, from http://www.unipacs.com/downloads/RSNA_2002.pdf

National Electrical Manufacturers Association (NEMA). (2004). *Digital imaging and communications in medicine (DICOM) part 1: Introduction and overview.* Report No PS. Retrieved February 12, 2008, from http://medical.nema.org/dicom/2004/04_01PU.PDF

NeoTool. (2007). *The HL7 evolution*. Retrieved February 12, 2008, from http://www.neotool.com/pdf/HL7-Version-3-with-HL7-Version-2-History.pdf

Noumeir, R. (2005). Benefits of the DICOM modality performed procedure step. *Journal of Digital Imaging*, *18*(4), 260–269. doi:10.1007/s10278-005-6702-3

Pianykh, O. S., Castañeda-Zuniga, W. D., D'Antonio, M. G., & Tyler, J. M. (2001a, August 6–12). Developing an advanced Web-accessible PACS. *International Conference on Advances in Infrastructure for Electronic Business, Science, and Education on the Internet, SSGRR 2001.* L'Aquila, Italy. Retrieved February 12, 2008, from http://www.unipacs.com/downloads/PaperItaly.pdf

Pianykh, O. S., Miltchenko, M. V., & Castaneda-Zuniga, W. D. (2001b, November 24–30). Efficient and reliable Web-based DICOM workstation. *RSNA 2001 Annual Meeting.* Chicago, IL. Scientific poster section. Retrieved February 12, 2008, from http://www.unipacs.com/downloads/Poster.pdf

Ratib, O. M., Ligier, Y., Rosset, A., Staub, J. C., Logean, M., & Girard, C. (2000, February 15). Self-contained off-line media for exchanging medical images using DICOM-compliant standard. In G. J. Blaine, & E. L. Siegel (Eds.), *Proceedings of the SPIE, "Medical Imaging 2000: PACS Design and Evaluation: Engineering and Clinical Issues"* (Vol. 3980, pp. 30–34). San Diego, CA.

Revet, B. (1997). *DICOM cook book for implementations in modalities*. Philips Medical Systems. Free download. Retrieved February 12, 2008, from ftp://ftp.philips.com/pub/pms-3003/DICOM_Information/CookBook.pdf

Tornhola, M. J. (2004). Medical imaging data representation with DICOM-XML. In P. Inchingolo, & R. Pozzi-Mucelli (Eds.), *EuroPACS-MIR 2004 in the Enlarged Europe*. Retrieved February 12, 2008 from http://www.tbs.ts.it/europacs2004/papers/99.pdf

KEY TERMS

Clinical Context Object Workgroup (CCOW): More commonly known as Clinical Context Management, enables the clinical end-user to experience the simplicity of interacting with one system, when in reality he or she may be using multiple independent applications through varying interfaces. Defined by HL7 standards, CCOW ensures secure and consistent access to patient data from varied sources.

Clinical Document Architecture (CDA): Also known as the Patient Record Architecture (PRA), provides an exchange model for clinical documents (such as discharge summaries and progress notes). CDA brings the healthcare industry closer to the realization of an electronic medical record.

Comma Separated Values (CSV): This file format is often used to exchange data between differently similar applications. CSV files have become somewhat obsolete, due to XML data exchange possibilities.

Digital Imaging and Communications in Medicine (DICOM): A standard for the distribution and viewing of medical images, such as CT scans, MRIs, and ultrasound. It describes a file format for the distribution of images and provides access to Storage Media independently from specific media storage formats and file structures.

Health Level Seven (HL7): A standard for exchanging information between medical applications. It is an event driven protocol that defines the format and the content of the messages that applications must use when exchanging data with each another in various circumstances.

Modality Performed Procedure Steps (MPPS): The MPPS service works in concert with the Modality Work List service to provide exam status updates. MPPS are used for two purposes: updates the exam state of patient and forward messages to another application entity, such as a RIS or other work list provider.

Modality Work List: The Modality Work List service provides patient demographic information to imaging modalities in the form of a work list. Modality work lists also allow technologists to sort their workload by time period, specific date or time, patient name or identifier, and modality.

Network Time Protocol/Simple Network Time Protocol (NTP/SNTP): NTP is an Internet protocol used to synchronize the clocks of computers to some time reference. SNTP (Simple Network Time Protocol) is basically also NTP, but lacks some internal algorithms that are not needed for all types of servers.

Picture Archive and Communication System (PACS): A network of computers dedicated to the storage, retrieval, distribution, and presentation of images. A PACS system provides a single point of access for images and their associated data. It also interfaces with existing hospital information systems, such as the hospital information system (HIS) and the radiology information system (RIS).

Service Class Provider (SCP): In DICOM, the relationship between both partners is defined by the Service Class description. The SCP plays the "server" role to perform operations and invoke notifications during an Association. An example of a Storage Service Class Provider would be an image storage device. The SCP role includes enabling the applications to receive DICOM objects locally from devices (image sources, workstations, servers, and so on) through the DICOM protocol.

Service Class User (SCU): In DICOM, the relationship between both partners is defined by the Service Class description. The SCU plays the "client" role to invoke operations and perform notifications during an Association. An example of a Storage Service Class User would be an image acquisition device. In this case, the image acquisition device will create and send a DICOM image by requesting that a Service Class Provider store that image.

Service Object-Pair (SOP): SOP classes identify the capabilities of the specific distributed processing for a certain Service Class. When partners agree to use a SOP class, both sides must ensure they will play their role as described, using the context of the enclosing Service Class. In each SOP Class definition, a single Information Object Definition or IOD is combined with one or more services.

Workflow Management System: A system that completely defines, manages, and executes "workflows" through the execution of software whose order of execution is driven by a computer representation of the workflow logic. The workflow is concerned with the automation of procedures where documents, information, or tasks are passed between participants according to a defined set of rules to achieve, or contribute to, an overall business goal (Hollingsworth, 1995).

This work was previously published in Encyclopedia of Healthcare Information Systems, edited by N. Wickramasinghe and E. Geisler, pp. 885-890, copyright 2008 by Medical Information Science Reference (an imprint of IGI Global).

Chapter 7.16

Analysing Clinical Notes for Translation Research:

Back to the Future

Jon Patrick
The University of Sydney, Australia

Pooyan Asgari
The University of Sydney, Australia

ABSTRACT

There have been few studies of large corpora of narrative notes collected from the health clinicians working at the point of care. This chapter describes the principle issues in analysing a corpus of 44 million words of clinical notes drawn from the Intensive Care Service of a Sydney hospital. The study identifies many of the processing difficulties in dealing with written materials that have a high degree of informality, written in circumstances where the authors are under significant time pressures, and containing a large technical lexicon, in contrast to formally published material. Recommendations on the processing tasks needed to turn such materials into a more usable form are provided. The chapter argues that these problems require a return to issues of 30 years ago that have been mostly solved for computational linguists but need to be revisited for this entirely new genre of materials. In returning to the past and studying the contents of these materials in retrospective studies we can plan to go forward to a future that provides technologies that better support clinicians. They need to produce both lexically and grammatically higher quality texts that can then be leveraged successfully for advanced translational research thereby bolstering its momentum.

INTRODUCTION

This volume gives a picture of the current progress in using Natural Language Processing to provide better access to written materials that are on the whole published under formal assessments and processes. Such materials are more amenable to different NLP tasks than the genre of content produced by clinicians working at the point of care with very sick and dying patients. The point-of-care texts are distinctly different in two important ways - *weaker adherence to grammatical structure*, and *the complexity and veracity of* lexical form. A further difference is in the objectives of the processing tasks themselves. The papers of this volume have defined the necessary task as that of information retrieval in and of itself. Processing clinical notes has a much larger number of objectives which makes it both more complex but also provides a greater number of opportunities to be creative and contribute to enhancements to the field of health care. Translational research, or more colloquially known as "bench to bed" research, is looming to be by far the most important field for improving our health care. This is the process of linking together the research performed in the laboratory to the processes and treatments conducted at the bedside. Much of this work is seen as personalized medicine that will produce drugs targeted at an individual's personal genome, however research into this ideal healthcare is highly restricted without technology that enables linking of the patient records created at the point-of-care with the models of drug-genome interaction built in the laboratory. NLP is a most important bridge between these two end points in the search for better healthcare. Without effective and accurate processing of the point-of-care records to provide evidence of the effectiveness of drugs and the course of diseases in patients under drug treatment there can be no development of evidence based drug treatment, and translational research will progress more slowly than it would otherwise.

This paper presents some of the models we have developed for representing the different processing needs of clinical staff and describes the lessons we have learned from problems encountered in analysing a large corpus of 44 million words of clinical notes.

BACKGROUND

The task of performing natural language processing over clinical notes goes back to 1983 Chi, E. C., Sager, N., Tick, L. J., & Lyman, M. S.; Gabrieli, E. R., Speth, D. J., 1986) with the work Chi, Sager, Tick and Lyman, and it is only gradually increased in activity to this date. However, in 2008 with have had the first conference specifically targeted at the "Text and Data Mining of Clinical Documents" with a conference organized by the Turku Centre for Computer Science, in Finland (Karsten, H., Back, B., Salakoski, T., Salanterä, S., & Suominen, H., 2008). Much of the work prior to the 1990s has been superceded by later shifts in processing power and new ideas on the software development for this task. The review of the literature in this paper is restricted to later topics that are particularly relevant to automated processing of the language of clinical notes.

In 2001, Taira and Soderland published their approach to information extraction from clinical notes in the radiology domain. They proposed a general structure for such applications which was later used by many other research groups (Huang, Y., Lowe, H., Klein, D., & Cucina, R., 2005; Arnold, C. W., Bui, A. A. T., Morioka, C., El-Saden, S., & Kangarloo, H., 2007; Thomas, B. J., Ouellette, H., Halpern, E. F., & Rosenthal, D. I., 2005; Sinha, U., & Kangarloo, H., 2002). Their proposal had five steps of processing for a complete data retrieval system: *Structural analyzer,* Lexical analyzer, Parser, Semantic interpreter and Frame constructor. They performed an evaluation on this structuring and reported obstacles in: deep understanding of the domain, ability to deal with ungrammatical writing styles, shorthand and telegraphic writings, finding solutions for assumed knowledge between the writer and reader, and handling a large vocabulary. Following their work, different studies have expanded their proposed system to other clinical domains or addressed the reported issues (Sun, J. Y., & Sun, Y., 2006) and in some cases reported new obstacles.

Table 1. Summary of survey of the literature on processing clinical note

NLP Topics	Major Issues	Proposed Solutions	
Lexical & Phrasal	Orthography, Keyboard competency & Spell Checking	Regular expression and UMLS based dictionaries	
	Verbalization of named-entities & Drug names	No Clear Answer	
	Abbreviations & Shorthand	Regular expressions and disambiguation algorithms	
	LOTE issues: Phonological Transformation	No Clear Solution	
	Neologisms & productive morphology	No Clear Solution	
	Issue with Multi-word expressions & Capturing Phrases	Complex parser and external knowledge source	
		compositional mapping	
		Part of speech tagging	
		statistical natural language parser	
Semantics	Word sense disambiguation	Variety of algorithms	
	Mapping issue among Terminologies, Thesauri, Ontologies & classifications (TTOCs)	Frames	
		semantic definitions	
		Diagrams	
		combination of lexical, logical & morphological	
	Negation	regular expression matching	
		grammatical parsing	
	Concept Recognition	Statistical	Rule based
		Lexical	
		Hybrid	

Our discussion of a structure for a medical information extraction system has some parts in common with Taira and Soderland. Moreover, we describe the commonalities in efforts which have been made to address existing issues in the life cycle and the operational objectives of an information extraction system. Table 1 shows a summary of this survey.

Lexical & Phrasal Issues

In clinical notes there is a high complexity to orthography not found in other prose materials such as press reports and formal publications. Some of these domain specific issues are:

1. A large number of mistakes especially for long words.
2. Special abbreviations for entities such as chemical names.
3. Specialist shorthand for idiosyncratic cultural items
4. LOTE (Language other than English) staff using different phonological transformations
5. Keyboard competency
6. Specialty complex terms with variable greco-latin roots
7. Neologisms
8. Verbalization of named entities, especially drug names

9. Productive morphology combined with neologisms
10. Staff access and use of correct materials

In the past decade, researchers have tried to address some of the above issues in many different ways. A short summary of these efforts follows.

Lexical Verification

NLP is used to perform a variety of low level tasks in information retrieval systems such as term identification. Ananiadou et al in 1994, Frantzi and others in 1998 and Savova et al in 2003 reported different approaches in term identification (Savova, G., Harris, M. R., Johnson, T., Pakhomov, S.V., &. Chute, C. G., 2003; Ananiadou, S., 1994; Frantzi, K., Ananiadou, S., & Tsujii, J., 1998). All reported the affect of orthographic variations in their results. In 2002, Ruch described an IR system which was able to cope with textual misspellings. He demonstrated the extent to which dealing with spelling issues can improve the performance of an IR system (Ruch, P., 2002).

In 2007, Tolentino, Matters, Walop, Law, and Tong described a prototype spell checker which used UMLS and WordNet as primary and secondary domain specific dictionaries, and regular expressions as a look up method. The result was satisfactory except they reported relatively slow processing and low performance.

Lexical verification in clinical notes deals with different types of data for which some researchers suggested different approaches. In 2005 Zhou and Han introduced a new approach in extracting three groups of data from clinical notes: *numeric values, medical terms and categorical values.* Their approach considered three different approaches for these three different groups of data. It was extended in 2006 and they reported satisfactory results (Zhou, X., Han, H., Chankai, I., Prestrud, A., & Brooks, A., 2006).

Abbreviation Identification

Pustejovsky et al. (2001) described a solution for identifying abbreviations based on regular expressions and syntactic information which lead to an increase in the accuracy of identification of noun phrase boundaries. Chang et al. (2001) described an algorithm that uses linear regression, Park and Byrd (2001) and Yu et al. (2002) introduced some rule-based algorithms for extraction of abbreviations. Schwartz in 2003 described a very simple but effective algorithm for identifying abbreviations in the biomedical domain. Systems have also been developed to map abbreviations to full forms such as AbbRE (abbreviation recognition and extraction) by Yu et al (2002). There does not seem to be any comprehensive or specific studies on mnemonics in clinical contexts.

Phrasal Level

Dealing with multi-word expressions (MWE) and phrases has been a principal focus of researchers in recent years. Multi-word expressions have been traditionally recognised though standard terminologies. However non-standardized MWEs (e.g. weights and measures, administrative entities) are major issues in phrase processing.

Identification of NPs in both simple and complex forms is one of the challenges in this field where achieving a high precision is the main goal (Yu et al., 2002). In past work MetaMap (Aronson, A. R., 2001), MedLee (Friedman, C., Alderson, P. O., Austin, J. H., et al., 1994) use phrase identification as one of their important steps. MedLee has a Component for Phrase-regularization which regularizes the output forms of phrases that are not contiguous. Moreover MedLee uses a compositional mapping approach which is the combination of central finding (mapped term e.g. enlarged) with its attributes (e.g. severe) or body location modifier (e.g. heart) compared to a concept dictionary and if there are new matches with more accuracy then the combination of words they would be captured as a phrase.

Part of speech tagging for phrase identification also has been used since 1994 when Sager et al. reported a preliminary investigation on mapping clinical terms to SNOMED III (Sager, N., Lyman, M., Nhan, N. T., et al., 2004).

In 2005, Huang et al addressed this issue by using a statistical natural language parser trained on a nonmedical domain in conjunction with using a UMLS Specialist Lexicon. Their results were promising when their custom-designed system achieved almost similar performance figures for both medical and general domains (Huang, Y., Lowe, H., Klein, D., & Cucina, R., 2005).

Semantic Level

Concept Recognition

There are a number of different approaches in concept matching. Between 1990 and 1994, a project at the University of Pittsburgh (Lowe, H. J., Buchanan, B. G., Cooper, G. F., & Vries, J. K., 2005; Miller, R. A., Gieszczykiewicz, F. M., Vries, J. K., & Cooper, G. F., 1992;Kanter, S. L., Miller, R. A., Tan, M., & Schwartz, J., 1994) compared two available methods in concept matching - lexical and statistical - evaluated and combine them. The results of their efforts were two different systems: PostDoc (lexical) and Pindex (statistical). Each program takes free text as input from a patient's electronic medical record, and as output it returns a list of suggested MeSH terms. Cooper and Miller (Cooper, G. F., & Miller, R. A., 1998) followed the Pittsburgh's Project in 1998 and performed evaluation on both statistical, lexical and the hybrid methods.

Lexical analysis is one of these approaches. The lexical approach is computationally fast and useful for real-time applications (Huang, Y., Lowe, H., Klein, D., & Cucina, R., 2005); however, this approach may not provide optimal results without combination with other methods (Zou, Q., Chu, W. W., Morioka, C., et al., 2003). An example of this combination is Purcell et al.'s study. In 1995 Purcell and Shortliffe reported their experience in considering context in concept matching where they used concepts encoded in headings of clinical documents to elevate the accuracy (Purcell, G. P., & Shortliffe, E. H., 1995). Following their study, Berrios combined Purcell's technique together with a vector space model and a statistical method to match text content to a set of query types (Huang, Y., Lowe, H., Klein, D., & Cucina, R., 2005; Berrios, D. C., 2000). In 2003 *IndexFinder* was developed by Zou et al. to add syntactic and semantic filtering to improve performance on top of lexical mapping (Huang, Y. et al., 2005; Zou, Q., et al., 2003). Before this point some important research had been done with researchers focused on applying more sophisticated NLP techniques to improve concept recognition accuracy. Friedmen (1994) by using phrase identification tried to improve the concept matching.

In 2001, Nedkarni et al. performed a feasibility study on using UMLS in a computational strategy to identify concepts in medical narrative text. They concluded that the level of noise in the UMLS database impacted on the accuracy of their system and considerable filtering needed to be performed to define a UMLS subset that is suitable for concept matching. In 2007 *Osornio et al.* developed a local interface for SNOMED CT to let users design their own concept subsets or to modify the database to make it more amenable to their concept matching needs.

In 2006, Elkin et al. evaluated the Content Coverage of SNOMED in representing a clinical problem list. They reported encouraging results but they reported improvements to synonymy and adding missing modifiers would lead to a better coverage of SNOMED and address some common problems. Later In 2007, Patrick et al. proposed a system to translate free text clinical notes into SNOMED CT as a web service.

They installed their system in an intensive care unit (ICU) to be tested and evaluated in a real scenario. They reported restricting the concept mapping to noun phrase chunks can rule out many false positives and also increase the speed of processing. They also reported on issues like many pre-coordinated terms and qualifications cross noun phrase boundaries.

MedLEE (Friedman, C., et al., 2003) a system developed by Friedman et al. to encode clinical texts, is a well known example of a concept matching through structure detection. Along with MedLEE there are a few other applications (Taira, R. K., & Soderland, S. G., 1999; Taira, R. K., Soderland, S. G., & Jakobovits, R. M., 2001; Christensen, L., Haug, P. J., & Fiszman, M., 2002) which encode modifiers together with core concepts in noun phrases (NPs). The MedLee authors and others in 2005 have extended this approach to other clinical domains and reported encouraging results however they reported that there were many different fields open for improvement and research (Hripcsak, G., Kuperman, G. J., & Friedman, C., 1998; Hripcsak, G., Austin, J. H., Alderson, P. O., & Friedman, C., 2002; Friedman, C.$^{, 2000).}$

MetaMap (Aronson, A. R., 2001) is another concept matching method by structure detection which identifies UMLS concepts in text and returns them in a ranked list in a five step process. Step 1: parsing text for syntactic tagging and then indicating the most important parts of a phrase. Step 2: extracting all possible variants of a phrase and scoring them, Step 3: retrieve all concepts from UMLS which has at least one listed variant. Step 4: evaluate the candidates based on their score. Step 5: combine best candidates to generate the closest concept in UMLS.

Word Sense Disambiguation (WSD)

Although word sense disambiguation is a general field in which a great deal of work has been done, it is still a major field of study and open to research in clinical domain. Ruch et al. (2001) reported that clinical notes compared to unrestricted or general texts is much less ambiguous, however Weeber et al. (2001) reported that the world's largest medical thesaurus (UMLS), has more than 7,000 ambiguous strings that map to more than one concept in a thesaurus.

Nadkarni et al. (2001) reported that a complete automatic concept indexing in medical notes may not be achieved without addressing ambiguity issue in free text. A good example of the efforts in this area is Aronson $^{(}$2001) study. In 2001, Aronson reported that addressing ambiguity issues is important for enhancing the performance of MetaMap, a mapping program for UMLS concepts. Later in 2001, Weeber and Aronson with an intention to evaluate different available algorithms for WSD, developed a manually sense-tagged test collection of data (Weeber, M., Mork, J., & Aronson, A., 2001) suitable for this purpose. This test collection became a good resource for different researchers to evaluate their algorithms against a standard corpus like the study which has been done by Liu et al. (2002).

Most of the available approaches to word sense disambiguation use or combine different machine learning techniques and refer to characteristics of the ambiguity and its surrounding words relying on a collection of examples Schuemie, M. J., Kors, J. A., & Mons, B., 2005$^{;}$ Leroy, G., &. Rindflesch, T. C., 2003; Resnik, P., & Yarowsky, D., 2000; Dorow, B., & Widdows, D., 2003). In 2005 by Schuemie et al. performed a comprehensive study about WSD in biomedical domain in recent years. They classified the current available approaches into a 5 major branches namely, WSD using:

1. Established knowledge.
2. Bilingual corpora.
3. Supervised learning.
4. Feature vectors.
5. Unsupervised learning.

They concluded that the lack of adequate test sets is probably the most important obstacle to the development and evaluation of effective WSD methods in this field.

Negation

One of most extensive studies on negation was published by Mutalik et al. in 2001. They reported Negation of most concepts in medical narratives can be reliably detected by a simple strategy depending on several factors, the most important being the accuracy of concept matching. Later in the same year, Chapman et al. conducted a study about negation recognition algorithms and they concluded that to be robust a negation algorithm triggered by the negation phrases should apply syntactic and lexical knowledge.

In 2005, Elkin et al improved the Chapman and Mutalik findings by comparing the accuracy of an automated mechanism for assignment of negation to clinical concepts with human assigned negation. They performed a failure analysis to identify the causes of poorly identified negation. Based on their findings, they introduced a new strategy of association of the negative concept to other concept(s) to increase the accuracy.

While most of the negation identification approaches rely on either regular expression matching (Chapman, W. W., Bridewell, W., Hanbury, P., Cooper, G. F., & Buchanan, B., 2001) or grammatical parsing (Huang, Y., & Lowe, H. J., 2005). In 2007 **Huang** and his group introduced a new hybrid method combining regular expression matching with grammatical parsing. They reported the grammatical parser enabled them to detect negated concepts more accurately at a distance from the negation phrase.

It seems, negation identification in clinical notes cannot be done effectively without addressing special requirements of these types of text such as multiple negations and indirect negations are important sub-types of negation.

Mapping between Terminologies, Thesauri, Ontologies & Classifications (TTOCs)

There are a variety of lexical resources available for processing clinical texts. Bodenreider (2006) completed a study of many of them and concluded there are difficulties in differentiating between terminologies, thesauri, ontologies and classifications (TTOCs). Each however can be used solely as a lexical resource without considering its structural organisation. Nevertheless, a major issue in natural language processing is a lack of a truly comprehensive clinical vocabulary (Sun, J. Y., & Sun, Y., 2006). Several algorithms have been proposed to automate translation across the variety of TTOCs. Frames (Rocha, R. A., Rocha, B. H. S. C., & Huff, S. M., 1993), semantic definitions (Dolin, R. H., Huff, S. M., Rocha, R. A., Spackman, K. A., & Campbell, K. E., 1998) adopting diagrams [11], and a mix of lexical, logical and morphological methods (Rocha, R. A., & Huff, S. M., 1994) are examples of these algorithms.

In 2004 a comprehensive study was published by Sun (2004) about different techniques and approaches to finding a mapping between two different medical terminologies. He introduced an application, MEDIATE, which adopted semantic networks as an intermediary representation of the databases then an automated mapping algorithm can locate equivalent concepts in different TTOCs. The algorithms take advantage of the conceptual ‘‘context’’ implemented within a semantic network to populate a list of candidate concepts (Sun, Y., 2004). Later in 2006 he extended his work and introduced the LINC tool and listed some new obstacles that confront the data mapping efforts. (Sun, J. Y., & Sun, Y., 2006) This remains an unsolved problem with most practical solutions resorting to some degree of manual processing.

A MODEL OF NLP SERVICES FOR CLINICAL WORK

There are two classes of written materials relevant to studies of clinical narratives. The first class is published content for example, case studies, medical knowledge and clinical protocols/pathways, and standardized care plans. These have correct English prose, shifting contexts, and scientific background knowledge from many aspects of medicine: diseases, procedures, chemistry, pharmaceuticals, family history, and current care plans. The good prose strategy allows for the use of many of the traditional methods of NLP analysis.

The second class of materials is progress notes or clinical notes from the point-of-care. They are collected in acute care as ward notes and are very different (putting handwriting problems aside) in that they are written rapidly, have rapid shifts in context, extensive abbreviations, significant faulty and improvised orthography and grammar. Sources of some errors are LOTE background and poor typing skills. They make significant assumptions about context and in the limit are written in the highest order of assumptions about a priori knowledge being solely for the benefit and understanding of the writer without consideration of another reader.

Content analysis of published materials is about supporting IR to deliver general medical knowledge to the practitioner. Ward notes are multi-pronged and directed at supporting the attending physicians and their team for a much broader range of activities. We define physicians as needing to serve four roles in their working environment:

1. Point-of-care clinician
2. Researcher
3. Administrator
4. Auditor

In each of these roles the experienced physician has to constantly serve the modes of both the professional and the teacher. The use of progress notes and therefore the types of processing that they require varies between these roles.

The *point-of-care clinician* requires access to the narrative of the notes to determine their next act of care, hence the processing system needs to produce an extract of the current state of the patient and the issues that need to be addressed immediately about their ongoing care whether that is a short term decision as in the Emergency Department or the Intensive Care Unit, or for the longer term at the point of discharge from a hospital. The processing needs are essentially information extraction of particular items such as current diagnoses, care plans, current pathology results (taken from a narrative report) etc. These needs have a high requirement for precision of retrieval as errors of "fact" can lead to disastrous consequences, were as errors of omission are less likely to have such effect and more likely to lead to user discontent of the system.

The *researcher physician* has a somewhat different demand in that they are most interested in aggregation over sets of patient records in the process of performing analytics. Under these circumstances some errors in retrieval are likely to be tolerable as the conclusions one draws from aggregation are likely to be understood to have their own error behaviors. However as the research process is seeking associations between variables the nature of retrieval is intrinsically about the association of one phenomenon with another. This problem can be defined if one so wishes as two or more independent information extraction tasks, however it is likely to be more valuable and possibly more reliable to perform retrieval exploiting a supposed relationship between two variables of interest. For example a study of fractures and hips, would lead to a strategy to extract references to either collocated or anaphoric cross-references to hips and fractures with processing to assess their grammatical relationships (the x-ray showed a 20mm mass just above the hip which became fractured in a later fall") rather than a hunt for "fractured hip" and its string variants. This role and the language processing functions to be provided for it are fundamental to translational research both for retrospective studies and prospective studies.

The *administrator physician* has similar functions to that of the researcher physician in that they require aggregation of content across collections of patients. The difference is that the target variables will come from issues about usage and management of clinical resources.

The fourth role is that of *auditor physician*, that is, a person who audits the processes in the clinical unit to ensure they are maximized for patient safety as well as throughput. The auditor needs processing systems to support analysis of both single patient records and aggregation. When investigating an individual case the auditor will need tools to make ad hoc queries about a single case and at the same time seek to understand the performance of the unit over collections of cases to establish if single cases are out of the norm.

Understanding the roles of clinicians and their needs enables targeting the design and development of language technology to attend to those needs and so deliver productivity and patient safety gains in the workplace.

In summary, the processing requirements are to perform information retrieval on single records to find the precise location in the record for a precise piece of information. For example a staff member attending a patient might want to ask a specific question *"what medications were ordered by this morning ward rounds staff"* which most closely matches an information extraction or Q&A process. Nevertheless another question could be *"what is this patient's care plan and how far have we progressed with?"* This question requires extracting a set of information that has some intrinsic coherence which may well not be all in the one place, in particular the record of actions in executing the care plan will be distributed over pages of notes recorded across the whole time period the patient has been in hospital.

The role of the researcher physician has both different and overlapping needs to the point-of-care clinician. The researcher requires aggregation over records as they investigate the behaviors of staff/processes/drugs/procedures over a collection of specially defined patients. They also need to be able to frame their questions in a manner that is linguistically formal but in the terminology of the clinical setting. The language processing needs for this role are formidable as it requires a number of processing sub-systems to be delivered:

1. Support the common language in the clinical setting in use in the user interface.
2. Information extraction from the individual patient records.
3. Co-ordination of record retrieval based on language and non-language variables.
4. Descriptive statistics analytics using the two types of variables concurrently. An example question might be: "*what is the mean hospital bed occupancy of all males over the 5-year age groups of 40-90 with lung cancer?*"
5. Analytical Statistics comparing hypotheses, for example: "*is there a statistically significant difference in the age of admission for women compared to men for an upper respiratory tract cancers treated by chemotherapy compared to radiotherapy?*"

The processing systems required by the roles of administrator and auditing should be catered for by the systems needed for point-of-care clinician and the researchers if they are designed with sufficient generality.

Experienced staff will need to place themselves in all four of these roles, and their modes of practitioner and teacher, many times in the working week. The objective of NLP should be to develop systems to serve these roles and their modes. The following case study of a corpus analysis identifies many of the problems associated with the current quality of clinical documentation and the strategies we have to implement to overcome them, so that the contents can be used for retrospective clinical research. Moreover building new language technologies to eliminate or minimise these problems paves the way to doing prospective studies in situ in the clinical context and thereby support the enhancement and momentum of translational research.

A CORPUS OF NARRATIVE NOTES FROM AN INTENSIVE CARE UNIT

Building practical language processing systems to serve the roles of physicians and hence support the care and safety of patients and as well as the advancement of medical science requires learning from retrospective studies the limitations of already recorded information and then to design and build new technologies to overcome them. This has been achieved in the case of a study of intensive care notes from an Australian hospital.

The corpus of this study was drawn from 6 years of progress notes (2002-2006) consisting of 44,000,000 words written about 12,000 patients. The notes represent the recordings of all disciplines working in the Intensive Care Service of the Royal Prince Alfred Hospital, Sydney Australia, including intensivists, visiting medical officers (medical specialists), nurses and allied health workers (physiotherapists, psychologists, dietitians, etc.). The corpus is to be known as the RPAH-ICU corpus.

Stages of Processing

This paper deals with a range of issues important to processing these materials before they reach the stage of being usable for information extraction, plus some of the issues related to working as collaborators with clinicians pertinent to the privacy of the records.

Anonymisation

While anonymisation is not directly related to information extraction for use in the clinical wards, it is important in obtaining access to these records so that they can be removed off-site to our own installation for extensive analysis. Hence it is a matter that all researchers have to resolve early in their work. The simplest form of anonymisation is achieved by removing the names and address of patients from the header of the record and only use a Medical Record Number (MRN) to identify the record. This step provides surface anonymisation but there may be other personal information in the record that can enable reconstruction of the patient identity. This can happen especially with distinctive information such as rare disorders, rare locations (e.g. the location of a motor car accident), distinctive names of relatives or attending physicians when combined with information such as age and gender of the patient.

Deep anonymisation requires replacement of the names of all third parties in the narrative notes, including hospital staff and relatives, the names of organisations including other hospitals. It is not normally sensible to remove references to age and gender of a patient as this information tends to be important in many aspects of care and so for any future processing tasks, however reference to specific dates of birth should be removed.

An effective method for identifying names of entities not found in suitable gazetteers is to complete a process of lexical verification over the complete corpus and then manually search the list of unknown words for named entities. Whilst this does not guarantee all named entities will be identified it will capture a very large proportion. We have found that the only names we have not been able to recognise are those from languages with which we are unfamiliar. One confounding variable in this process is the names of medical entities which carry the name of a person. This

Table 2. Distribution of the known and unknown words in the RPAH-ICU corpus

Token Type	No. of token types	No. of tokens in corpus	Percentage
Alphabetic words	157,866	31,646,421	71.8%
Words in Moby	32,081	28,095,490	63.7%
Words in SNOMED	22,421	29,008,594	65.8%
Words in UMLS (excludes SNOMED words)	25,956	27,893,156	63.3%
Words in SNOMED but not in Moby	5,005	1,985,391	4.5%
Words in either SNOMED or Moby	37,086	30,080,881	68.3%
Words in neither SNOMED nor Moby (Unknown words)	120,780	1,565,540	3.6%

is a problem in two situations: when the word is miss-spelt and when the name is not recorded in the medical lexicon, e.g. Hudson mask.

Lexical Verification

Lexical verification is specifically separated from other lexical processing e.g. tagging, spelling correction, because there is a very significant problem in completing this task with narrative clinical notes. We have identified three phases to lexical verification. The first phase is compiling a set of lexica that can be used for verification. The second phase is separating out the unknown words and providing putative known words, and the third stage is capturing true words unknown to the current lexica in an automatic way that makes them readily re-usable.

Assembling Lexica

Lexica for medical NLP need to be assembled from a variety of locations. A lexicon of common English words was taken from the MOBY resource. Medical terminology was drawn from the UMLS and also SCT. SCT is not strictly a lexicon but an ontology consisting of a large collection of medical concepts (approx 360,000). In our work we stripped the individual words of each concept to make a lexicon. The concepts were used in a later processing stage. Many more lexical resources can be found on the Internet for single word processing but are not available for high volume batch throughput. The RPAH-ICU corpus was processed through each of these lexica with the results shown in Table 2.

Identifying and Correcting Unknown Words

Medicine has a highly productive use of language that is, it uses the rules of English word formation very regularly to produce new words, especially the combination of semantic fragments to form new clinical words. In our corpus we have discovered approximately 1000 words indicating medical anatomy and procedures that are not present in SNOMED CT, e.g. anteroseptoapicolateral, heparinise.

The former example shows the morphology of the concepts antero-, septo-, apico- and lateral. The later example has a range of forms that show multiple morphologoical transformations, its longest form so far discovered is “reheparinisation”, which demonstrates a process of taking a noun neologism, verbalizing it, nominalising the verb and then adding a prefix of repetition. Further cases are new forms of existing abbreviations, which might be treated as spelling errors, entirely new abbreviations, and new/proprietary drug names.

The RPAH-ICU corpus provided 120,780 unknown word types representing about 5% of the alphabetic words (Table 2) although they only constitute 3.6% of the total corpus. Whilst there is some temptation to treat this error rate as tolerable in a very large corpus it is not advisable. On an assumption of an average of 10 words per sentence then this error rate represents one unknown word in every second sentence which would produce a parsing error in 50% of the sentences, without allowing for errors from other sources.

The unknown word list was processed for putative corrections by computing the edit distances of 1 and 2 edits to known words. The results were divided into three classes: words that had only one candidate correct word (64,152), words that had multiple candidates (27,610), and words that had no candidates (29,018). The verification process involved inserting the words into a spreadsheet with their putative correct forms, manually checking the offered correction and accepting it or providing an alternative word. Checking was done by an experienced English speaker (JP) from personal knowledge and with support from use of dictionaries sources available from the Internet and Google searching. Unidentifiable words were referred to medical colleagues. Ever word type in the single candidate and no candidate classes have been manually corrected in this way. In the multiple candidate class all words down to a frequency of 4 (6312 types) have been manually verified, giving a total of about 100,000 corrected words.

Avenues of research created by having this material will be valuable for future work. Better automatic spell checking at the point of data entry of narrative notes will enhance the quality of the English and make post processing and especially semantic search and concomitant analytics more reliable. Further support at the point and time of data entry can be created and improved, e.g. automatic expansion of acronyms and abbreviations, verification of clinical terminology, autocompletion of difficult terminology for trainees and LOTE speakers.

Two other ICU corpora have been offered to us for similar analyses. This processing will significantly reduce the amount of effort we have to input into preparing these materials and providing analyses. Also we will be able to investigate the differences in lexicon and language usage from different instances of the same communities and thereby recognise the phenomena that are common to all and also triangulate on the level of differences that exist. The continuity of this work both within the community of Intensive Care Services and the potential to expand into other clinical disciplines makes it vitally important to effectively and automatically manage the collection of new language lexica and usage in the course of studying each corpus.

Capturing New Words

Identifying a "correct" form of a word is straight forward despite being very time consuming. However it is most important that the results of this work are captured whilst the work is progressing. Part of the process of manually verifying unknown words provide the opportunity to collect other information to attach to the word. In our case we have added semantic classes to words and descriptions of their morphological components where applicable. The morphology is useful in the future to recognise hyphenated and un-hyphenated version of words even though they have not been seen in the current corpus. The semantic class information we expect to assist us in later tasks of knowledge representation of the patient case, but we have no specific need for it at this stage.

New words need to be provided to subsequent lexical verification processes after they are initially captured. In principle this merely requires adding the word to the current word list used in the processing system. However if the full value of the process of acquiring new words is to be obtained a record needs to be kept of the source of the word and any other classificatory information that is collected at the time of verification, as described above. This approach demands the compilation of the history of the discovery and usage of the lexical item, which self evidently indicates the need to develop a lexical database to record the relevant content. The database should contain all the words identified from the corpus, which by implication includes the misspelt forms so that they can be readily used in later spell checking software. However, the primary function of the lexical database is to record the first source of the word (to the processing system) and then other classical lexicographical information. In a large production processing system the database itself would not be invoked but rather wordlists would be extracted from it for use in "in-memory" processing applications.

Spelling Correction

Automatic and semi-automatic spelling correction at the time of data entry can be based on two alternative premises. The first premise is that the true word can be found by searching a nearby space of letter configurations for the incorrect word – this is the edit distance model and it is effective if the true solution is truly close to the original word. The limitation is created by the fact that computing edit distance alternatives is expensive given real-time response is needed and it generates a large number of alternative answers. The second premise is that a mapping from the erroneous form to the true form is stored in a lexical database with perhaps better than 90% reliability. This approach is most limited when the true word is not stored. The alternative strategy is to build a statistical spell checker based on a supervised machine learner that estimates the type of mistake made by the user and offers alternatives based on the statistical characteristics of typical spelling errors. To develop such an approach requires the accumulation of the data we have collected by manually correcting the RPAH-ICU corpus.

Spell correcting as a post hoc process required for the analysis of a collected corpus requires some variations in these processes.

1. Word substitutions may sometimes be incorrect because the corrected word has not been identified in situ.
2. Some words cannot be corrected and remain "unknown".
3. The consequences of changing the text after the fact can be serious if any mark-up annotation has already been done to the text.

Appropriate planning for the acquisition of new words and their reuse in later processing needs to be carefully engineered. This is an on-going task for poorly composed materials which arises from the continual variation of content that is introduced in a large and busy hospital unit with diverse and ever-changing staff and patient populations.

The objective of the NLP research in this domain should be to draw an ever increasing amount of content from other clinical disciplines, where each new additional corpus will be better served with a continued accumulation of new terminology and new usages of it.

Entity and Concept Recognition

The recognition of medical entities is a vexed and thorny problem for a number of reasons, namely:

1. There are many knowledge resources in existence and a subset has to be chosen to do a particular piece of work, and any selected resources will have their own gaps in the knowledge one needs to give complete coverage for a given corpus.

2. Even with the use of a comprehensive resource like SNOMED CT when gaps are detected there is no ready mechanisms for inserting the nearly discovered content into the original resource.
3. Rich entity resources have concept entities written in linguistically idiosyncratic ways which create their own obstacles to being used for ready recognition in narrative notes. For example the SCT concept of "third degree burn of elbow with loss of limb" can be written in a myriad of other grammatical forms. In another classification it might have the form "burn, 3rd degree". The processing system needs to be able to reduce both the resource text and the narrative text into canonical forms so there is a better chance of matching the narrative with the concept definitional text.

The RPAH-ICU corpus was analysed for concepts using a methodology reported in Patrick et al. (2007) which indexes every SCT concept for its words (excluding stop words) and then reduces the target text to chunks which are in turn canonicalised. Matches with the SCT words are made and the highest ranked matching concept is accepted as the authentic concept representation of that chunk in the narrative notes. Figure 1 shows an example of a block of narrative text, the SCT concepts recognised and the locations they have in the SCT ontology. Apart from 6 true positives there are 4 false negatives: "Cholycystectomy" is "Cholecystectomy" in SCT, a spelling error in "hypogylcaemics", BSL is an unknown abbreviation in SCT, and cardiac failure is an incomplete expression in SCT used in a total of 27 different concepts. Manual inspection of concept identification suggests the error rate on false negatives is between 20-30% without allowing for all forms of orthographic variation. The amount of false of positives has not been estimated yet, as they require extensive manual analysis of the texts.

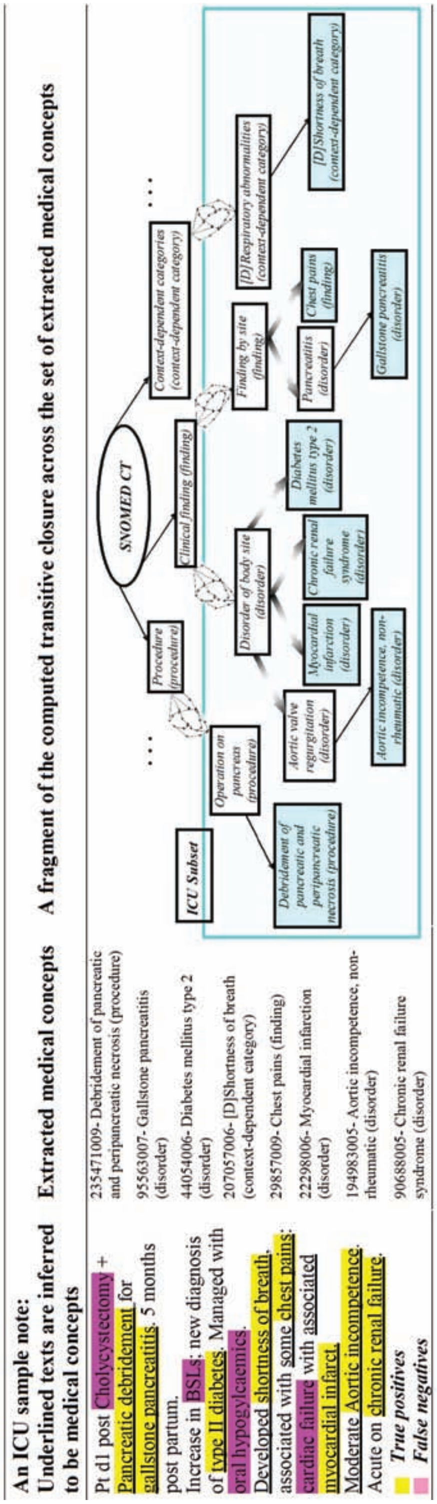
Terminology Server

An infrastructure for supporting the analysis of text requires an underpinning data repository that stores all the language resources and also supports a variety of processing tasks. Typically NLP projects have used a lexical database for this function however this is not sufficient for clinical NLP. In this field the medical knowledge is invariably stored in more complex knowledge schemata such as TTOCs, from which the terminology server has to deliver all their structure to an application as is necessary. Design issues of terminology servers have not been visited since the late 1990s (Chute, C., Elkin, P. L., Sheretz, D. D., & Tuttle, M. S., 1999) and require a review which we are undertaking. However the practical experience of this research indicates that a terminology server must serve at least the needs of concept identification, data analytics, Inter TTOC mapping, and decision support. It is within the terminology server that medical terminology that is acquired during processing a corpus is not only recorded but placed within a TTOC framework to maximize its potential re-use in knowledge modelling – not just language processing.

Research Objectives

A set of SCT concepts extracted from a large corpus brings the opportunity to inductively infer the most appropriate subset of SCT for Intensive Care services. There are 13,136,022 concept instances making up about 30,000 unique concept types detected in the corpus. Reducing the set of concepts to those of a frequency 100 and more yields the reduced set comprising 2718 codes, which covers 6,177,077 of the 6,428,597 codable item instances or 96.09% of all codable items. The remaining 3.91% of codable items (n=251,520) requires an additional 21,375 SCT codes. Restricting the set to only the top 1000 codes by usage would cover 89.25% of the codable items in the corpus.

Figure 1. *Example of clinical narrative notes annotated of SCT codes and illustration of their relationships in the SNOMED CT ontological structure*



Subsequent to computing the SCT subset evidenced in the corpus another stage of computing the minimal superset of the evidenced set and the local sub-trees around them has to be performed. This ensures coverage beyond what has been observed to what might reasonably be observed without allowing the subset to expand too greatly. The subset inferred from this strategy produced about 15,000 concepts and relationships or about 1% of the total SCT database.

The process has a number of advantages over recruiting a panel of experts to define a suitable SCT subset, namely:

1. It constitutes the evidence for the subset in an unchallengeable manner.
2. It is not susceptible the vagaries of human memory and preferences to compose the list.
3. It provides a small enough list for the subset to be manually reviewed and modified to create an improvement on "native" SCT.
4. Once the methodology is systematized it provides a strategy reusable for any and all clinical specialties.
5. It should prove to be both a highly economical and efficient method of deriving subsets that are more reliable.
6. It shrinks SCT enough so that description logic engines might perform queries for users in real-time.

PRACTICAL APPLICATIONS OF NLP IN THE HOSPITAL WARD

The use of entity and concept identification can assist in a number of fundamental tasks in the care process. In the two use cases described below (WRIS and CliniDAL) the SCT concept identification enables a semantic index to be created over the narrative notes and thereby provide a mechanism for fast retrieval and categorization of their contents. Much of the activities in processing narrative notes can be viewed as research for academic purposes and contributing to computational linguistics research in its own right. However, it is more valuable and rewarding to affix the research to objectives of providing improved processing for the medical care work of itself. Described below are two projects that require the use of our knowledge and research into the ICU corpus but where that knowledge has been put to use for practical benefit for our medical collaborators.

Ward Rounds Information System

The Ward Rounds Information System (WRIS) is a two part processing system aimed at gaining work productivity in carrying out ward rounds in the ICU (Ryan, A., Patrick, J., & Herkes, R., 2008). In the past the system for performing ward rounds entailed a junior doctor reading many pages of the clinical IS and compiling the most appropriate recent information into a report. This process was error prone, tedious and timely costly taking between 5-10 minutes per patient and needing to be repeated across a 50 bed ward. The first phase of WRIS was to build a complementary system that read the wanted data from the host IS and presented it on a web page. The second phase of the WRIS was for the medical staff to write their clinical notes into the web page and then submit them for conversion to SCT codes. These codes are presented to the staff along with the original text and they are asked to confirm or reject the computed codes. The accepted codes can then be written to the patient record and by being resident there they constitute an index of the record for later retrievals and analytics. The rejected codes form a body of knowledge that can be used to improve the text to SCT encoding process. This technology is now the basis of a wider project to produce a generic strategy for generating Handover reports based on natural language processing.

Clinical Data Analytics Language (CliniDAL)

The CliniDAL is a controlled language for expressing queries to perform retrievals and data analytics on the patient records held in the host clinical information system. It is especially designed to support the use of local clinical dialectal language to express queries, but also it executes those queries over the clinical notes as well as the structured parts of the database. CliniDAL contains a mapping table of every data field in the database relating it to a user interface term, SCT expression (where possible) and the community's clinical sociolect. Furthermore the SCT indices created in the WRIS process are used for retrievals across the clinical notes.

CONCLUSION

All medical imaging and measurement eventually becomes language so NLP is the most important innovation required to advance medical research using the information captured at the coalface of health care – the patient record. Using the patient record retrospectively requires solving serious problems in dealing with linguistically inferior content. Learning how to solve these problems for the retrospective material is fundamental to creating aids for current staff to create future records of a much better linguistic quality and thereby enhance the quality and purposefulness of future language processing systems. There are major problems in giving full coverage to a very broad range of terminologies and concepts needed to be recorded in acute care situations. Better language processing is needed but it is also important that mechanisms ensure knowledge is captured at its time of first recognition and passed back into the processing system for continual reuse. It is an important facet of language processing that any created resource is always reusable and never suffers from depreciation, although the technology that exploits it might.

The narrative of the clinical record constitutes the most important piece of evidence collected in the process of caring for sick and infirmed people. Efforts to relate the outcomes of care processes to their interventions and the medicines will only be achieved on a large scale by harnessing the contents of the patient record, and at the moment, most of the relevant content is locked in the written text. While some valuable content is available from the structured part of the clinical record substantial advances in translational research are dependent on retrieving content locked up in the narrative texts. The technology required to achieve this access has to move through two major phases. Firstly significant studies have to make use of retrospective content to establish the nature of the contents and the best methods for dealing with the processing problems intrinsic to the nature of the data. We have described examples of those problems in this paper with respect to materials from one intensive care service. The second phase is inferring from this knowledge the technologies we have to build to support and shape the behaviours of clinical staff in the future so that firstly they minimise the problems we currently encounter, but also that the technology supports improvement in the way they record the content relevant to not only patient needs at the point of care but also to the larger objectives of translational research. Once such objectives are attained then natural language processing will be able to serve the prospective needs of medical science in very significant ways.

ACKNOWLEDGMENT

We wish to acknowledge the contributions of our partners and collaborators: Dr Robert Herkes and Angela Ryan from the Royal Prince Alfred Hospital, Peter Budd, Yefeng Wang and Yitao Zhang from the University of Sydney, and Prof

Alan Rector, Dr. Sebastian Brandt and Jeremy Rogers from the University of Manchester,and Bahram Vazirnezhad, Tehran University of Technology, Iran.

REFERENCES

Ananiadou, S. (1994). A methodology for automatic term recognition. In *Proceedings of COLING*, (pp. 1034—1038).

Arnold, C. W., Bui, A. A. T., Morioka, C., El-Saden, S., & Kangarloo, H. (2007). Informatics in Radiology: A Prototype Web-based Reporting System for Onsite-Offsite Clinician Communication. *Radiographics*, *27*(4), 1201–1211. doi:10.1148/rg.274065124

Aronson, A. R. (2001). Effective mapping of biomedical text to the UMLS Metathesaurus: the MetaMap program. *Proc AMIA Symp.*, (pp. 17–21).

Berrios, D. C. (2000). Automated indexing for full text information retrieval. *Proc AMIA Symp.*, (pp. 71–5).

Bodenreider, O. (2006). Lexical, terminological and ontological resources for biological text mining. *Text mining for biology and biomedicine*, (pp. 43-66). Artech House.

Chang, J. T., Schütze, H., & Altman, R. B. (2001). Creating an Online Dictionary of Abbreviations from MEDLINE. *J Am Med Inform Assoc*.

Chapman, W. W., Bridewell, W., Hanbury, P., Cooper, G. F., & Buchanan, B. (2001). Evaluation of negation phrases in narrative clinical reports. In *Proceedings of AMIA Symposium*, (pp. 105—109).

Chi, E. C., Sager, N., Tick, L. J., & Lyman, M. S. (1983). Relational data base modelling of free-text medical narrative. *Med Inform* (London).

Christensen, L., Haug, P. J., & Fiszman, M. (2002). MPLUS: a probabilistic medical language understanding system. *Proc Workshop on Natural Language Processing in the Biomedical Domain* (pp. 29–36). Philadelphia, PA.

Chute, C., Elkin, P. L., Sheretz, D. D., & Tuttle, M. S. (1999). Desiderata for a Clinical Terminology Server. *Proceedings of the AMIA Symposium* (pp. 42-46).

Cohen, A., & Hersh, W. (2005). A survey of current work in biomedical text mining. *Briefings in Bioinformatics*, *6*, 57–71. doi:10.1093/bib/6.1.57

Cooper, G. F., & Miller, R. A. (1998). An experiment comparing lexical and statistical methods for extracting MeSH terms from clinical free text. *Journal of the American Medical Informatics Association*, *5*, 62–75.

Dolin, R. H., Huff, S. M., Rocha, R. A., Spackman, K. A., & Campbell, K. E. (1998). Evaluation of a “lexically assign, logically refine” strategy for semi-automated integration of overlapping terminologies. *Journal of the American Medical Informatics Association*, *5*, 203–213.

Dorow, B., & Widdows, D. (2003). Discovering corpus-specific word senses. *EACL, Conference Companion* (research notes and demos), (pp. 79–82).

Elkin, P. L. (2006). Evaluation of the content coverage of SNOMED CT: Ability of SNOMED clinical terms to represent clinical problem lists. *Mayo Clinic Proceedings*, *81*(6), 741–748. doi:10.4065/81.6.741

Elkin, P. L., Brown, S. H., Bauer, B. A., Husser, C. S., Carruth, W., Bergstrom, L. R., & Wahner-Roedler, D. L. (2005). A controlled trial of automated classification of negation from clinical notes. *BMC Medical Informatics and Decision Making*, *5*, 13. doi:. doi:10.1186/1472-6947-5-13

Frantzi, K., Ananiadou, S., & Tsujii, J. (1998). The *C*-value/NC-value method of automatic recognition for multi-word terms. In *Proceedings of ECDL Symposium*, (pp. 585—604).

Friedman, C. (2000). A broad-coverage natural language processing system. *Proc AMIA Symp.*, (pp. 270–4).

Friedman, C., Alderson, P. O., & Austin, J. H. (1994). A general natural language text processor for clinical radiology. *Journal of the American Medical Informatics Association*, *1*, 161–174.

Friedman, C., Shagina, L., Lussier, Y., & Hripcsak, G. (2004). Automated encoding of clinical documents based on natural language processing. *Journal of the American Medical Informatics Association*, *11*(5), 392–402. doi:10.1197/jamia.M1552

Gabrieli, E. R., Speth, D. J. (1986). Automated analysis of the discharge summary,. *J. Clin Comput.*

Hahn, U., Honeck, M., Piotrowski, M., & Schulz, S. (2001). Subword segmentation—leveling out morphological variations for medical document retrieval. *Proc AMIA Symp.*, (pp. 229–33).

Hahn, U., Romacker, M., & Schulz, S. (2002). MedsynDikate—a natural language system for the extraction of medical information from findings reports. *International Journal of Medical Informatics*, *67*, 63–74. doi:10.1016/S1386-5056(02)00053-9

Hearst, M. (1999). Untangling text data mining. In *Proceedings of the 37th Annual Meeting of the Association for Computer Linguistics (*ACL'99), (pp. 3—10).

Hripcsak, G., Austin, J. H., Alderson, P. O., & Friedman, C. (2002). Use of natural language processing to translate clinical information from a database of 889,921 chest radiographic reports. *Radiology*, *224*, 157–163. doi:10.1148/radiol.2241011118

Hripcsak, G., Friedman, C., Alderson, P. O., DuMouchel, W., Johnson, S. B., & Clayton, P. D. (1995). Unlocking clinical data from narrative reports: a study of natural language processing. *Annals of Internal Medicine*, *122*(9), 681–688.

Hripcsak, G., Kuperman, G. J., & Friedman, C. (1998). Extracting findings from narrative reports: software transferability and sources of physician disagreement. *Methods of Information in Medicine*, *37*, 1–7.

Huang, Y., Lowe, H., Klein, D., & Cucina, R. (2005). Improved Identification of Noun Phrases in Clinical Radiology Reports Using a High-Performance Statistical Natural Language Parser Augmented with the UMLS Specialist Lexicon. *Journal of the American Medical Informatics Association*, *12*, 275–285. doi:10.1197/jamia.M1695

Huang, Y., & Lowe, H. J. (2005). A grammar based classification of negations in clinical radiology reports. *Proc AMIA Annu Fall Symp*, (pp. 988-92).

Huang, Y., & Lowe, H. J. (2007). A novel hybrid approach to automated negation detection in clinical radiology reports. *Journal of the American Medical Informatics Association*, *14*, 304–311. doi:10.1197/jamia.M2284

Humphrey, S. M. (1999). Automatic indexing of documents from journal descriptors: A preliminary investigation. *Journal of the American Society for Information Science American Society for Information Science*, *50*(8), 661–674. doi:10.1002/(SICI)1097-4571(1999)50:8<661::AID-ASI4>3.0.CO;2-R

Kanter, S. L., Miller, R. A., Tan, M., & Schwartz, J. (1994). Using PostDoc to recognize biomedical concepts in medical school curricular documents. *Bulletin of the Medical Library Association*, *82*, 283–287.

Karsten, H., Back, B., Salakoski, T., Salanterä, S., & Suominen, H. (Eds.). (2008). *Proceedings of The First Conference on Text and Data Mining of Clinical Documents.* Louhi'08. Turku, Finland.

Lau, L. M., Johnson, K., Monson, K., Lam, S. H., & Huff, S. M. (2002). A method for automated mapping of laboratory results to LOINC. *Proc AMIA Symp.*

Leroy, G., & Rindflesch, T. C. (2005). Effects of information and machine learning algorithms on word sense disambiguation with small datasets. *International Journal of Medical Informatics*, *74*, 573–585. doi:10.1016/j.ijmedinf.2005.03.013

Liu, H., Johnson, S. B., & Friedman, C. (2002). Automatic resolution of ambiguous terms based on machine learning and conceptual relations in the UMLS. *Journal of the American Medical Informatics Association*, *9*, 621–636. doi:10.1197/jamia.M1101

Lopez Osornio, A., Luna, D., Gambarte, M. L., Gomez, A., Reynoso, G., & Gonzalez Bernaldo de Quiros, F. (2007). Creation of a Local Interface Terminology to SNOMED CT [online]. In K. A. Kuhn, J. R. Warren, & T-Y. Leong (Ed.), *Medinfo 2007: Proceedings of the 12th World Congress on Health (Medical) Informatics; Building Sustainable Health Systems* (pp. 765-769). Amsterdam: IOS Press, 2007. Studies in health technology and informatics, ISSN0926-9630.

Lowe, H. J., Buchanan, B. G., Cooper, G. F., & Vries, J. K. (1995). Building a medical multimedia database system to integrate clinical information: an application of high performance computing and communications technology. *Bulletin of the Medical Library Association*, *83*, 57–64.

Miller, R. A., Gieszczykiewicz, F. M., Vries, J. K., & Cooper, G. F. (1992). Chartline: Providing bibliographic references relevant to patient charts using the UMLS Metathesaurus knowledge sources. *Proc Symp Comput Appl Med Care,* (pp. 86-90).

Mutalik, P. G., Deshpande, A., & Nadkarni, P. M. (2001). Use of general-purpose negation detection to augment concept indexing of medical documents: A quantitative study using the UMLS. *Journal of the American Medical Informatics Association*, *8*, 598–609.

Nadkarni, P., Chen, R., & Brandt, C. (2001). UMLS concept indexing for production databases: A feasibility study. *Journal of the American Medical Informatics Association*, *8*, 80–91.

Park, Y., & Byrd, R. J. (2001). Hybrid Text Mining for Finding Abbreviations and Their Definitions. *Proceedings of the Conference on Empirical Methods in Natural Language Processing*, (pp. 126- 133). Pittsburgh, PA, June 2001.

Patrick, J., Budd, P., & Wang, Y. (2007). An automated system for Conversion of Clinical notes into SNOMED CT. Health Knowledge & Data Mining Workshop. *Research & Practice in Information Technology*, *68*, 195–202.

Prather, J. C., Lobach, D. F., Goodwin, L. K., Hales, J. W., Hage, M. L., & Hammond, W. E. (1997). Medical Data mining: Knowledge discovery in a clinical data warehouse. *AMIA Annual Fall Symposium*, (pp. 101-5).

Purcell, G. P., & Shortliffe, E. H. (1995). Contextual models of clinical publications for enhancing retrieval from full-text databases. *Proceedings of the Annual Symposium on Computer Applications in Medical Care*, ▪▪▪, 851–857.

Pustejovsky, J. (2001). Automation Extraction of Acronym-Meaning Pairs from Medline Databases. *Medinfo*, *10*(Pt 1), 371–375.

Pustejovsky, J., Castaño, J., Cochran, B., Kotecki, M., & Morrell, M. &. Rumshisky, A. (2001). Extraction and Disambiguation of Acronym-Meaning Pairs in Medline. *unpublished manuscript*.

Resnik, P., & Yarowsky, D. (2000). Distinguishing systems and distinguishing senses: New evaluation tools for words sense disambiguation. *Natural Language Engineering*, *5*(3), 113–133.

Rocha, R. A., & Huff, S. M. (1994). Using diagrams to map controlled medical vocabularies. *Proceedings of the Annual Symposium on Computer Applications in Medical Care*, ▪▪▪, 172–176.

Rocha, R. A., Rocha, B. H. S. C., & Huff, S. M. (1993). Automated translation between medical vocabularies using a frame-based interlingua. *Proceedings of the Annual Symposium on Computer Applications in Medical Care*, ▪▪▪, 690–694.

Rosenbloom, S. T., Kiepek, W., & Belletti, J. (2004). Generating complex clinical documents using structured entry and reporting. *Medinfo*, *11*, 683–687.

Ruch, P. (2002). Using contextual spelling correction to improve retrieval effectiveness in degraded text collections. In *Procedings of the 19th international Conference on Computational Linguistics (COLING) - Volume 1* (Taipei, Taiwan, August 24 - September 01, 2002).

Ruch, P., Baud, R., Geissbuhler, A., & Rassinoux, A. M. (2001). Comparing general and medical texts for information retrieval based on natural language processing: an inquiry into lexical disambiguation. In *Proceedings of Medinfo Symposium*, (pp. 261—265).

Ryan, A., Patrick, J., & Herkes, R. (2008). Introduction of Enhancement Technologies into the Intensive Care Service, Royal Prince Alfred Hospital, Sydney. *Health Information Management Journal*, *37*(1), 39–44.

Sager, N., Lyman, M., & Nhan, N. T. (1994). Automatic encoding into SNOMED III: A preliminary investigation. *Proceedings of the Annual Symposium on Computer Applications in Medical Care*, ▪▪▪, 230–234.

Savova, G., Harris, M. R., Johnson, T., Pakhomov, S. V., & Chute, C. G. (2003). A data-driven approach for extracting ‘‘the most specific term’’ for ontology development. In *Proceedings of the AMIA Symposium*, (pp. 579—583).

Schuemie, M. J., Kors, J. A., & Mons, B. (2005). Word sense disambiguation in the biomedical domain: An overview. *Journal of Computational Biology*, *12*, 554–565. doi:10.1089/cmb.2005.12.554

Schwartz, A. S., & Hearst, M. A. (2003). A simple algorithm for identifying abbreviation definitions in biomedical text. In *Proceedings of the 8th Pacific Symposium on Biocomputing* (pp. 451–462).3rd–7th January, Hawaii.

Sinha, U., & Kangarloo, H. (2002). Principal Component Analysis for Content-based Image Retrieval. *Radiographics*, *22*(5), 1271–1289.

Sun, J. Y., & Sun, Y. (2006). A system for automated lexical mapping. *Am Med Inform Assoc*, *13*(3), 334–343. doi:10.1197/jamia.M1823

Sun, Y. (2004). Methods for automated concept mapping between medical databases. *Journal of Biomedical Informatics*, *37*(3), 162–178. doi:10.1016/j.jbi.2004.03.003

Taira, R. K., & Soderland, S. G. (1999). A statistical natural language processor for medical reports. *Proc AMIA Symp.*, (pp. 970–4).

Taira, R. K., Soderland, S. G., & Jakobovits, R. M. (2001). Automatic structuring of radiology free-text reports. *Radiographics*, *21*, 237–245.

Taira, R. K., Soderland, S. G., & Jakobovits, R. M. (2001). Automatic structuring of radiology free-text reports. *Radiographics*, *21*, 237–245.

Thomas, B. J., Ouellette, H., Halpern, E. F., & Rosenthal, D. I. (2005). Automated Computer-Assisted Categorization of Radiology Reports. *AJR. American Journal of Roentgenology*, *184*(2), 687–690.

Tolentino, H. D., Matters, M. D., & Walop, W. Law, **&** Tong, W. (2007). *BMC Medical Informatics and Decision Making.*

Weeber, M., Mork, J., & Aronson, A. (2001). Developing a Test Collection for Biomedical Word Sense Disambiguation. *Proc. AMIA Symp.*, (pp. 746-750).

Yu, H., Hripcsak, G., & Friedman, C. (2002). Mapping abbreviations to full forms in biomedical articles. *Journal of the American Medical Informatics Association*, *9*(3), 262–272. doi:10.1197/jamia.M0913

Zhou, X., Han, H., Chankai, I., Prestrud, A., & Brooks, A. (2006). Approaches to text mining for clinical medical records. In *Proc ACM Sympos Applied Computing* (SAC 2006), (pp. 235–239). April 2006. NY: ACM Press.

Zou, Q., Chu, W. W., Morioka, C., et al. (2003). IndexFinder: a method of extracting key concepts from clinical texts for indexing. *Proc AMIA Symp.,* (pp. 763–7).

This work was previously published in Information Retrieval in Biomedicine: Natural Language Processing for Knowledge Integration, edited by V. Prince and M. Roche, pp. 357-377, copyright 2009 by Medical Information Science Reference (an imprint of IGI Global).

Chapter 7.17

Multicriteria Models for E-Health Service Evaluation

Gulcin Buyukozkan
Galatasaray University, Turkey

R. Ufuk Bilsel
The Pennsylvania State University, USA

ABSTRACT

The use of advanced telecommunications and information technologies has been investigated for several decades as an effort in improving healthcare services. Over the last ten years, in particular, efforts have been centered on telemedicine, which has become an increasingly attractive field of research in healthcare service delivery. This chapter discusses multiple criteria evaluation of electronic healthcare (e-health) services, a branch of telemedicine, with both users' and practitioners' (service provider) perspectives. The proposed approach integrates several analytical decision making techniques and can be helpful in increasing the flexibility and efficiency of e-health service planning. Several different discrete alternative methods, namely AHP, Borda Count, LINMAP, and PROMETHEE are utilized to prioritize different e-health services and to evaluate preferences of both users and practitioners.

INTRODUCTION

Quality of healthcare service delivery has been one of the major issues facing healthcare providers, employees, employers, and government agencies. Healthcare delivery is mainly constrained by geographical location and economic status of intended receovers and operational efficiency at service providers. As a result, the healthcare community has faced challenges in distributing healthcare resources, providing healthcare equally to all socio-economic segments of the population, and controlling healthcare costs. One way to efficiently handle these limitations is to incorporate innovative information technologies (IT) in healthcare service delivery. Telemedicine has been proposed as a multifaceted IT based response to solve the above mentioned problems (Bashshur, 1997). American Telemedicine Association (ATA) defines telemedicine as the use of medical information, exchanged from one location to another via means of electronic communication, to improve health status of patients (ATA, 2006). The objectives of telemedicine, and of electronic health (e-health) which is an implementation of telemedicine, are to enhance patients' equality in the availability of various medical services despite geographical and economic barriers (McConnochie et al., 2006), reduce direct and indirect costs (loss of production or income) to patients and to healthcare industry (de Toledo et al., 2006), save travel time for both practitioners and patients (Samii et al., 2006), reduce waiting time and cut lines in healthcare institutions (MacFarlane et al., 2006) and improve consultation and co-operation among geographically distributed healthcare units by bridging the distance between practitioners and specialists (Harrison et al., 1996).

Telemedicine continues to become a facilitator in healthcare delivery. A recent article by Samii et al. (2006) describes a telemedicine application in Parkinson treatment. They used telemedicine to conduct follow up controls of 34 patients at several regional centers located 67 to 2,400 kilometers away from a main healthcare facility. They report cost, time and travel savings amounting up to $37,000, 1,500 patient hours and 100,000 kilometers. McConnochie et al. (2006) comment on benefits of telemedicine in the treatment of childhood illnesses. They tested the effectiveness of two practices: patients actually visiting physicians and patients treated via telemedicine. They found out that about 85% of cases were suitable for treatment via telemedicine and that telemedicine provided the same service effectiveness as personal visits. de Toledo et al. (2006) report a telemedicine service that delivers home care to chronic obstructive pulmonary disease patients. They tested the service during a period of one year and reported the improvements through telemedicine implementation. One of their major findings was that the telemedicine services resulted in up to 51% increase in the number of patients that were not readmitted and required low implementation costs. MacFarlane et al. (2006) report telemedicine applications in Ireland and provide some comments from actual practitioners and users of these services. They argue that reducing patient traveling and removing isolation from professionals for people in rural areas are among the significant benefits of telemedicine. Several other publications report successful telemedicine applications worldwide, including in Canada (Jennett & Andruchuk, 2001), Europe (Lareng, 2002), Nigeria (Adewale, 2004) and eastern Asia (Chen et al., 2001; Kasitipradith, 2001).

Surprisingly, despite the increasing popularity of telemedicine, published work in telemedicine service assessment is limited. One reason behind this scarcity is the lack of extensions of well developed brick-and-mortar service quality models to electronic services (e-services). Particularly, most of the e-health service evaluation literature is at the level of conceptual work (e.g. Bedini et al. (2006) and Giansanti et al. (2007)). A few papers addressing the issue via analytical approaches also exist. For instance, Bilsel et al. (2006) proposed a ranking method to evaluate hospital websites and presented an application in Turkey. They argued that telemedicine service assessment should be based on several evaluation criteria and proposed a multicriteria decision making (MCDM) scheme. They teamed up with actual decision makers (DMs) in their study and modeled their verbal judgments as fuzzy numbers for integration in the MCDM framework.

This chapter fills the service assessment gap in research on telemedicine service delivery evaluation by proposing MCDM methods and applying them to evaluate e-health applications. We study e-health services with both users' and practitioners' perspectives. Our aim in this separation is to bring a broader view to e-health service evaluation by acknowledging potential differences between what users are looking for and what practitioners are seeking to offer. Criteria of the problem are grouped in two sets in a way to reflect expectations of both parties and their understanding of e-health services. The proposed approach integrates analytical decision making techniques and can be helpful in increasing efficiency of e-health service planning and delivery. Our methodology will affect e-health service providers in at least two ways. Firstly, our results are valuable in better understanding demands and needs of customers. Moreover, the evaluation framework presented here can be extended with additional criteria and alternatives and be used in professional pre implementation and feasibility analyses.

This chapter is organized as follows. The immediately following section presents the overall evaluation framework. The next section, introduces problem alternatives and evaluation criteria followed by descriptions of MCDM methods used in the application. The section that follows presents results of two studies we conducted; Study 1 which treats the problem from users' point of view and Study 2 which provides a practitioners' perspective. Discussion and conclusions section compares and contrasts the two studies and concludes the chapter with a future research agenda.

EVALUATION FRAMEWORK

This section provides an overview of the evaluation framework proposed in this chapter. The first step is identifying the alternatives to evaluate and criteria to be used in evaluation. The second step selects appropriate MCDM methods for use in the ranking of alternatives. The third step involves interactions with DMs and acquires their preference information. The final step is the application of the MCDM methods to determine the ranking of alternatives. The framework can be summarized as below,

- *Step 1:* Determine the alternatives to evaluate and appropriate criteria to use in evaluation. This step should be carried out through a literature survey and by consulting the practitioners and users.
- *Step 2:* Determine one or several MCDM methods. The selection of the MCDM method depends on the number and type of alternatives. In our study, both criteria and alternative sets are finite and discrete (see the next section); therefore, we use discrete alternative MCDM methods.
- *Step 3:* Determine the DMs and the preference data collection method. The selection of the preference collection method depends on the number of DMs. Nominal Group Technique or Delphi Method are suitable for relatively small sized groups. For large groups questionnaires or surveys may perform better.
- *Step 4:* Collect preference data and apply the selected MCDM methods to rank alternatives. This step processes gathered data and derives conclusions using the selected MCDM methods.

We shall follow the above sequence in detailing the proposed framework.

ALTERNATIVES AND CRITERIA

In this section we present the evaluation criteria and alternatives used in the e-health service assessment study. We analyze e-health services from two different perspectives. In our first study we approach the problem from the perspective of e-health service users. The second study treats the same problem from the practitioners' point of view. Alternatives compared in these two studies are the same but there are differences in the criteria sets to acknowledge that the two parties may approach the same problem in distinct ways and criteria appropriate for one group is not necessarily valid for the other. All evaluation criteria and alternatives are derived from published literature including Parasuraman et al, (1988), Jennett & Andruchuk (2001), Cox & Dale (2002), Richardson (2002), González & Palacios (2004), Kim & Stoel

(2004), Van Iwaarden et al. (2004), ATA (2006), de Toledo et al. (2006), EHNAC criteria report (2006) and Bilsel et al. (2006). We have also made several modifications in the criteria sets following the suggestions of DMs prior to preference data collection sessions.

Alternatives

We consider the following six e-health services as alternatives in our analysis. The alternatives are determined in coherence with published literature including Richardson (2002), ATA (2006), de Toledo et al. (2006), EHNAC (2006) and through communications with practitioners. Some of these alternatives have been widely implemented in healthcare institutions which provide e-health services (e.g. teleconsultation) while some others are in trial phases in very few institutions (e.g. remote patient monitoring). The alternatives are as follows:

Teleconsultation (A1): A teleconsultation system is an e-health application to be used by physicians to inspect the medical symptoms of patients at remote locations. Teleconsultation may be performed either in real-time or asynchronously. In real-time teleconsultation, specialized medical staff inspects vital signals and images of patients and makes a diagnosis at the end of the session. In the asynchronous case, on the other hand, physicians accesses medical data at a later convenient time.

O*nline appointment (A2)*: An online appointment application is a service that allows patients to schedule physician appointments on the Internet. This service potentially eliminates human errors such as mistyping the appointment time or entering patient data wrong and may simplify the scheduling procedure. Online appointment can also reduce costs and increase efficiency of bookkeeping at healthcare institutions.

Online pharmacy (A3): An online pharmacy service functions similar to electronic marketplaces like Amazon.com or Buy.com and allows patients to purchase drugs over the Internet. The online pharmacy service involves online money transactions and may require physician's prescriptions as well.

Remote patient monitoring service (A4): Electronic patient monitoring is an advanced service that collects data at patient's location and sends it to a monitoring station for interpretation. Also referred to as home telehealth applications, electronic patient monitoring services might include transmission of specific vital signs such as blood glucose, heart ECG or a variety of indicators for homebound patients. Such services are proposed as a replacement to visiting nurses.

Electronic medical library service (A5): Electronic medical libraries are healthcare databases; patients can use these online applications to access information on various diseases and relevant suggestions about how to get cured. An electronic library service requires a well formed database to keep and deliver requested information and an intelligently created website to attract patients.

Electronic medical record (EMR) access (A6): An EMR contains a patient's health history and is highly confidential. A patient that needs to access his or her record would be able to do so electronically if such a service is provided.

Criteria for Study 1

We present below six criteria used in Study 1, the evaluation of e-health services from users' perspective. Criteria are derived from published literature on service quality including Parasuraman et al., (1988), González & Palacios (2004), Kim & Stoel (2004) and Van Iwaarden et al. (2004). The criteria set is slightly modified after interactions with DMs: accessibility was previously the second criterion in this set but was modified to access speed following DMs suggestions. Criteria used in Study 1 are as follows,

Web design (C_u1): This criterion represents the quality of the web page through which the e-health service is delivered. An effective web design should be user oriented and customizable. Site layout, graphic animations and presentation are also important features. A sophisticated web design may attract more users; hence, web design criterion is to maximize.

Access speed (C_u2): Access speed emphasizes the importance of the time required to get information from the web server. This criterion was proposed by the DMs of Study 1. It is assumed that all users have the same bandwidth, so that the access speed would depend only on the size of the application and the upload rate of the e-health service server. The access speed criterion is to maximize.

Attractiveness (C_u3): Attractiveness measures the attitude of potential customers towards an e-health service. If the DMs think that a particular service would be useful they assign a high attractiveness score. Hence the attractiveness criterion is to maximize.

Safety threat (C_u4): This criterion is used to measure the users' attitude towards the level of exposure to threat while using a particular e-health service. If the DMs think there is a high possibility of personal information theft while using a particular service, the safety thereat for that service is high. Safety threat criterion is to minimize.

Quality of content (C_u5): Quality of content refers to the relevance of the content of an e-health service, level of detail of the information and frequency of updates. Quality of content criterion is to maximize.

Interactiveness (C_u6): Interactiveness is related to the degree of responsiveness of an e-service. It is an important feature for an e-service to be user friendly and practical. Interactiveness criterion is to maximize.

Criteria for Study 2

The second set of criteria is used in the evaluation of the e-health service alternatives from the practitioners' point of view. These criteria are denoted with a subscript *p* to distinguish them from the criteria used in Study 1. Except for the web design criterion, criteria for Study 2 are different from criteria used in Study 1. Criteria of Study 2 are derived mainly from the following references: Jennett & Andruchuk (2001), Cox & Dale (2002), Bilsel et al. (2006) and through interactions with the DMs of Study 2.

Web design (C_p1): The web design criterion in Study 2 represents the same concept as in C_u1 of Study 1. The web design criterion is to maximize.

Service readying time (C_p2): Service readying time represents time spent to prepare the content of the e-service to offer and to execute required operations before going online; such as testing and validating the web site operability. Some services might require acquiring special permissions or may be subject to some particular regulations that need to be satisfied and meeting these requirements might be time consuming. In the contemporary competitive business environment, institutions that can offer new services faster have better chance to gain competitive edge over their rivals; therefore, a shorter readying time should be preferred. Hence, the service readying time criterion is to minimize.

Customer potential (C_p3): The customer potential criterion represents the expected number of customers that would use the new e-health service. The estimated number of future users is vital to the success of the e-health service. The customer potential criterion is to maximize.

Setup difficulty (C_p4). Setup difficulty represents the complexity of the operations executed during the service readying period such as the complexity of the underlying software, synchronization of the new e-health service with the current hospital IT systems, etc. This criterion is to be minimized.

Staff training (C_p5). Current staff at a medical institution may require additional training to provide a new e-health service. For instance, in a teleconsultation service physicians should be familiar with setting and conducting video conferences and online data sharing. If practitioners do not have the required background, they have to receive training to be able to offer the new e-health service and may delay the implementation. These instruction sessions will also consume resources such as time and money. Hence, the staff training criterion is to be minimized.

Expected utility (C_p6). The expected utility criterion represents possible outcomes of offering a new e-health service. The expected utility criterion is proposed by the DMs who participated this study and is mostly perceived as financial benefits. The expected utility criterion is to be maximized.

EVALUATION METHODS

MCDM methods provide the flexibility of considering multiple measures in comparing and ranking a set of alternatives. These methods are especially useful in problems where analysts and DMs desire to treat the problem using more than one criterion. MCDM is one of the rare operations research techniques where DMs are involved in the solution process. This feature brings two significant advantages: the problem can be easily structured corresponding to DMs requests and the results are more easily adopted by DMs since they are actively involved in the solution procedure (Masud and Ravindran, 2007). We have determined four MCDM methods to be used in our framework. Following subsections detail these methods and justify our selection.

The PROMETHEE Method

PROMETHEE (Preference Ranking Order METHod for Enriched Evaluations), developed by Brans (1982) and further extended by Brans & Vincke (1985) and Brans & Mareschal (1994) is an effective ranking method which is accepted as one of the most intuitive of all discrete alternative MCDM methods (Pomerol & Barba Romero, 2000). PROMETHEE has found a large domain of application such as finance (Bouri et al., 2002), transportation (Ülengin et al., 2001), energy source selection (Topçu & Ülengin, 2004), information technology strategy selection (Albadvi, 2004), and hospital website evaluation (Bilsel et al., 2006).

The PROMETHEE approach is based on a preference function Ω which expresses the DM's preference for an alternative against other alternatives. For two alternatives α and β and a criterion j to be maximized, let the evaluation of the alternative α under criterion j be denoted as $C_j(\alpha)$ and let the difference of the evaluations of α and β as $d_j(\alpha, \beta)$ as in Equation (1).

$$d_j(\alpha, \beta) = C_j(\alpha) - C_j(\beta) \quad (1)$$

Two critical values, an indifference threshold q and a strict preference threshold p can be introduced to customize the preference function. Then, Ω can be presented as in Equation (2)

$$\Omega_j(\alpha,\beta) = \Omega_j\left[d_j(\alpha,\beta)\right] = \begin{cases} 0 \ if \ d_j < q \\ H_j(d_j) \ if \ q \le d_j \le p \\ 1 \ if \ d_j > p \end{cases} \quad (2)$$

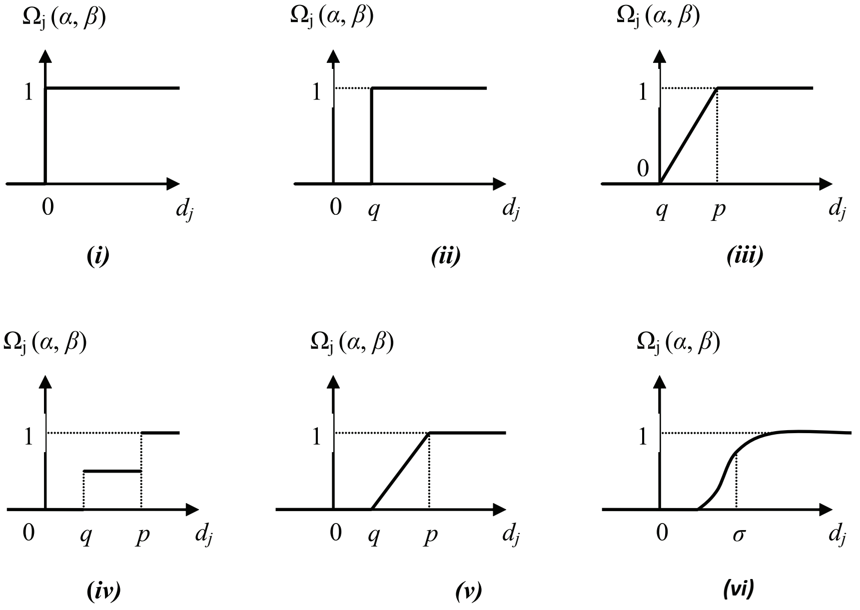
where H_j is a criterion function varying in the interval [0, 1]. Six different H_j functions have been proposed to be used in PROMETHEE. These functions are given in Figure 1. Note that the preference function Ω takes values in the interval [0, 1].

Once the type of the H_j function to be used for each criterion j is determined, the preference index $c(\alpha, \beta)$ can be calculated as follows,

$$c(\alpha,\beta) = \sum_j w_j \Omega_j(\alpha,\beta) \quad (3)$$

where w_j represents the weight of criterion j. For a proper application of the PROMETHEE method, weights should be strictly positive and

Figure 1. H_j functions. i: Simple criterion; ii: Jump with indifference threshold q; iii: Linear passage with indifference threshold 0 and strict preference threshold p; iv: Staircase; v: Linear passage with indifference threshold q and strict preference threshold p; vi: Gaussian. (Schärlig, 1996)



normalized. Several different methods can be used to calculate the w_j values. In this chapter PROMETHEE weights are calculated using the Analytic Hierarchy Process (AHP) detailed in the next subsection. Several other publications followed the same approach as here (see for example Macharis et al., 2004, Bilsel et al., 2006)

The next step calculates flow values of alternatives. PROMETHEE uses two types of flows: *leaving flow* and *entering flow*. The leaving flow of an alternative α is an indicator of preference of α over all other alternatives. It quantifies the relative "strength" of alternative α. The leaving flow is calculated as in Equation (4).

$$\Phi^{+}(\alpha) = \sum_{x \in A} c(\alpha, x) \tag{4}$$

where A is the set of alternatives. Entering flow of an alternative α, on the other hand, indicates the superiority of all other alternatives over α; that is, it quantifies the relative "weakness" of alternative α. The entering flow is calculated as in Equation (5)

$$\Phi^{-}(\alpha) = \sum_{x \in A} c(x, \alpha) \tag{5}$$

In PROMETHEE I, alternative α is declared superior to alternative β if the leaving flow of α is greater than that of β and the entering flow of α is smaller than that of β. Using our notation, α outranks β if $\Phi^{+}(\alpha) \geq \Phi^{+}(\beta)$ and $\Phi^{-}(\alpha) \leq \Phi^{-}(\beta)$. α and β cannot be compared if $\Phi^{+}(\alpha) > \Phi^{+}(\beta)$ and $\Phi^{-}(\alpha) > \Phi^{-}(\beta)$ or if $\Phi^{+}(\alpha) < \Phi^{+}(\beta)$ and $\Phi^{-}(\alpha) < \Phi^{-}(\beta)$. The PROMETHEE II method can be applied to overcome the issue of incomparability and to obtain a complete ranking. PROMETHEE II takes into consideration the net flow values, Φ^{net}, calculated as the difference of leaving and entering flows as in Equation (6). The alternative with a higher net flow value is better than the ones with smaller net flows.

$$\Phi^{net}(\alpha) = \Phi^{+}(\alpha) - \Phi^{-}(\alpha) \tag{6}$$

PROMETHEE provides an intuitive and tractable approach to treat MCDM problems. It poses relatively less burden on the DMs compared to other well known methods (AHP for instance); and therefore, it's more attractive. Finally, PROMETHEE is very flexible since it provides analysts with a wide range of criterion function shapes (see Figure 1).

The Analytic Hierarchy Process

Analytic Hierarchy Process (AHP), developed by Saaty (1980), is one of the most widely applied discrete alternative MCDM methods. It has been used in a wide area of applications including telecommunication systems selection (Tam & Tummala, 2001), supplier selection (Chan, 2003), new product development (Ayag, 2005) and flexible manufacturing systems (Bayazit, 2005). Moreover, AHP is also used as a means of generating weights to be used in other MCDM methods, e.g. PROMETHEE (see for instance Macharis et al., 2004)

AHP consists of constructing a problem hierarchy, defining priorities between the elements of the hierarchy and checking for overall consistency of DM´s evaluations. The first act when applying AHP is to recast the decision problem into a hierarchy with a goal at the top, criteria and sub-criteria at descending levels and sub-levels and decision alternatives at the bottom. Then, elements of the constructed hierarchy are compared in pairs in order to set their relative priority with respect to elements at the immediately upper level. The DM is suggested to use a fundamental 1-9 scale defined by Saaty (1980) to assess the priority scores. In this context, the assessment of score 1 for a pairwise comparison indicates equal importance of the compared criteria. A score of 3 indicates the first criterion is preferred moderately more, 5 strongly more, 7 very strongly more and 9 extremely more. The intermediate values 2, 4, 6, and 8 are allotted to indicate compromise between the scale values.

AHP requires pairwise comparisons of criteria among themselves to determine criteria weights. In a problem with *N* criteria, preference values are stored in an N-by-N pairwise comparison matrix $\mathbf{A}_{\mathbf{NxN}}$. Let the entry at the intersection of row *i* and column *j* of **A** be a_{ij}. A criteria weight vector $\boldsymbol{w}$ is obtained by normalizing the a_{ij} values first with respect to the columns of **A** using the L_1 norm as in Equation (7) and then with respect to rows as in Equation (8).

$$r_{ij} = a_{ij} \Big/ \sum_{i=1}^{N} a_{ij} \tag{7}$$

$$w_i = \frac{1}{N}\sum_{i=1}^{N} r_{ij} \tag{8}$$

AHP assumes that the weights calculated verify Equation (9) where λ_{max} is the largest eigenvalue of **A**.

$$\mathbf{A}.\boldsymbol{w} = \lambda_{\max}.\boldsymbol{w} \tag{9}$$

λ_{max} is used to evaluate the consistency of DM's pairwise comparison inputs. λ_{max} can be approximated as in Equation (10).

$$\lambda_{\max} \approx \frac{1}{N}\sum_{i=1}^{N} \frac{(Aw)_i}{w_i} \tag{10}$$

Consistency of DM's inputs is checked in two steps. First, the λ_{max} value is fed into Equation (11) to calculate a consistency index (CI) value.

$$CI = \frac{\lambda_{\max} - N}{N - 1} \tag{11}$$

Then, the CI value is divided by an empirical consistency value RI which depends on the problem size. Usually, the DM's inputs are assumed to be consistent if the final consistency ratio is smaller than 0.10. If the DM's inputs are inconsistent, then he needs to provide new pairwise comparison data until consistency is reached. The above process is repeated to get the pairwise comparison results of alternatives with respect to each criterion. The scores of alternatives are recorded in a matrix **B** and the final ranking is obtained through multiplying **B** by the criteria weight vector ***w*.** A more detailed description of AHP can be found in Masud and Ravindran (2007).

AHP provides a systematical way to structure a MCDM problem as a hierarchy, analyze the hierarchy using matrix calculations and check for consistency for assessing the overall quality of the analysis. It also provides criteria weights as a byproduct which can be used in other MCDM methods. For large problems however, AHP requires tedious calculations and may pose significant cognitive burden on the DMs.

Borda Count Method

Borda Count is a discrete alternative MCDM method where a DM ranks alternatives in order of preference. For an MCDM problem with P criteria, the criterion ranked first by the DM gets P points, the criterion ranked second gets $P - 1$ points, etc., where the last criterion gets 1 point. Let S denote the sum of all points. Then the first ranked criterion gets a score of P/S; the second ranked criterion gets a score of $(P - 1)/S$, etc. and the last criterion is assigned a score of $1/S$. The score of an alternative is calculated by multiplying the alternative´s evaluation for a criterion with the weight of that criterion. The overall score of an alternative is calculated by summing the scores of that alternative over all criteria.

Borda Count is less frequently applied compared to AHP and PROMETHEE. It has been used in engineering design (Dym et al., 2002) and pattern recognition (Nanni & Lumini, 2006). Borda Count is relatively easier to apply compared to other MCDM methods with less cognitive and computational burden.

The LINMAP Method

LINMAP is a discrete alternative method based on pairwise comparison of alternatives (Srinivasan and Shocker, 1973). Using these comparisons, a linear programming formulation is crated to minimize the inconsistency of DMs. Let **A** be the matrix of paired comparisons of alternatives with respect to P criteria and let $S_i = \sum_{j=1}^{P} a_{ij} w_j$ be the score of alternative i. Decision variables in LINMAP are the criteria weights denoted by w_j. If alternative i is superior to alternative k, then the score of alternative i should be greater than the score of alternative k; that is, $S_i > S_k$. However, this inequality may not be verified if the DM is not consistent. LINMAP accounts for DM´s inconsistency and introduces an error term x_{ik} for the comparison of alternatives i and k. The objective of LINMAP is to minimize the sum of the x_{ik} error terms. The generic form of a LINMAP model is as follows,

$$\begin{aligned}
&\min \sum_i \sum_k x_{ik} \\
&s.t. \\
&S_i - S_k + x_{ik} \geq 0 \quad \forall i, k \ni i \succ k \\
&w_j \geq 0 \quad \forall j
\end{aligned}$$

Note that the first set of constraints can be expanded as in Equation (12).

$$S_i - S_k + x_{ik} \equiv \sum_j a_{ij} w_j - \sum_j a_{kj} w_j + x_{ik} \tag{12}$$

LINMAP provides a structured way to calculate criteria weights and assess DM´s inconsistency. Like the Borda Count method, it has been less frequently applied compared to other MCDM techniques. Recently, Xia et al. (2006) proposed a fuzzy extension of LINMAP. Zhang and Lu (2006) applied LINMAP to solve a reverse logistics problem.

Table 1. PROMETHEE evaluation scores of alternatives with respect to study 1 criteria (scores represent consensus evaluations of DMs)

Alternative	Criterion						H_j	q	p
	C_u1	C_u2	C_u3	C_u4	C_u5	C_u6			
A1	6	9	6	4	2	9	*iii*	0	5
A2	8	5	9	5	2	3	*iii*	0	5
A3	9	5	6	9	5	3	*iii*	0	5
A4	4	9	4	7	1	8	*iii*	0	7
A5	6	5	4	1	7	1	*iii*	0	6
A6	8	3	3	5	7	3	*iii*	0	5

Preference Data Collection Method

There are several techniques that can be used to collect preference information from a group of DMs for later use in management improvement studies. In this study we use the Nominal Group Technique (NGT) in acquiring the inputs of DMs. First proposed by Delbecq and Van de Ven (1971), NGT is a structured brain storming technique to extract and aggregate multiple participants' opinions on a problem. NGT is suggested to be used with groups of up to 10 people, can be carried out in relatively short time; and therefore, fits very well with the constraints of our DM groups. An NGT session has the following steps:

Step 1: Silent generation of ideas in writing,
Step 2: Round-robin recording of ideas,
Step 3: First discussion,
Step 4: Preliminary voting,
Step 5: Second discussion,
Step 6: Final voting.

We followed these steps during interactions with DMs and recorded their preferences to use in our multi criteria ranking studies.

STUDY 1: EVALUATION OF E-HEALTH SERVICES FROM THE USER'S PERSPECTIVE

The first study aims to rank the e-health alternatives with respect to users' preferences. To demonstrate the methodology, we present a case study that involves four participants. The DMs were graduate students at the Pennsylvania State University, one PhD and one MSc student from Industrial and Manufacturing Engineering Department, one MSc student from Computer Science Department and one PhD Student from the Department of Learning Systems and Performance. All DMs were frequent Internet users and have previously used an e-health application. An NGT session was conducted in order to collect and aggregate the DMs' scores to obtain a consensus evaluation. The problem, alternatives, criteria and methods to be used were first presented. Then the DMs provided scores to be used in PROMETHEE, pairwise comparison results to be used in AHP and LINMAP and Borda Count rankings. During the execution of this step, the DMs were allowed to discuss about the importance of each criterion and were asked to provide a single final evaluation which represents their consensus on the evaluation. During the AHP data collection the evaluation scores were tested for consistency using the Expert Choice software and in any case of inconsistency, the DMs were asked to come up

Table 2. Summary of study 1 weight calculations

Method	*AHP*	*Borda Count*	*LINMAP*
Criterion	***Weight***	***Weight***	***Weight***
C_u1	0.118	0.190	0.000
C_u2	0.039	0.048	0.058
C_u3	0.154	0.143	0.256
C_u4	0.345	0.286	0.056
C_u5	0.278	0.238	0.331
C_u6	0.066	0.095	0.299

with a different evaluation. Various reasons of inconsistency were explained to the DMs before starting this final step. A sample output from the NGT session is given in Table 1. Columns C_u1 to C_u6 record the preference values assigned by the DMs to be used in PROMETHEE and LINMAP calculations. The last three columns show the type of criterion function and relevant threshold values for PROMETHEE application.

There are no strict rules for selecting H_j functions and threshold values. Threshold values are given by DMs and H_j functions are proposed by the author and DMs together. Note that type *iii* is the most widely used function type in PROMETHEE applications.

DMs provided the following ranking to calculate Borda Count weights. The criterion on the left side of the $\succ$ sign is superior to the criterion on the right.

$$C_u4 \succ C_u5 \succ C_u1 \succ C_u3 \succ C_u6 \succ C_u2$$

Finally, DMs provided the below pairwise comparisons to use in LINMAP calculations. Note that AHP pairwise preference inputs are not shown here due to space considerations.

$1 \succ 2 \quad 1 \succ 3 \quad 1 \succ 4 \quad 1 \prec 5 \quad 1 \succ 6$
$2 \prec 3 \quad 2 \prec 4 \quad 2 \succ 5 \quad 2 \succ 6$
$3 \prec 4 \quad 3 \prec 5 \quad 3 \succ 6$
$4 \prec 5 \quad 4 \succ 6$
$5 \prec 6$

Results of Study 1

Results obtained using the AHP method ranks A4 as the first alternative. A4 is followed by A1 and A3. PROMETHEE II yields a different ranking than AHP where A5 occupies the first spot and

Table 3. Summary of study 1 alternative rankings

Method	*LINMAP*		*Borda Count*		*AHP*		*PROMETHEE II*	
Alt.	**Score**	**Rank**	**Score**	**Rank**	**Score**	**Rank**	***$\Phi^{net}(\alpha)$***	***Rank***
A1	5.1871	1	2.619	3	0.344	2	0.352	3
A2	3.8768	4	2.381	4	0.062	4	0.153	4
A3	3.8770	3	1.715	5	0.080	3	-0.529	5
A4	3.8772	2	0.762	6	0.441	1	-1.640	6
A5	3.8766	6	3.429	1	0.045	5	1.247	1
A6	3.8768	4	2.619	2	0.029	6	0.418	2

is followed by A6 and A1. Borda Count gives the same ranking as PROMETHEE II.

The LINMAP model was coded and solved using the LINDO optimization software. The objective value was found to be 1.31, which indicates that there is a slight inconsistency with the DMs' pairwise comparisons. A close look at the solution revealed that the inconsistency resulted from the comparison $1 \prec 5$. To correct this problem we contacted the DMs and had their approval to change $1 \prec 5$ to $1 \succ 5$. The new objective value was very close to zero to indicate that the inconsistency issue has been resolved. A summary of criteria weights and alternative rankings for each method are given in Tables 2 and 3.

Table 2 indicates that different methods yield different weights. For instance AHP and Borda Count declare C_u4 as the most important criterion; whereas according to LINMAP, C_u4 is only the fifth most important criterion. Obviously, each method uses a different approach in calculating weights and treating alternatives; which explains the difference in the results. Rank reversals (different methods yielding different criteria and alternative rankings) is a common observation in MCDM problems (see for instance Wadhwa & Ravindran (2006) for a recent example in applications). On the other hand, all three techniques rank C_u5 as either as the most important or the second most important criterion. Overall, we can say that criteria C_u3 (attractiveness), C_u4 (safety threat) and C_u5 (quality of content) are the important criteria from users' perspective.

Rank reversals can also be observed in the alternative rankings (see Table 3). For instance alternative A4 comes in the first place in AHP and second place in LINMAP, but it is the least preferred alternative according to Borda Count and PORMETHEE II. On the other hand, all methods rank alternative A1 among top three alternatives. Overall, we can conclude that users are most interested in alternative A1 (teleconsultation). Furthermore, we can judge that alternatives A4 (remote patient monitoring), A5 (electronic medical library) and A6 (electronic medical record access) are also promising since they are ranked in top two by at least two evaluation methods. Therefore, according to our case study, installing one or more of these e-health services would increase the customer demand. However, the previous statement makes the assumption that the service installation is feasible and practical for the service provider; which might not always be true. To have a complete judgment on which e-health service might add value, one needs to consider the problem from the practitioners' point as well. Study 2 presented next addresses this issue.

STUDY 2: EVALUATION OF E-HEALTH SERVICES FROM PRACTITIONER'S PERSPECTIVE

The second study we present in this chapter focuses on the problem of e-health service evaluation from practitioners' perspective. Alternatives in Study 2 are the same as in Study 1 where we treated the problem from users' perspective. However, as opposed to Study 1, the evaluation criteria are different to reflect the preference of practitioners (see the section *Criteria for Study 2*). We present a case study to convey the application of our method. Practitioners (DMs) in our case were three IT professionals specialized in hospital IT systems and e- health services. They were interviewed during a hospital IT implementation project in Istanbul, Turkey. As in Study 1, the problem at hand, alternatives, criteria and methods to be used were first presented to the DMs. They then provided PROMETHEE scores, pairwise comparisons and Borda Count rankings. Note that DMs commented that availability of one or several e-healthcare services in an institution would have an impact on these judgments and provided scores for an institution that does not offer any e-healthcare services. These inputs are then used to calculate criteria weights and alternative rankings as in Study 1. Table 4 presents

Table 4. PROMETHEE evaluation scores of alternatives with respect to study 2 criteria (scores represent consensus evaluations of DMs)

Alternative	**Criterion**						H_j	q	p
	C_p1	C_p2	C_p3	C_p4	C_p5	C_p6			
A1	9	5	3	7	9	6	*iii*	0	5
A2	9	7	5	5	5	6	*iii*	0	5
A3	9	7	5	5	5	6	*iii*	0	5
A4	5	9	1	1	9	4	*iii*	0	7
A5	9	8	8	7	3	9	*iii*	0	6
A6	9	7	6	6	9	5	*iii*	0	5

performance scores of alternatives with respect to criteria of Study 2.

Similar to Table 1 in Study 1, in Table 4 above H_j denotes the type of function to be used in PROMETHEE and p and q are threshold values. These values can be modified whenever judged as appropriate in a particular implementation. Moreover, we asked DMs to provide a ranking of criteria for use in Borda Count weight calculations. The following ranking was obtained,

$$C_p3 \succ C_p1 \succ C_p6 \succ C_p4 \equiv C_p2 \succ C_p5$$

Finally, the DMs provided the below pairwise comparison of alternatives to be used in LINMAP programming,

$$1 \succ 2 \quad 1 \prec 3 \quad 1 \succ 4 \quad 1 \prec 5 \quad 1 \prec 6$$
$$2 \succ 3 \quad 2 \succ 4 \quad 2 \prec 5 \quad 2 \prec 6$$
$$3 \prec 4 \quad 3 \prec 5 \quad 3 \prec 6$$
$$4 \prec 5 \quad 4 \prec 6$$
$$5 \succ 6$$

Again, we skip the AHP pairwise inputs due to space considerations.

Study 2 Results

All of the weight calculation methods we tested put the largest weight on C_p3, the *customer potential* criterion. Furthermore, AHP and Borda Count weights follow a similar order but with different magnitudes. LINMAP weights on the other hand are substantially different than the weights provided by the former two methods. Note that

Table 5. Summary of study 2 weight calculations

Method	*AHP*	*Borda Count*	*LINMAP*
Criterion	***Weight***	***Weight***	***Weight***
C_p1	0.260	0.227	0.000
C_p2	0.117	0.136	0.333
C_p3	0.425	0.273	0.334
C_p4	0.118	0.136	0.333
C_p5	0.046	0.045	0.000
C_p6	0.268	0.182	0.000

LINMAP had an objective value of 0.67 which indicates a very slight inconsistency in DMs' pairwise comparisons. A full output of Study 2 criteria weights is given in Table 5.

Similar to the weight values, we have some consensus in alternative rankings, at least about the best alternative. All methods we used ranked A5, the *electronic library service* as the best alternative to implement. The rest of the rankings, however, varies from one method to the other. LINMAP ranks A4 as the second best and A6 as the third best alternative. According to Borda Count, the second and third best alternatives are A6 and A3 respectively. AHP reports A1 and A3 as the second and third best alternatives; and finally, PROMETHEE ranks A2 and A3 in the second and third spots in the alternative ranking. A summary of alternative Study 2 alternative rankings is given in Table 6.

As we discuss above the electronic library service is ranked as the most viable e-health service. It is hard to assess a runner-up using these data since rankings are very different from one method to the other. Nevertheless, we can argue that A2, A3 and A6 would occupy the second, third and fourth places. Furthermore, A1 and A4 seem to be the least attractive e-health services and should get the last two ranks. In order to have a more complete and well distinguished ranking, alternatives A2 - A3 - A6 and A1 - A4 might further be evaluated with respect to additional criteria.

DISCUSSION AND CONCLUSION

This chapter presents an MCDM framework for e-health service assessment. The problem falls under the domain of discrete alternative MCDM studies and is treated using four different methods; namely, PROMETHE, AHP, Borda Count and LINMAP. We approach the problem from two complementary sides in two Studies. Study 1 presents an evaluation from users' perspective and incorporates a set of criteria that reflects the users' preferences. Study 2 approaches the problem from practitioners' point of view and evaluates a different set of criteria. The alternatives on the other hand are the same for both Study 1 and Study 2.

Both Studies were conducted with the participation of actual DMs. For Study 1, we teamed up with a group of graduate students that previously used e-health services. Study 2 was conducted with IT professionals specialized in the area of hospital IT systems and e-services. Each group of DMs participated in separate NGT sessions, one for Study 1 and another for Study 2, and provided their performance evaluations to be used in the calculations of the MCDM methods. AHP evaluations and LINMAP programming use consistency measures that should be verified for

Table 6. Summary of study 2 alternative rankings

Method	**LINMAP**		**Borda Count**		**AHP**		*PROMETHEE II*	
Alt.	**Score**	**Rank**	**Score**	**Rank**	**Score**	**Rank**	$\Phi^{net}(\alpha)$	***Rank***
A1	0.336	6	4.087	5	0.160	2	-0.631	5
A2	2.336	4	4.997	3	0.146	4	0.495	2
A3	2.336	4	4.997	3	0.149	3	0.464	3
A4	2.998	2	3.629	6	0.140	5	-3.249	6
A5	3.005	1	6.136	1	0.327	1	2.469	1
A6	2.337	3	5.132	2	0.079	6	0.451	4

proper implementation. We contacted the DMs for revisions in cases where they were inconsistent with their judgments. After acquiring the evaluation results, we used Expert Choice to finalize the AHP study, and LINDO and MS EXCEL for the other methods.

We found that Study 1 results differ from one method to the other. However, we were able to conclude that overall, users are most attracted to alternative A1 (teleconsultation) according to all methods. Also, alternatives A4 (remote patient monitoring), A5 (electronic medical library) and A6 (electronic medical record access) were declared as promising e-health services since they were ranked in top two by at least two evaluation methods. Therefore, according to our case study, installing one or more of these e-health services is expected to increase the customer demand. The results of Study 2 showed better consensus in determining the winning alternative; but it was harder to interpret the runner-ups. Alternative A4 (electronic medical library) came in first and was followed by alternatives A2 (online appointment), A3 (online pharmacy) and A6 (electronic medical record access), not necessarily in this order.

Bridging the outcomes of Study 1 and Study 2 would provide valuable information for institutions aiming to deliver e-health services. Our results show that alternative A4 should be given priority because it holds high rankings in both studies. Furthermore, A6 appears in both rankings as a mid-valued alternative which can be considered as a second priority service. We found that neither users nor practitioners who took part in our study value the other alternatives as much as A4 and A6. We believe these results directly serve as beneficial guidelines for parties developing and implementing future e-health services and for current service providers in matching patient requests to services offered. Furthermore, institutions currently not focusing on e-health might use these results as directions towards new service offerings which would focus on patient demand and increase customer potential.

Practitioners considering using the conclusions presented in this chapter should note that the results reflect preferences of a rather small group of users and practitioners. A well diversified and larger group of participants would yield more accurate results; and therefore, is suggested for professional implementation of our methodology. Furthermore, the number of alternatives and evaluation criteria might change and increase in relation to the group size and institution. On the other hand, some methods we present here, AHP in particular, may not be practical to use in large scale implementations due to the heavy cognitive burden it poses on decision makers. In such cases, we suspect that PROMETHEE and Borda Count would be the better methods to use.

Future efforts include running the same studies with larger groups. Service alternatives and criteria that did not get high scores in our study may be replaced with others. Additionally, our study involves many qualitative criteria. Dealing with qualitative criteria in decision making applications has always been challenging since DMs are only able to provide vague linguistic assessments for these criteria. Fuzzy MCDM methods have been developed and used to account for DMs' vague assessments (see for instance Bilsel et. al 2006). We argue that solving the problem presented here using a fuzzy MCDM method may provide additional insights.

ACKNOWLEDGMENT

The authors appreciate Dr. A. Ravi Ravindran's comments and help in developing earlier drafts of this work.

REFERENCES

Adewale, O. S. (2004). An internet-based telemedicine system in Nigeria. *International Jour-*

nal of Information Management, *24*, 221–234. doi:10.1016/j.ijinfomgt.2003.12.014

Albadvi, A. (2004). Formulating national information technology strategies: A preference ranking model using PROMETHEE method. *European Journal of Operational Research*, *153*, 290–296. doi:10.1016/S0377-2217(03)00151-6

American Telemedicine Association (ATA). Retrieved on October 8, 2007, from http://www.atmeda.org/

Ayag, Z. (2005). A fuzzy AHP-based simulation approach to concept evaluation in a NPD environment. *IIE Transactions*, *37*(9), 827–842. doi:10.1080/07408170590969852

Bashshur, R. L. (1997). Telemedicine and the health care system. In R. L. Bashshur, J. H. Sanders & G. W. Shannon (Eds.), *Telemedicine theory and practice* (pp. 5-35). Springfield, IL: Charles C. Thomas Publishers.

Bayazit, O. (2005). Use of AHP in decision-making for flexible manufacturing systems. *Journal of Manufacturing Technology Management*, *16*(7), 808–819. doi:10.1108/17410380510626204

Bedini, R., Belardinelli, A., Giansanti, D., Guerriero, L., Macellari, L., & Morelli, S. (2006). Quality assessment and cataloguing of telemedicine applications. *Journal of Telemedicine and Telecare*, *12*(4), 189–193. doi:10.1258/135763306777488735

Bilsel, R. U., Buyukozkan, G., & Ruan, D. (2006). A fuzzy preference-ranking model for a quality evaluation of hospital websites. *International Journal of Intelligent Systems*, *21*, 1181–1197. doi:10.1002/int.20177

Bouri, A., Martel, J. M., & Chabchoub, H. (2002). A multi-criterion approach for selecting attractive portfolio. *Journal of Multi-Criteria Decision Analysis*, *11*, 269–277. doi:10.1002/mcda.334

Brans, J. P. (1982). L'ingénierie de la décision: Elaboration d'instruments d'aide à la décision. Méthode PROMETHEE. In R. Nadeau & M. Landry (Eds.), *L'aide à la décision: Nature instruments et perspectives d'avenir* (pp. 183–214). Québec, Canada: Presses de l'Université Laval.

Brans, J. P., & Mareschal, B. (1994). The PROMCALC and GAIA decision support system for MCDA. *Decision Support Systems*, *12*, 297–310. doi:10.1016/0167-9236(94)90048-5

Brans, J. P., & Vincke, P. (1985). A preference ranking organization method: The PROMETHEE method. *Management Science*, *31*, 647–656. doi:10.1287/mnsc.31.6.647

Chan, F. (2003). Interactive selection model for supplier selection process: An analytical hierarchy process approach. *International Journal of Production Research*, *41*(15), 3549–3579. doi:10.1080/0020754031000138358

Chen, H.-S., Guo, F.-R., Chen, C.-Y., Chen, J.-H., & Kuo, T.-S. (2001). Review of telemedicine projects in Taiwan. *International Journal of Medical Informatics*, *61*, 117–129. doi:10.1016/S1386-5056(01)00134-4

Cox, J., & Dale, B. G. (2002). Key quality factors in web site design and use: An examination. *International Journal of Quality & Reliability Management*, *19*, 862–888. doi:10.1108/02656710210434784

de Toledo, P., Jimenez, S., del Pozo, F., Roca, J., Alonso, A., & Hernandez, C. (2006). Telemedicine experience for chronic care in COPD. *IEEE Transactions on Information Technology in Biomedicine*, *10*(3), 567–573. doi:10.1109/TITB.2005.863877

Delbecq, A. L., & Van de Ven, A. H. (1971). A group process model for problem identification and program planning. *The Journal of Applied Behavioral Science*, *7*, 466–492. doi:10.1177/002188637100700404

Dym, C. L., Wood, W. H., & Scott, M. J. (2002). Rank ordering engineering designs: Pairwise comparison charts and Borda counts. *Research in Engineering Design*, *13*(4), 236–242.

EHNAC Healthcare Network Accreditation Program. (2006). Retrieved on October 8, 2007, from http://www.ehnac.org/images/stories/downloads/Criteria/criteriav9.2.pdf

Giansanti, D., Morelli, S., & Macellari, V. (2007). Telemedicine technology assessment. Part II: Tools for a quality control system. *Telemedicine Journal and e-Health*, *13*(2), 130–140. doi:10.1089/tmj.2006.9988

González, F. J. M., & Palacios, T. M. B. (2004). Quantitative evaluation of commercial web sites: An empirical study of Spanish firms. *International Journal of Information Management*, *24*, 313–328. doi:10.1016/j.ijinfomgt.2004.04.009

Harrison, R., Clayton, W., & Wallace, P. (1996). Can telehealthcare be used to improve communication between primary and secondary care? *British Medical Journal*, *313*, 1377–1380.

Jennett, P. A., & Andruchuk, K. (2001). Telehealth: ‘real life’ implementation issues. *Computer Methods and Programs in Biomedicine*, *64*, 169–174. doi:10.1016/S0169-2607(00)00136-X

Kasitipradith, N. (2001). The Ministry of Public Health telemedicine network of Thailand. *International Journal of Medical Informatics*, *61*, 113–116. doi:10.1016/S1386-5056(01)00133-2

Kim, S., & Stoel, L. (2004). Dimensional hierarchy of retail website quality. *Information & Management*, *41*(5), 619–633. doi:10.1016/j.im.2003.07.002

Lareng, L. (2002). Telemedicine in Europe. *European Journal of Internal Medicine*, *13*, 1–3. doi:10.1016/S0953-6205(01)00188-1

MacFarlane, A., Murphy, A. W., & Clerkin, P. (2006). Telemedicine services in the Republic of Ireland: An evolving policy context. *Health Policy (Amsterdam)*, *76*, 245–258. doi:10.1016/j.healthpol.2005.06.006

Macharis, C., Springael, J., De Brucker, K., & Verbeke, A. (2004). PROMETHEE and AHP: The design of operational synergies in multicriteria analysis. Strengthening PROMETHEE with ideas of AHP. *European Journal of Operational Research*, *153*, 307–317. doi:10.1016/S0377-2217(03)00153-X

Masud, A. S. M., & Ravindran, A. (2008). Multiple criteria decision making. In A. Ravindran (Ed.), *Operations research and management science handbook*. Boca Raton, FL: CRC Press.

McConnochie, K. M., Conners, G. P., Brayer, A. F., Goepp, J., Herendeen, N. E., Wood, N. E., Thomas, A., Ahn, D. S., & Roghmann, K. J. (2006). Effectiveness of telemedicine in replacing in-person evaluation for acute childhood illness in office settings. *Telemedicine and e-Health, 12*(3), 308-316.

Nanni, L., & Lumini, A. (2006). Detector of image orientation based on Borda Count. *Pattern Recognition Letters*, *27*(3), 180–186. doi:10.1016/j.patrec.2005.08.023

Parasuraman, A., Zeithaml, V. A., & Berry, L. L. (1988). SERVQUAL: A multiitem scale for measuring consumer perceptions of service quality. *Journal of Retailing*, *64*, 2–40.

Pomerol, J.-C., & Barba Romero, S. (2000). *Multicriterion decision in management: Principles and practice*. Norwell: Kluwer Academic Publishers. Richardson, R. (2002). E-Health for Europe. *Eurohealth, 8*, 1-4. Retrieved on October 8, 2007, from http://www.lse.ac.uk/collections/LSEHealth/pdf/eurohealth/vol8no2.pdf

Saaty, T. L. (1980). *The analytic hierarchy process*. New York: McGraw-Hill.

Samii, A., Ryan-Dykes, P., Tsukuda, R. A., Zink, C., Franks, R., & Nichol, W. P. (2006). Telemedicine for delivery of health care in Parkinson's disease. *Journal of Telemedicine and Telecare*, *12*(1), 16–18. doi:10.1258/135763306775321371

Schärlig, A. (1996). *Pratiquer ELECTRE et PROMETHEE, un complement à décider sur plusieurs critères*. Lausanne: Presses Polytéchniques et Universitaires Romandes.

Srinivasan, V., & Shocker, A. D. (1973). Linear programming techniques for multi-dimensional analysis of preferences. *Psychometrika*, *38*(3), 337–369. doi:10.1007/BF02291658

Tam, M. C. Y., & Tummala, V. M. R. (2001). An application of the AHP in vendor selection of a telecommunications system. *Omega*, *29*(2), 171–182. doi:10.1016/S0305-0483(00)00039-6

Topçu, Y. İ., & Ülengin, F. (2004). Energy for the future: An integrated decision aid for the case of Turkey. *Energy*, *29*, 137–154. doi:10.1016/S0360-5442(03)00160-9

Ülengin, F., Topçu, Y. İ., & Şahin, Ş. Ö. (2001). An integrated decision aid system for Bosphorus water crossing problem. *European Journal of Operational Research*, *134*, 179–192. doi:10.1016/S0377-2217(00)00247-2

Van Iwaarden, J., Van der Wiele, T., Ball, L., & Millen, R. (2004). Perceptions about the quality of Web sites: A survey amongst students at Northeastern University and Erasmus University. *Information & Management*, *41*, 947–959. doi:10.1016/j.im.2003.10.002

Wadhwa, V., & Ravindran, A. (2007). Vendor selection in outsourcing. *Computers & Operations Research*, *34*, 3725–3737. doi:10.1016/j.cor.2006.01.009

Xia, H.-C., Li, D.-F., Zhou, J.-Y., & Wang, J.-M. (2006). Fuzzy LINMAP method for multiattribute decision making under fuzzy environments. *Journal of Computer and System Sciences*, *72*(4), 741–759. doi:10.1016/j.jcss.2005.11.001

Zhang, C.-Q., & Lu, Y.-C. (2006). The reverse logistics evaluation based on KPCA-LINMAP model. In *Proceedings of the 2006 International Conference on Machine Learning and Cybernetics* (pp. 2531-2535).

KEY TERMS AND DEFINITIONS

AHP: An MCDM method.

E-Health: Application of advanced information technologies in healthcare delivery.

MCDM: Multicriteria Decision Making, a set of techniques involving multiple evaluation criteria facilitating in managerial decision making.

NGT: Nominal group technique, a method used to retrieve preference information from a group of decision makers.

PROMETHEE: An MCDM method.

Rank Reversal: Obtaining different rankings for a same problem using different MCDM methods.

This work was previously published in Handbook of Research on Information Technology Management and Clinical Data Administration in Healthcare, edited by A. Dwivedi, pp. 143-160, copyright 2009 by Medical Information Science Reference (an imprint of IGI Global).

Chapter 7.18

An Evidence-Based Health Information System Theory

Daniel Carbone
University of Melbourne, Australia

ABSTRACT

The aim of this chapter is to bridge the gap between what is known about IS theory and the specifics characteristics of health to develop an evidence based health information systems theory. An initial background first sets the significance for the need to have a solid information systems theory in health and then argues that neither the information systems literature nor the health sector have been able to provide any satisfactory pathway to facilitate the adoption of information systems in health settings. The chapter further continues by reviewing the common pathway to develop information systems theory and the knowledge foundations used in the process, and then proceeds to highlight how this theory was developed. Subsequently, the building blocks (constructs, premises, supporting evidence and conclusions) that underpins the constructs and a brief explanation of the relationships between them is included. A discussion and limitation section is then followed by a conclusion.

BACKGROUND

The importance of having information systems theories that will be conducive to the adoption of new technologies in health settings cannot be underestimated. To place it in context, the health-care sector is not only one of the world's most knowledge-intensive industries but also one of the largest employers; for example the National Health Service (NHS) in the UK is the largest employer of staff in Europe and third largest in the world (Herzlinger & Ricci, 2002; Leitch, 2008).

More important is the worldwide, current and urgent need to improve the uptake of technology in health settings to improve clinical care and associated costs through the use of technology, as clearly defined in the literature (AIHW, 2006; Department of Health and Aged Care, 2003; Grol et al, 1998; Gross et al., 2003; HealthConnectSA, 2007; Nader, 2007; Schuster et al., 2003; WHO, 2008). This is currently occurring despite mounting evidence suggesting positive clinical care improvements due to the introduction health information systems (Celler et al., 2003; WHO, 2008).

This current failure to adopt technology in health settings appears to point to gaps in the understanding of technology implementation and adoption in the health sector.

The current literature on health information systems implementation and adoption suggests that perhaps the health sector suffers from a fixation with 'technology driven implementations' to the detriment of other factors (Aarts et al., 2004; Bates, 2005; Chaudhry et al., 2006; Humber, 2004). That is, the focus of change management strategies to implement these technologies in health settings is seen almost exclusively as a technical (computer/technology system) issue. Moreover, most information technology applications have centered on administrative and financial transactions rather than on the core business of health: the delivery of clinical care (Audet et al., 2004). The concept of clinical care is the central principle associated with the field of health and known these days as Evidence-Based Medicine (EBM). The most important aspect associated with Evidence-Based Medicine is the measure of clinical improvement on patients or a term also known as health outcomes (Heckley, 2004).

In summary, the health sector appears to lack solid theoretical knowledge in organizational change, workflow redesign, human factors, and project management issues involved with realizing benefits from health information technology to tackle the clinical and financial burdens in current health systems (Chaudhry et al., 2006). Moreover, and central to this paper, the health specific literature on information systems implementations appears to fail to acknowledge the role of Evidence-Based Medicine (and health outcomes specifically) in the implementation process.

Perhaps, the solution is to consult the information systems literature in search for theoretical foundations that would support the adoption of technology in health settings.

The Information Systems (IS) literature on the other hand, mainly focused on the business sector and having left much of the 'technology-driven' approaches failures behind, has long benefited from a much more humanistic and contextualized appreciation of non-technological factors (i.e. Human, environmental, Social, etc) to improve adoption; However, in spite of the availability of more than fifty information systems theories and many others form other fields to inform practitioners, implementation failures in health settings still continue unabated to this day (HealthConnectSA, 2007; Schneberger & Wade, 2006). It would appear that even the existing broad knowledge in the IS sector is still not enough to affect effective technological uptake in health settings. What appears to be missing is 'specific' knowledge that would support the adoption of technology in health settings.

As a conclusion, the preceding and very brief literature review suggests that neither the health nor the information systems sectors have succeeded in developing solid theoretical knowledge that would lead to the successful implementation and adoption of information systems in health settings.

This chapter will advance some theoretical constructs regarding observed phenomena that might help bridge the gap between existing knowledge and new knowledge gained in the field and through relevant information systems research in health settings by the author. This examination leads the author to believe that perhaps there is a misalignment in the understanding of current information systems theories and health constructs; more specifically, that existing theories do not specifically focus on the 'core businesses of health' (Evidence-Based Medicine).

It must be also noted that this paper is not meant produce a definitive full-fledged theory, but contribute to the beginning of a theoretical discourse in information systems for health specific settings. Although initially built from an existing theoretical framework; it is intended to go above and beyond the founding theoretical frameworks as suggested recently by the editors of MIS Quarterly (Markus & Saunders, 2007).

THE KNOWLEDGE FOUNDATIONS OF INFORMATION SYSTEMS THEORY

The most common approach to developing or building on theory in the discipline of information systems is to use an established theory (authoritative knowledge) from a reference discipline, develop and adapt it to the information system context by 'trial and error'; this is also known as 'the logic of science' (Popper, 1979). In this approach, an established theory is used to categorize and classify information systems phenomena through a deductive approach (Lind & Goldkuhl, 2006).

Another approach is the inductive analysis of empirical data for the creation of a theory; Grounded theory is perhaps the most widely known methods of inductive theory building (Glaser & Strauss, 1967). This form of theory building was called 'logic of inquiry' by philosopher John Dewey in 1938 (Dewey, 1938), and involves the idea of 'application' grounding, including observational grounding to develop theory (Lind & Goldkuhl, 2006). This method has lead to the creation of concepts and theory useful for practical workplace change and is in line with the notion of a 'practical theory' (Cronen, 2001). However, the lack of relationship to other existing theories and unclear epistemological basis have been sited as criticism of this approach (Bryant, 2002; Charmaz, 2000).

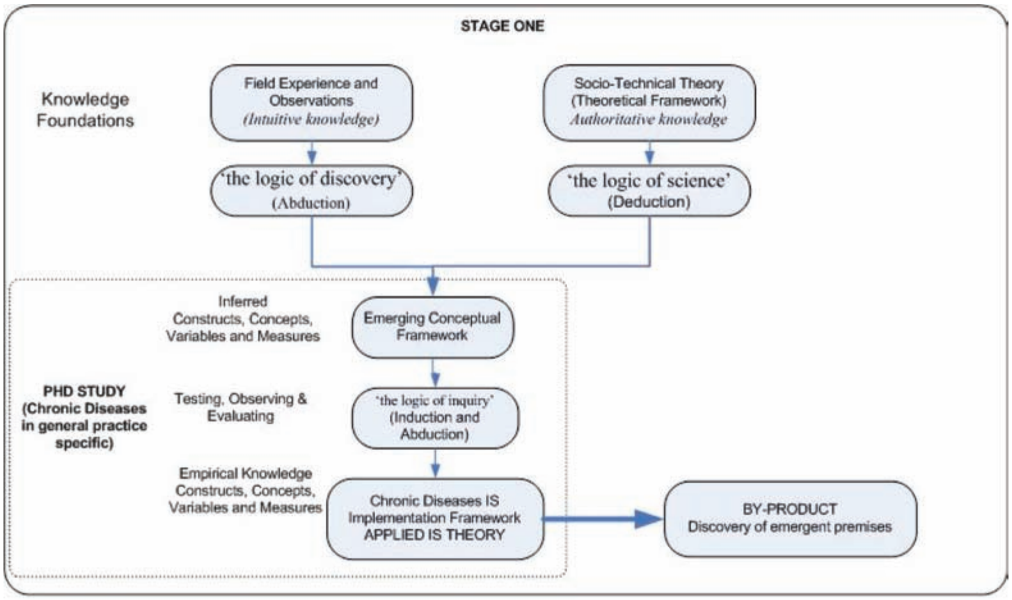
There is, yet another closely related logic called 'logic of discovery' and it seems to underpin abductive reasoning (Popper, 1979; Wirth, 2008). Wirth (1998) defines abduction as 'the process of adopting an explanatory hypothesis' and covers two operations: the selection and the formation of plausible hypotheses. He goes on further to explain that 'as a process of finding premises, it is the basis of interpretive reconstruction of causes and intentions, as well as of inventive construction of theories' (Wirth, 2008). It is motivated by the observation of a surprising fact or an anomaly that disappoints an expectation; abductive reasoning is a strategy of solving problems and discovering relevant premises. It is "inference to the best explanation". However, from a logical point of view, Pierce (1958) suggested that reasoning backwards is no valid form of inference. It is conjectural, or presumptive thinking, aiming at matching pragmatic standards of plausibility, guided by the reasoner´s guessing instinct (Peirce, 1958; Wirth, 1998).

Further epistemological and ontological strengths and weaknesses of every approach can be discerned in a number of other resources (Bryant, 2002; Charmaz, 2000; Urquhart, 2001; Wirth, 2008).

Bob Zmud (1998), ex editor-in-chief of MIS Quarterly, suggested that to truly contribute to theory building, it is necessary to develop and describe a rich conceptual understanding of an information systems phenomena so that it serves to enhance the field's collective understanding of the phenomena and as a basis for future empirical and theoretical work (Zmud, 1998).

More importantly—as the basis for the development of the particular theory to be examined in this chapter stands solely on the author understands of the phenomena, it is imperative that the phenomenon's constructs are augmented compellingly (Zmud, 1998). Arguments, for the purpose of this paper, are defined as set of one or more declarative sentences (or propositions) known as the premises along with another declarative sentence (or proposition) known as the conclusion. Premises are those statements that are taken to provide the support or evidence and the conclusion is that which the premises allegedly support (Fieser & Dowden, 2008). Furthermore, arguments can be deductive and inductive; according to Fieser and Dowden

Figure 1.



(2008), a deductive argument is an argument in which it is thought that the premises provide a guarantee of the truth of the conclusion. Conversely, an inductive argument is an argument in which it is thought that the premises provide reasons supporting the probable truth of the conclusion. In an inductive argument, the premises are intended only to be so strong that, if they are true, then it is unlikely that the conclusion is false. Moreover, Fieser and Dowden further clarify that even if the author of the argument does not think that the truth of the premises definitely establishes the truth of the conclusion, but nonetheless believes that their truth provides good reason to believe the conclusion true, then the argument is inductive (Fieser & Dowden, 2008).

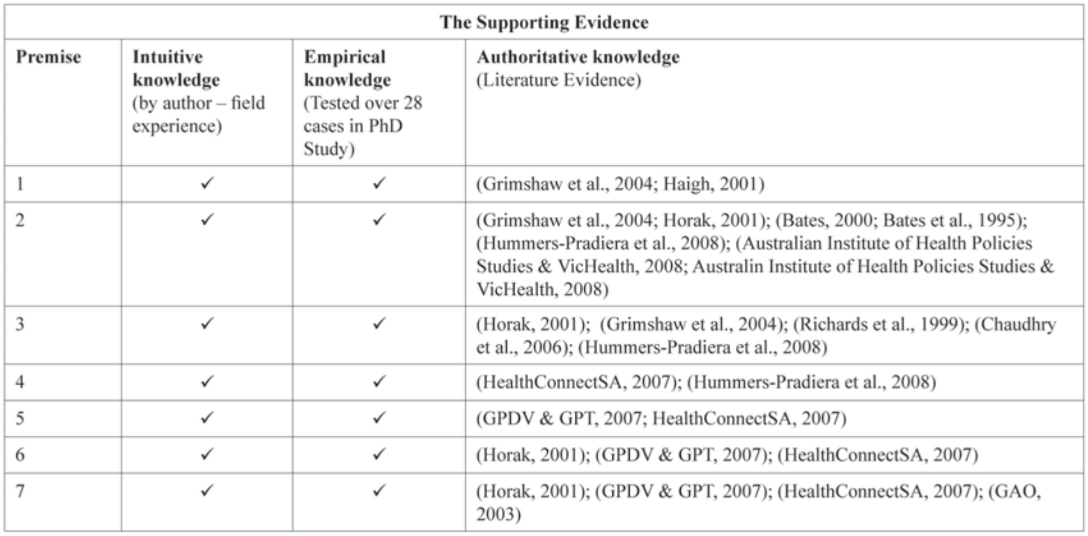
Zmud (1998) further suggested a four step development pathway to developing sound theory including: (1) the description of the phenomenon, (2) the construct creation, development and explication, (3) the identification of key relationships and (4) the development, justification and articulation of these relationships. (Zmud, 1998). These headings will be used to develop the theoretical discourse.

The Context of the Emerging Phenomena

The first stage in this examination evolved as the observation of emerging facts and anomalies (abductive approach) as a result of the development of the author's PhD information system framework (Carbone, 2008); from where a set of new constructs or 'by-products' of the PhD emerged. The PhD study began its own development as a conceptual framework; a product of adapting existing theoretical constructs (authoritative knowledge) and the researcher's own field experience and observations (abductive reasoning). Socio-technical theory provided the theoretical framework to guide the research processes (Clegg, 2000; Land, 2000; Liehr & Smith, 2001; Mumford, 2003, 2006a, 2006b; Williamson, 2002). The testing process itself was inductive in nature (logic of inquiry), aiming at the empirically provable coherence between the premises and experience, in order to derive a probable generalization (Wirth, 2008).

The PhD research focussed specifically on developing an information systems framework to support the prevention and management of

Figure 2.



The Supporting Evidence			
Premise	**Intuitive knowledge** (by author – field experience)	**Empirical knowledge** (Tested over 28 cases in PhD Study)	**Authoritative knowledge** (Literature Evidence)
1	✓	✓	(Grimshaw et al., 2004; Haigh, 2001)
2	✓	✓	(Grimshaw et al., 2004; Horak, 2001); (Bates, 2000; Bates et al., 1995); (Hummers-Pradiera et al., 2008); (Australian Institute of Health Policies Studies & VicHealth, 2008; Australin Institute of Health Policies Studies & VicHealth, 2008)
3	✓	✓	(Horak, 2001); (Grimshaw et al., 2004); (Richards et al., 1999); (Chaudhry et al., 2006); (Hummers-Pradiera et al., 2008)
4	✓	✓	(HealthConnectSA, 2007); (Hummers-Pradiera et al., 2008)
5	✓	✓	(GPDV & GPT, 2007; HealthConnectSA, 2007)
6	✓	✓	(Horak, 2001); (GPDV & GPT, 2007); (HealthConnectSA, 2007)
7	✓	✓	(Horak, 2001); (GPDV & GPT, 2007); (HealthConnectSA, 2007); (GAO, 2003)

chronic conditions (i.e. Asthma and Diabetes) in general practice following a pre-determined deduction/induction pathway. While this was satisfactory for the needs of the PhD study, it left a number of wider emergent constructs outside its limited scope. The limitation included the focus to just chronic conditions and to general practice settings only, even though the emergent premises observed were seen to be applicable to the wide clinical care continuum and other health settings as well.

The following graph in Figure 1 represents the knowledge foundations and research pathway just described above down to the emerging premises discovered in the study.

Phenomena Description

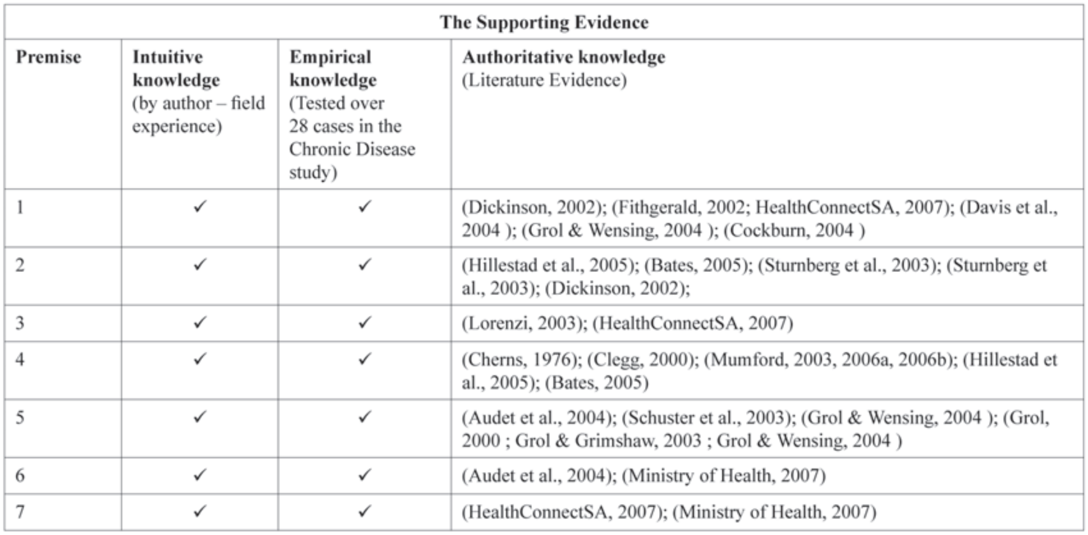
Successful implementation and adoption of information systems within the scope of chronic conditions and general practice were formally examined within the PhD study. Similar successful adoptions were observed by the author's own work role as an IS practitioner in a variety of other health settings like Hospitals and Community Health Centres. Furthermore, the practical implementation of information systems outside the realm chronic conditions provided additional opportunities to observe the same phenomenon in action.

This 'logic of discovery', based on abductive principals, requires a process of adopting an explanatory hypothesis covering the selection and the formation of plausible hypotheses (Wirth, 2008). To this effect a plausible hypothesis to explain the emerging phenomenon under examination here suggests broadly that:

Health settings will adopt information systems if a clear alignment of its core business with the proposed system outcomes is facilitated through the proper mechanisms.

More specifically, any implementation strategy must take into account the hierarchical socio-technical and clinical values exclusive to every health setting and the system development must be facilitated by catalyst that can clearly understands and align their value structures to the intended information systems.

Figure 3.



The Supporting Evidence			
Premise	**Intuitive knowledge** (by author – field experience)	**Empirical knowledge** (Tested over 28 cases in the Chronic Disease study)	**Authoritative knowledge** (Literature Evidence)
1	✓	✓	(Dickinson, 2002); (Fithgerald, 2002; HealthConnectSA, 2007); (Davis et al., 2004); (Grol & Wensing, 2004); (Cockburn, 2004)
2	✓	✓	(Hillestad et al., 2005); (Bates, 2005); (Sturnberg et al., 2003); (Sturnberg et al., 2003); (Dickinson, 2002);
3	✓	✓	(Lorenzi, 2003); (HealthConnectSA, 2007)
4	✓	✓	(Cherns, 1976); (Clegg, 2000); (Mumford, 2003, 2006a, 2006b); (Hillestad et al., 2005); (Bates, 2005)
5	✓	✓	(Audet et al., 2004); (Schuster et al., 2003); (Grol & Wensing, 2004); (Grol, 2000 ; Grol & Grimshaw, 2003 ; Grol & Wensing, 2004)
6	✓	✓	(Audet et al., 2004); (Ministry of Health, 2007)
7	✓	✓	(HealthConnectSA, 2007); (Ministry of Health, 2007)

Construct Creation, Development and Explication

Within this phenomenon, three distinct constructs are identified: The catalyst; the sub-system hierarchy and the evidence-based system. To strengthen the claim for each of these constructs, and avoid being based solely on the author's understanding of the phenomena, inductive arguments will provide reasons (premises) supporting (via varied sources of evidence) the probable truth of the conclusions.

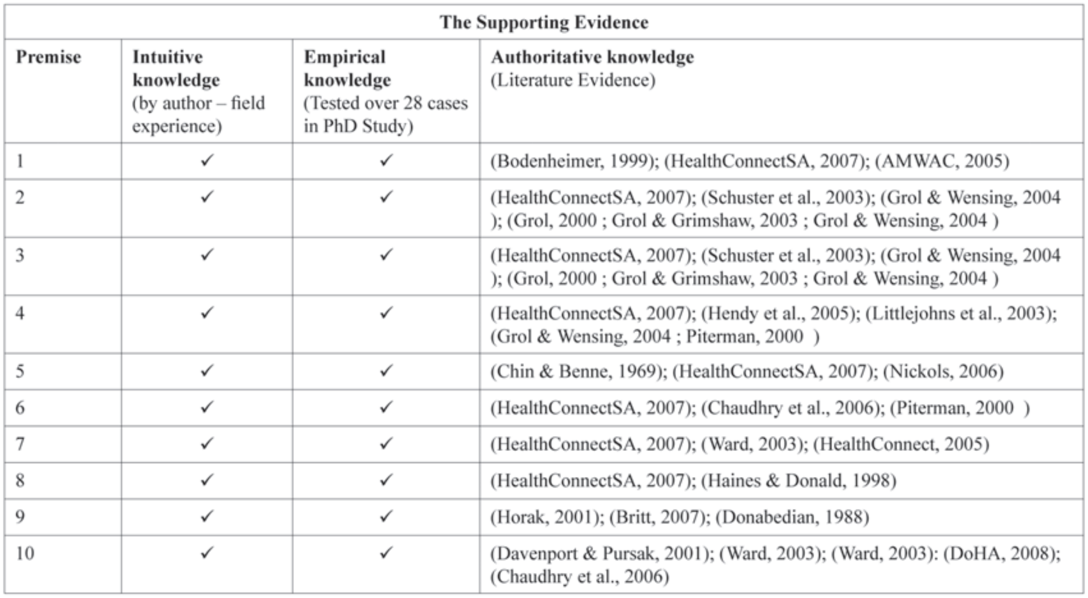
Due to space limitations, and bearing in mind that, as suggested earlier, this examination is not meant to be exhaustive or conclusive (but is meant to begin dialog and further empirical work), premises (or propositions) will be reduced down to short list of declarative sentences and its supporting evidence will also be presented in succinct table format to further reduce the length of the explanations. The conclusions are also provided in short declarative sentences (propositions).

THE CATALYSTS CONSTRUCT

This construct relates directly to individuals (acting as change/external agents) that find and analyse the evidence and facilitate and support the whole implementation and optimization of subsystems in health settings. The specific catalyst functions are identified through the argumentation that follows:
Premises:

- The skills required to find (research), analyse and feed-back empirical evidence to clinicians (decision makers) are not readily available in health settings.
- Research and information management skills are needed to produce evidence to drive change and measure outcomes.
- Access to health seating electronic health records is necessary for local evidence.
- External agents specifically trained have the skills but not the access to clinicians and health setting databases.
- Most health settings have 'key' individuals (in health called referred to as 'champions') that have access to databases and the ears of the clinicians/decision makers.

Figure 4.



The Supporting Evidence			
Premise	**Intuitive knowledge** (by author – field experience)	**Empirical knowledge** (Tested over 28 cases in PhD Study)	**Authoritative knowledge** (Literature Evidence)
1	✓	✓	(Bodenheimer, 1999); (HealthConnectSA, 2007); (AMWAC, 2005)
2	✓	✓	(HealthConnectSA, 2007); (Schuster et al., 2003); (Grol & Wensing, 2004); (Grol, 2000 ; Grol & Grimshaw, 2003 ; Grol & Wensing, 2004)
3	✓	✓	(HealthConnectSA, 2007); (Schuster et al., 2003); (Grol & Wensing, 2004); (Grol, 2000 ; Grol & Grimshaw, 2003 ; Grol & Wensing, 2004)
4	✓	✓	(HealthConnectSA, 2007); (Hendy et al., 2005); (Littlejohns et al., 2003); (Grol & Wensing, 2004 ; Piterman, 2000)
5	✓	✓	(Chin & Benne, 1969); (HealthConnectSA, 2007); (Nickols, 2006)
6	✓	✓	(HealthConnectSA, 2007); (Chaudhry et al., 2006); (Piterman, 2000)
7	✓	✓	(HealthConnectSA, 2007); (Ward, 2003); (HealthConnect, 2005)
8	✓	✓	(HealthConnectSA, 2007); (Haines & Donald, 1998)
9	✓	✓	(Horak, 2001); (Britt, 2007); (Donabedian, 1988)
10	✓	✓	(Davenport & Pursak, 2001); (Ward, 2003); (Ward, 2003): (DoHA, 2008); (Chaudhry et al., 2006)

- External agents can work with champions produce local evidence and optimise sub-systems.
- External agents can train champions and other health setting members to become trainers of other members and improve monitoring and maintenance of the sub-systems.

Conclusions:

An external agent working in conjunction with health setting champions is an effective catalyst to drive change management strategies, development, maintenance and evaluation of health information systems.

THE SUB-SYSTEM HIERARCHY CONSTRUCT

The first phenomenon observed was perhaps not a new theoretical construct per se, but perhaps an extension of existing Socio-technical theory; nevertheless, the construct is seen as new in the sense that it exclusively applies to health context.

Socio-technical systems theory is theory about the social aspects of people and society and technical aspects of machines and technology. Socio-technical refers to the interrelatedness of social and technical aspects of an organisation. Socio-technical theory therefore is about joint optimization, with a shared emphasis on achievement of both excellence in technical performance and quality in people’s work lives (Ropohl, 1999).

The contribution by socio-technical theory should be self-evident albeit with some specific tweaks to reflect the ‘fit’ to health settings. The recognition of the need to harmonise all existing sub-systems has always been the cornerstone of the socio-technical approach (Schneberger & Wade, 2006). This authoritative knowledge was well supported during the testing phase in twenty eight case studies and well supported by the literature. The following premises were discerned during practice throughout the chronic diseases study further supporting the literature in informing the conclusions and augments in this construct:

Premises:

- All health settings are unique (i.e. structural and cultural complexity and variation)
- There are many subsystems in health settings.
- Sub-systems are interdependent in different measures to their own contexts
- All subsystems need attention to maximise optimization.
- Not all sub-systems are valued equally by everyone in health settings.
- There is a well defined hierarchy apparent in health settings.
- Patient Care is the most valued sub-system (a kind of health 'bottom-line').

Conclusions:

Every health setting possesses a number of interdependent sub-systems that need to be optimised; that are value laden and unique to their context; and the most important is the 'Patient Care' sub-system.

EVIDENCE BASED SYSTEM CONSTRUCT

The concept of evidence is not new to health settings; however in health the use is normally reserved for medico-clinical endeavours only. The findings from this examination and the relevant authoritative literature suggest evidence to be the key conduit or foundation pathways where information system implementation are quickly accepted and sustainably adopted. The arguments are drawn on the following premises and conclusions:

Premises:

- Health settings are owned and/or run by clinicians (decision makers).
- Patient care (sub-system) shortcomings are important motivating factors to clinicians.
- Other sub-systems (risk management, financial, etc) are also of concern to decision makers.
- Clinicians are trained in scientific thought (empirical-rational methods).
- Empirical-rational change management strategies exist.
- Empirical-rational methods influence clinical practice (behavioural change/motivational drive).
- Evidence of care deficit in clinical practice is found in the local (electronic) health records.
- Empirical-rational change management strategies using local data (evidence) affects behavioural change positively.
- Sustainability of change and further change depends on the evidence of success.
- Local empirical evidence and analyses is needed to measure success (patient health outcomes).

Conclusions:

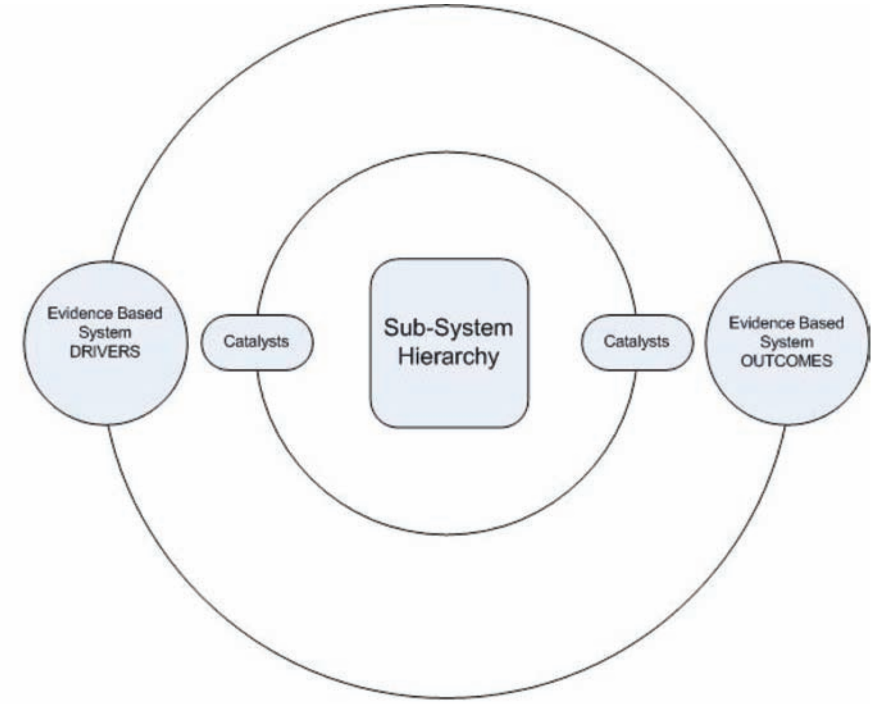
Clinicians need empirical evidence that highlights care gaps to affect behavioural change in their clinical practice. Clinicians also need concrete evidence that their efforts are benefiting their patients (health outcomes) and all other subsystems are working efficiently.

The Identification of Key Relationships

A sound theory must offer —besides arguments and conclusions for each construct, a compelling discussion on the phenomena resulting from the relationship between these constructs (Zmud, 1998). A complete discussion is in the scope of this paper is clearly limited; however a concise emergent dialog will follow:

The relationships between the three main constructs identified earlier can be readily represented as the analogy of a computer system: two concentric operating and application software

Figure 5.

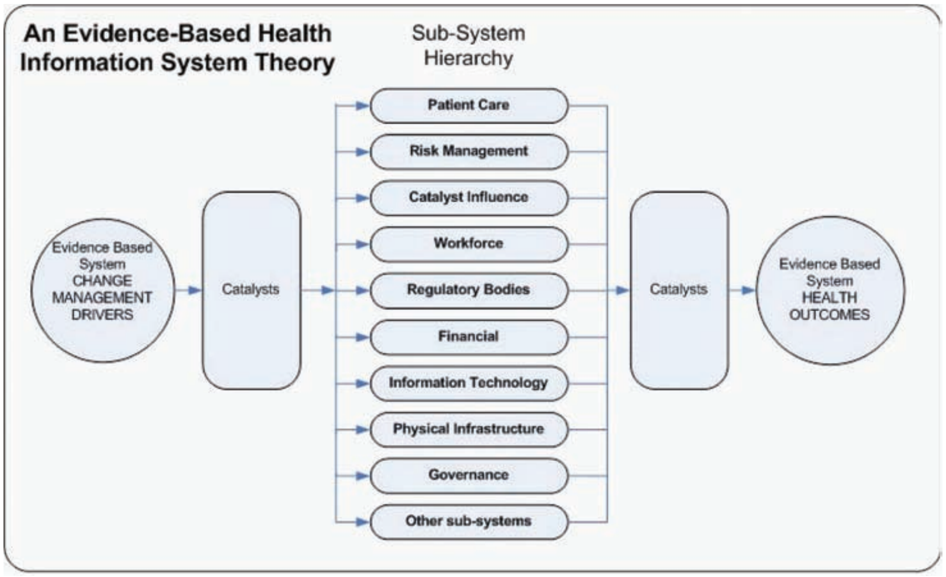


systems over a set of interconnected hardware. As per diagram shown in Figure 5.

Where the evidence based system construct represents the core business of health (patient care). Identifiable by its twin concerns: input task (drivers) and output task (outcomes). It can be thought of clinical task (business) that needs to be performed or improved (though the adoption of information systems) like the management, prevention or treatment of clinical problem in any health setting. As such it subsumes all other concerns in this theory. The bottom line, to borrow a business term is: 'the clinical improvement of patient care'.

The catalyst, as with an operating system is the enabler of that overall "clinical ncare" task. However, along the way (from input to output) the catalyst, like an operating system, must make sure that a set of circumstances or optimisation occurs to allow the clinical (input) task —driven by the expectation of improving the health of an individual or population is satisfactorily carried out (output), known in the health field as a clinical outcome. The tasks carried out by the catalyst (operating system) to enable the evidence-based system to succeed are multiple: for example, just to name a few of the potential sub-systems in health settings, it must allow members of the clinical team (Doctors, Nurses, staff, etc) to communicate with each other; it must make sure that risk management systems exist to follow up on patients that might miss out on clinical care; it must ensure that there is a sound financial systems underpinning the work being carried out and it must be capable of providing clinical information required on-time/every time to assist with clinical tasks. Perhaps the most important task that an operating system engages in a computer system is in "bootstrapping" (booting/starting) the system; this analogy essentially matches the first of the two principal role of the catalyst. The first task of this external (or internal if existing) change agent is to kick start the system by providing the initial "momentum" (data feedback) of what clinical business is at

Figure 6.



hand (what clinical care needs improving at the health setting by analysing gaps in care within its own patients). The second principal role is to measure the success in achieving that original task (improvement in health outcomes).

The hierarchical set of sub-systems construct represents in this analogy, the existing sub-systems that need to be optimized to allow for the core business (patient care) to be carried out successfully (outcomes). At this point in time, many of this sub-systems exist, however they can be paper-bases (in the case of financial records, recall and reminder letters, appointment books, to name but a few). It is important at this stage to recognize that any system being replaced must be "better", whatever the meaning for users (time efficient, error free, economical, etc) than existing ones. This also will include having the skills and broad knowledge to affect clinical, financial, legal and organisational systems including the provision of education and training. Many important sub-systems, in the author experience, do not exists and need to be developed from scratch. More importantly, every setting is completely unique in almost every aspect (governance, culture, workforce, etc), hence the catalysts must be always willing to adapt and customize solutions that might not optimize a system, but will make individuals feel in control of their setting and their culture.

A key aspect of this theory is the relationship between catalysts and the human/workforce sub-system. This relationship needs to be built around principles of mutual trust and purposeful action between individuals that appear to share a common 'end' goal (health outcomes improvements). This connection between the catalyst and health setting is not always evident as sometimes 'individual's short term goals' might no be the same; for example, the IS practitioner (catalyst) might be more concerned with training and technical processes while the practice champion might be more compelled to be financially and workforce savvy; each sharing their expertise to create a contextually customised and optimized health information system. This explanation is by no means comprehensive, but begins to discuss the basic assumptions behind the constructs' relationship.

Development, Justification and Articulation of these Relationships

Presenting a complete theoretical treatise in the space of single chapter is at best misguided. However an attempt will be made to succinctly summarise the main thrust of this emerging theory.

The simplest approach to do this to follow the suggestion made by one of the greatest mind of our century when he said:

…unless a theory has a simple underlying picture that the layman can understand, the theory is probably worthless...
Einstein (Pescovitz, 2005)

The following graphic in Figure 6 represents the main components in this emergent theory, including some of the sub-systems and potential hierarchy. Further explanation follows.

While a picture can paint a thousand words, a misinterpreted picture can lead future researchers down the wrong path. In "reading" this conceptual framework it is important to define the development and articulation of the relationships in this theory as it would apply to a "real world" situation. Let not forget that this theory is based on 'real' observed successful implementation and adoptions.

To start with, the intended implementation and consequent adoption of an information system in a health setting, according to this theoretical model, depends on the potential for that system to improve patient health. However, this position assumes that health settings are aware of their own deficiencies in patient care. In the author's experience, via a purposeful PhD study and everyday observations, there has never been a single case when a clinician has been aware of such deficiencies. In this circumstance, possessing a great solution to a problem that is not perceived to exist is next to useless.

The key to this model then does not start with "the solution", but finding "the problem". That is having access to or securing access to the health setting's medical records. This is in itself is a challenging task, particularly in countries like Australia where patient health data in well protected by law and clinician's own concerns for its use.

This has implications not just for being able to carryout further validating research in practice, but also for policy at the governmental level; as it suggests that health settings need to be supported by dedicated and well trained health information systems professionals to achieve any degree of success in implementing information systems in health settings. The amount of time resources needed by a well trained catalyst to support the health setting adopt information systems, including education and training and software support are considerable, although easily offset by the gains in health outcomes at the population level.

This is where the catalyst construct comes into its own, particularly as recognised earlier on, that there are no individuals in health settings that possess the multiplicity of skills needed to retrieve, review and analyse their own clinical data. This is further exacerbated when it is considered that there are financial, legal, communication and organisational skills still to be used in the optimization of all remaining sub-systems.

The catalyst would also have to build a high level of trust to be allowed impute (and optimization) in every sub-system; this is perhaps achieved in time as relationships develop. In my own experience it has taken me sometimes three to four years to develop enough rapport in some cases to truly affect the more sensitive sub-systems systems (i.e. financial and governance).

Perhaps the most important relationship a catalyst will make is with a "champion"; these individuals are more often than not the key to fully access every sub-system in health settings. These can be managers, nurses, doctors or staff members; they are the most valuable asset for a catalyst.

When looking at the sub-system hierarchical list on the diagram, it must be made clear that the hierarchy will change form setting to setting and country to country, and is probably time specific as certain development occurs (for example, laws might be passed that incline a health setting to value risk management more than patient care). In Australia for example general practices are private businesses, so there will be a lot more emphasis on financial sub-system outcomes compared to other countries where clinicians are paid a fixed fee.

DISCUSSION AND LIMITATIONS

There is a general awakening in the health sector that sustained behaviour change in clinical practice cannot be brought about solely by traditional dissemination methods (Peer-reviewed journals and re-education). Theoretical approaches to clinical change management require efficient and wide ranging change processes and implementation processes and procedures. These implementations must integrate the individual and existing inter-related human networks. These theoretical approaches must also acknowledge that organisations exist in unique contexts with unique structures and processes all supported by information systems of one type or another; all underpinning the 'core business' (clinical patient care) through evidence-based medicine.

The author sees in these developments an emergent opportunity for the field of information systems to take a leading role in the development and improvement of the health sector. However, to achieve this role, a solid theory of information systems in health is essential. This emergent theory is a small step towards a more empirically strong theory.

However, the limitations of this examination are many, the content of this chapter was never meant to be comprehensive or conclusive, what it does do however, is to begin a discourse in the hope that others join in its future development. Of the three constructs that were exposed here, only marginal coverage was provided with many premises (if not all) needing further research and critical appraisal; particularly over a broader population than originally studied (general practices). Although there is an emergent authoritative literature supporting some of the premises and conclusions in the constructs; the use of evidence to influence change and validate success and patient outcomes needs further investigation; as does the critical discussion of the extent and role and influence of the catalysts along the artisans-technician and internal-external consultant continuums. Furthermore, the proposition of hierarchical nature of socio-technical sub-systems in health settings needs further verification.

This theory would be better served by further purposeful quantitative and qualitative research that would test every construct down to every single premise. It should focus on a variety of health settings and across a number of countries and across a number of health conditions to better generalise its potential usefulness.

In summary, what was concisely offered here is the beginning of a unique discourse (Hassan, 2006); a theoretical introduction to a multidisciplinary fields not well understood by the information system discipline. In essence an evidence-based health information systems theory holds that: "an information system implementation approach in health setting must be guided, first and foremost by clinical evidence supporting the need for such change in that specific health setting. This evidence is predominantly focused on discovering gaps in local patient care populations to drive change management strategies. Secondly there is a hierarchical necessity to focus on the optimization of all contextual and interdependent subsystem. And thirdly, any measure of success must also be based on the evidence of specific patient health outcome and all other subsystems, keeping in mind their hierarchical importance to the health setting. The facilitation process for all this to happen is through the collaboration of an IS field expert and a site 'champion' that share common goals and objectives".

CONCLUSION

The chapter provided a succinct summary of the context, immediacy and significance for the need to successfully implement information systems in health settings. It briefly discussed the need to consider the core business of health (patient care). The chapter also pointed to the influence that evidence-based medicine (EBM) exerts on health settings and physicians. It suggested mainly a lack of theoretical understanding in the fit between EBM and how it interacts with prospective information systems that are used to research and analyse patient data to improve patient clinical care.

The chapter continued providing the context and foundations for the new constructs discovered in the author's own PhD study to then finally submitting the beginnings of a theoretical foundation to discuss the potentials for the further development of a new evidence-based health information theory. The emerging trends in the health literature suggest many opportunities for the information systems field if solid theories are developed. Future research needs to strengthen the findings that were outlined as well as the need to further expand on this exploratory chapter. It also suggested that a longer treatise with multiple and international contributors is perhaps a more desired approach for further development.

REFERENCES

Aarts, J. (2004). Understanding implementation: The case of a computerized physician order entry system in a large dutch university medical center. *Journal of the American Medical Informatics Association*, *11*(3), 207–216. doi:10.1197/jamia.M1372

AIHW. (2006). *Chronic disease and associated risk factors in Australia, 2006*. Canberra: Australian Government, Department of Health and Ageing.

AMWAC. (2005). *The general practice workforce in Australia: Supply and requirements to 2013*. Australian Medical Workforce Advisory Committee.

Audet, A. M. (2004). Information technologies: When will they make it into physicians' black bags? *MedGenMed [Electronic Resource] : Medscape General Medicine*, *6*(2).

Australian Institute of Health Policies Studies, & VicHealth. (2008). *A platform for advancing the health of all Australians*. Australian Institute of Health Policies Studies, Melbourne, Australia.

Bates, D. W. (2000). Using information technology to reduce rates of medication errors in hospitals. *British Medical Journal*, *320*, 788–791. doi:10.1136/bmj.320.7237.788

Bates, D. W. (2005). Physicians and ambulatory electronic health records. *Health Affairs*, *24*(5), 1180–1189. doi:10.1377/hlthaff.24.5.1180

Bates, D. W. (1995). Incidence of adverse events and potential adverse drug events: Implications for preventions. *Journal of the American Medical Association*, *274*, 29–34. doi:10.1001/jama.274.1.29

Bodenheimer, T. (1999). The American health care system; The movement for improved quality in health care. *The New England Journal of Medicine*, *340*, 488–492. doi:10.1056/NEJM199902113400621

Britt, H. (2007). The quality of data on general practice: A discussion of BEACH reliability and validity. *Australian Family Physician*, *36*(1/2).

Bryant, A. (2002). Re-grounding grounded theory. *The Journal of Information Technology Theory and Application*, *4*(1), 25–42.

Carbone, D. (2008). Information systems in general practice: A framework to implement the management and prevention of chronic diseases. Unpublished doctoral dissertation, Victoria University.

Celler, B. G. (2003). Using information technology to improve the management of chronic disease. *MJA*, *179*(5), 242–246.

Charmaz, K. (2000). Grounded theory: Objectivist and constructivist methods. In N. K. Denzin & Y. S. Lincoln (Eds.), *Handbook of qualitative research*. Thousands Oaks, CA: Sage.

Chaudhry, B. (2006). Systematic review: Impact of health information technology on quality, efficiency, and costs of medical care. *Annals of Internal Medicine*, *144*(10).

Cherns, A. (1976). The principles of sociotechnical design. *Human Relations*, *29*(8), 783–792. doi:10.1177/001872677602900806

Chin, R., & Benne, K. (1969). The planning of change. In *General strategies for effecting changes in human systems* (2nd ed.) (Vol. 1). New York: Holt, Rinehart & Winston.

Clegg, C. W. (2000). Sociotechnical principles for systems design. *Applied Ergonomics*, *31*, 463–477. doi:10.1016/S0003-6870(00)00009-0

Cockburn, J. (2004). Adoption of evidence into practice: Can change be sustainable? *MJA*, *180*, S66–S67.

Cronen, V. (2001). Practical theory, practical art, and the pragmatic-systemic account of inquiry. *Communication Theory*, *11*(1). doi:10.1111/j.1468-2885.2001.tb00231.x

Davenport, T. H., & Pursak, L. (2001). Information ecology: Mastering the information and knowledge environment. *Business History Review*, *3*(75), 15–61.

Davis, D. A. (2004). Solving the information overload problem: A letter from Canada. *MJA*, *180*, S68–S71.

Department of Health and Aged Care. (2003). *Practice incentive payments*. Retrieved November, 2003, from http//: www.health.gov.au/pip/index.htn

Dewey, J. (1938). *Logic: The theory of inquiry*. New York: Henry Holt.

Dickinson, J. (2002). General practice. *MJA*, *176*(1), 17.

DoHA. (2008). National primary care collaboratives. Retrieved April 28, 2008, from http://www.npcc.com.au/

Donabedian, A. (1988). The quality of care. How can it be assessed? *Journal of the American Medical Association*, *260*, 1743–1748. doi:10.1001/jama.260.12.1743

Fieser, J., & Dowden, B. (2008). *Deductive and inductive arguments*. Retrieved from http://www.iep.utm.edu/

Fithgerald, P. (2002). General practice corporatisation: The half-time score. *MJA*, *177*(2), 90–92.

GAO. (2003). *Information technology: Benefits realized for the selected health care functions.* Report to the Ranking Minority Member. US Senate.

Glaser, B. G., & Strauss, A. L. (1967). *The discovery of grounded theory: Strategies for qualitative research*. Chicago: Aldine.

GPDV & GPT. (2007). *Outcomes of the CQI in information management workshop*. Melbourne: General Practice Victoria and General Practice Tasmania.

Grimshaw, J., et al. (2004). Effectiveness and efficiency of guideline dissemination and implementation strategies. *Health Technol Assess*.

Grol, R. (2000). Implementation of evidence and guidelines in clinical practice: A new field of research? *International Journal for Quality in Health Care*, *12*(6), 455–456. doi:10.1093/intqhc/12.6.455

Grol, R. (1998). Attributes of clinical guidelines that influence use of guidelines in general practice: Observational study. *British Medical Journal*, *315*, 418–421.

Grol, R., & Grimshaw, J. (2003). From best evidence to best practice: Effective implementation of change. *Lancet*, *362*, 1225–1230. doi:10.1016/S0140-6736(03)14546-1

Grol, R., & Wensing, M. (2004). What drives change? Barriers to and incentives for achieving evidence-based practice. *MJA*, *180*, S57–S60.

Gross, P. F. (2003). Australia confronts the challenge of chronic disease. *MJA*, *179*(5), 233–234.

Haigh, T. (2001). Inventing information systems: The systems men and the computer, 1950-1968. *Business History Review*, *3*(75), 15–61. doi:10.2307/3116556

Haines, A., & Donald, A. (1998). Getting research findings into practice: Making better use of research findings. *The British Journal of General Practice*, *317*(7150), 72–75.

Hassan, N. (2006). *Is information systems a discipline? A Foucauldian and Toulminian analysis.* Paper presented at the 27th International Conference on Information Systems, Milwaukee, WI.

HealthConnect. (2005). *About HealthConnect*. Retrieved June 04, 2005, from http://www7.health.gov.au/healthconnect/about/index.htm

HealthConnectSA. (2007). *GP change management strategy: Engagement with general practice*. South Australian Department of Health.

Heckley, P. H. (2004). Evidence-based medicine in 2006: A survey of health plan leaders identifies current and emerging stratgies. *Healtcare Informatics,* (April 2004).

Hendy, J. (2005). Challenges to implementing the national programme for information technology (NPfIT): A qualitative study. *BMJ (Clinical Research Ed.)*, *331*, 331–336. doi:10.1136/bmj.331.7512.331

Herzlinger, R. E., & Ricci, R. J. (2002). Dr. know: Can physicans share their experience? *Think Leadership Magazine from IBM*.

Hillestad, R. (2005). Can electronic medical record systems transform health care? Potential health benefits, savings and costs. *Health Affairs*, *24*(5), 1103–1117. doi:10.1377/hlthaff.24.5.1103

Horak, J. B. (2001). Dealing with human factors and managing change in knowledge management: A phased approach. *Topics in Health Information Management*, *21*(3), 8–17.

Humber, M. (2004). National programme for information technology. *British Medical Journal*, *328*, 1145–1146. doi:10.1136/bmj.328.7449.1145

Hummers-Pradiera, E. (2008). Simply no time? Barriers to GPs' participation in primary health care research. *Family Practice*, 1–8.

Ingelse, K. (1997). *Theoretical frameworks*. Retrieved January 6, 2008, from http://jan.ucc.nau.edu/~kmi/nur390/Mod2/theoretical/lesson.html

Lammy, D. (2008). *David Lammy - Leitch and healthcar*e. Retrieved April 28, 2008, from http://www.dius.gov.uk/speeches/lammy_leitch_020408.html

Land, F. (Ed.). (2000). *Evaluation in a socio-technical context*. Boston: Kluwer Academic Publishers.

Liehr, P., & Smith, M. (2001). Frameworks for research. Retrieved January 6, 2008, from http://homepage.psy.utexas.edu/homepage/class/Psy394V/Pennebaker/Reprints/Liehr%20Class.doc

Lind, M., & Goldkuhl, G. (2006). How to develop a multi-grounded theory: The evolution of a business process theory. *Australasian Journal of Information Systems, 13* (2).

Littlejohns, P. (2003). Evaluating computerised health information systems: Hard lessons still to be learnt. *British Medical Journal*, *326*, 860–863. doi:10.1136/bmj.326.7394.860

Lorenzi, N. (2003). *Strategies for creating successful local health information infrastructure initiatives*. Tennessee: Dept of Biomedical Informatics, Vanderbilt University.

Markus, M. L., & Saunders, C. (2007). Looking for a few good concepts…and theories…for the information systems field. *MIS Quarterly*, *31*(1), 3–6.

Ministry of Health. (2007). *How to monitor for population health outcomes: Guidelines for developing a monitoring framework*. Wellington, New Zealand: Ministry of Health.

Mumford, E. (2003). *Redesigning human systems*. Hershey, PA: IRM Press.

Mumford, E. (2006a). Researching people problems: Some advice to a student. *Information Systems Journal*, *16*(4), 383–389. doi:10.1111/j.1365-2575.2006.00223.x

Mumford, E. (2006b). The story of socio-technical design: Reflections on its successes, failures and potential. *Information Systems Journal*, *16*(4), 317–342. doi:10.1111/j.1365-2575.2006.00221.x

Nader, C. (2007, November 9). Expert warn of a health ‘tsunami’. *The Age*.

Nickols, F. (2006). *Change management 101: A primer*. Retrieved March 29, 2008, from http://home.att.net/~nickols/change.htm

Peirce, C. S. (1958). Collected papers. In C. Hartshorne & P. Weiß (Eds.), (pp. 1931-1935). Cambridge, MA: Harvard University Press.

Pescovitz, D. (2005). HOWTO write a theory of everything. Retrieved April 2, 2005, from http://www.boingboing.net/2005/08/04/howto-write-a-theory.html

Piterman, L. (2000). Methodological/ethical issues and general practice research. *Australian Family Physician*, *29*(9), 890–891.

Popper, K. (1979). *Objective knowledge - an evolutionary approach*. Oxford.

Richards, B., et al. (1999). *Information technology in general practice: A monograph commissioned by the general practice branch of the Commonwealth Department of health and Ageing*. Commonwealth Department of Health and Ageing.

Ropohl, G. (1999). Philosophy of socio-technical systems. In *Society for philosophy and technology* (Vol. 4).

Schneberger, S., & Wade, M. (2006). *Theories used in IS research*. Retrieved from http://www.istheory.yorku.ca

Schuster, D. M. (2003). Involving users in the implementation of an imaging order entry system. *American Medical Informatics Association*, *10*(4), 315–321. doi:10.1197/jamia.M1208

Sturnberg, J. (2003). Rethinking general practice for the 21st century: The patient counts! *Australian Family Physician*, *32*(12), 1028–1031.

Urquhart, C. (2001). An encounter with grounded theory: Tackling the practical and philosophical issues. In E. M. Trauth (Ed.), *Qualitative research in IS: Issues and trends*. Hershey, PA: Idea Group Publishing.

Ward, M. H. (2003). What’s happening with IT in general practice? *GPEA,* 6-7.

WHO. (2008). *What works: The evidence for action*. Retrieved January 8, 2008, from http://www.who.int/chp/chronic_disease_report/part3_ch2/en/index13.html

Williamson, H. (2002). *Research methods for students, academics and professionals: Information management and systems* (2nd ed.). Wagga Wagga, Australia: Charles Sturt University.

Wirth, U. (1998). Abductive inference. In P. Bouissac (Ed.), *Encyclopedia of semiotics*. Oxford, UK: Oxford University Press.

Wirth, U. (2008). What is abductive inference? from http://user.uni-frankfurt.de/~wirth/inferenc.htm

Zmud, B. (1998). MISQ: Editor's coments. *MIS Quarterly*, *22*(2), 1–3.

KEY TERMS AND DEFINITIONS

Abduction: Is the process of adopting an explanatory hypothesis (CP 5.145) and covers two operations: the selection and the formation of plausible hypotheses. As process of finding premises, it is the basis of interpretive reconstruction of causes and intentions, as well as of inventive construction of theories.

Concepts: A term or label to describe aspects of reality that can be consciously sensed or experienced; the term or description given to events, situations or processes. Evidenced that is sense-based or grouped together through thought connections.

Conceptual Framework: This is a structure of concepts and/or theories which are pulled together as a map for the study as opposed a ready made map (Theoretical Framework).

Constructs: Is a term or label invented by the researcher for a specific purpose to describe a phenomenon or group of phenomena. In other words, it is a summary of thoughts related to a phenomenon.

Deduction: Determines the necessary consequences, relying on logically provable coherence between premises and conclusion. Induction is aiming at empirical provable coherence between the premises and experience, in order to derive a probable generalization.

Empirical-Rational theory of Change Management: People are rational and will follow their self-interest - once it is revealed to them. Successful change is based on the communication of information and the offering of incentives. People can be persuaded AND 'bought' ('carrot' side of carrot-and-stick) (Chin & Benne, 1969).

Induction: Is aiming at empirical provable coherence between the premises and experience, in order to derive a probable generalization. Yet, induction only classifies the data.

Inductive Argument: Asserts that the truth of the conclusion is supported by the premises. (a deductive argument asserts that the truth of the conclusion is a logical consequence of the premises).

Theoretical Framework: This is the structure of concepts which exists in the literature, a ready-made map for the study; it provides the structure for examining a problem; serves as a guide to examine relationships between variables (Liehr & Smith, 2001).

Theory: A theory is an organized and systematic articulation of a set of statements related to questions in a discipline that are communicated in a meaningful whole. Its purpose is to describe (set forth what is -Descriptive), explain (account for how it functions - Explanative), predict (under what conditions it occurs), and prescribe (under what conditions it should occur) (Ingelse, 1997).

This work was previously published in Handbook of Research on Contemporary Theoretical Models in Information Systems, edited by Y. Dwivedi, B. Lal, M. Williams, S. Schneberger, and M. Wade, pp. 95-111, copyright 2009 by Information Science Reference (an imprint of IGI Global).

Section VIII

Emerging Trends

This section highlights research potential within the field of health information systems while exploring uncharted areas of study for the advancement of the discipline. Chapters within this section highlight new trends in the creation of personal health records, healthcare education, and coding and messaging systems for health informatics. These contributions, which conclude this exhaustive, multi-volume set, provide emerging trends and suggestions for future research within this rapidly expanding discipline.

Chapter 8.1

Toward a Better Understanding of the Assimilation of Telehealth Systems

Joachim Jean-Jules
Université de Sherbrooke, Canada

Alain O. Villeneuve
Université de Sherbrooke, Canada

ABSTRACT

A number of healthcare authorities are considering bringing telehealth systems out of experimental settings into mainstream clinical care. As most literature on telehealth systems to date has focused on their adoption and their evaluation, more work is warranted to understand how telehealth systems can be assimilated and to identify factors that may facilitate or impinge onto this assimilation. Borrowing from institutional, structuration and organizational learning theories, we propose a conceptual model of the determinants relevant for the assimilation of telehealth systems in healthcare organizations. The result is summarized in eight conjectures and a conceptual model. This work not only goes beyond the common methods of analyzing and discussing telehealth systems with user acceptance models, but it also draws a strong link between the assimilation of technological innovations and their institutional context. We hope it will contribute to guide research and managerial actions directed toward integrating telehealth systems in the workplace.

INTRODUCTION

Many western countries have undertaken telehealth projects for providing healthcare services to underserved populations living in remote regions and low-cost specialty services to areas where full-time staffing is uneconomical.

The term telehealth is presently used to describe all possible variations of healthcare services using information and communications technology (ICT) such as tele-education, teleconsultation, and teletraining, among others.

Given the centrality of information technology in telehealth, many studies in information systems (IS) research have been devoted to telehealth systems. A close examination of these studies revealed three salient streams, namely 1) user acceptance/adoption of telehealth systems (Mitchell, Mitchell and Disney, 1996; Hu and Chau, 1999; Cohn and Goodenough, 2002), 2) the characteristics of these systems (McKee et al., 1996), and 3) the effectiveness of telehealth systems compared to conventional face-to-face delivery in different medical specialties (Picolo et al., 2000; Nordal et al., 2001; Bishop et al., 2002). Although our knowledge has been enriched by such diversity, we need to go a step forward in order to consider the organizational assimilation of telehealth systems. The following reasons justify such an endeavor.

First, since telehealth programs have demonstrated clinical value and technical feasibility (Shore, Brooks and al., 2007; Duplantie, Gagnon and al., 2007; Putnam, 2007), they must move from experimental settings to the real world calling for adjustments to healthcare organization's administrative and clinical routines (Saga and Zmud, 1994; Zucker, 1977) as well as into its work systems and technological configuration to account for its assimilation as a technological innovation (Kwon, 1987; Cooper and Zmud, 1990; Chatterjee and Segars, 2001; Keen and McDonald, 2000).

Second, innovation adoption is not always accompanied by widespread deployment (Fichman and Kemerer, 1999). For instance, Eveland and Tornatzky (1990) and Cooper and Zmud (1990) reported that new technology enjoying widespread adoption may fail to be widely deployed.

To be truly valuable, a technological innovation must be routinized and infused in the adopting organization's operational or managerial work systems (Zmud and Apple, 1992). Consequently, to materialize the benefits of telehealth systems, we need to better understand the mechanisms through which their assimilation into administrative and clinical practices occurs. Little is known, however, about the process of telehealth systems assimilation and about assimilation enabling and impeding factors since most studies to date have focused on user acceptance and adoption little being said on what happens after the initial adoption decision has been taken.

This article attempts to add to our knowledge of assimilation of large-scale IS by developing a mixed determinants model of telehealth systems and is structured as follows. First, we explain the nature of telehealth systems, the concerns raised by their deployment and elicit on this basis the underlying mechanisms of their assimilation. Next, we develop the conceptual model by integrating insights from three influential theories: the sociocognitive theory of organizational learning, the institutional theory and the structuration theory. Then, we proceed with our contributions to both theory and practice. Finally, we conclude by indicating the future steps of this research.

THEORETICAL BACKGROUND

We first propose a conceptualization of telehealth system to identify its characteristics. We then cover the role and nature of the technological artifact and their articulation with the social and institutional contexts in which the systems and the adopting organization are embedded (Orlikowski and Iacono, 2001). Such a theorizing strategy ensures that the technological artifact is at the core of the model.

Understanding Telehealth Systems

Information technology systems for telehealth projects are large-scale systems linking two or more organizations and many categories of actors. Considerations about social context are essential to insure the success of systems deployment. An understanding of social relations, work structures, cultural factors and the organization's experience with IT are additional imperatives. Given the scope of telehealth information systems, decisions are far too numerous and technology is too diffuse and complex to be grasped by a single person's cognitive ability. Moreover, acquisition and deployment decisions of such systems are not generally situated within the discretionary power of a single member of the organization (Eveland and Tornatzky, 1990 p.

124). When deployment of an information system requires complex organizational arrangements regarding the location of individual decisions, its adoption and application are the product of numerous decisions dictated by economic and social forces that go beyond managerial logic. The organizations' institutional properties, their work politics as well as certain environmental characteristics (Orlikowski, 1992) can be included into the conceptual model by means of the use of relevant social theories to better understand participating organizations' IT assimilation. Most telehealth initiatives to date aimed at extending conventional health systems by overcoming their limitations such as the inability to provide proper and accessible care throughout large geographical areas. Telehealth projects, combining primary as well as specialized services, not only enable health care coverage beyond geographical boundaries, but also offer the organizational integration of entities with distinct vocations. The rationale for this type of integration goes beyond the logic specific to each organization. All these reasons suggest that assimilation of telehealth systems is influenced by institutional factors, if only to mobilize the necessary resources required to the system integration.

Further, since telehealth systems comprise a variety of technologies such as home healthcare monitoring, telemedicine and tele-education, the very nature of the technology must be accounted for in our conceptual model. Telehealth applications are diverse and are deployed based on numerous technologies such as teleconferencing, digital imaging, data storage and retrieval (sound, images, and alphanumeric data), robotic, two-way interactive television, etc. An appropriate infrastructure enabling data transmission and data entry, the creation of multimedia databases as well as communication between different partner organizations must be in place. Accordingly, telehealth information systems comprise different classes of technology. These vary from technologies that do not interact with users to more advanced technologies that require high interaction with professionals as they intrude into health care practices. Some technologies not only support clinical activities, they also provide reasoning behind medical evaluation and training (Grémy and Bonnin, 1995). Finally, they include infrastructure-type technologies, the purpose of which consists of managing large flows of information coming from numerous sources and going to numerous places, services or persons within the organization. These technologies have no reason for existence in and of themselves; they are an integral part of the telehealth organization (Grémy and Bonnin, 1995). When faced to such a broad range of technologies, individuals can feel threatened about partly losing control over their work schedule and professional autonomy. Moreover, given that the systems impose their own representations of the world, individuals' choices become limited. Feelings can range from fascination for some users to frustration for others. .

Telehealth systems combine several heterogeneous parts made up of numerous intrinsically complex components (Paré and Sicotte, 2004). Therefore, it appears more appropriate to conceptualize them as focal technological systems linked by a web of connections to its social, political, and institutional contexts (Kling and Scacchi, 1982). As such, despite the reality that the technological artifact is central to telehealth systems, it remains that it is an element of an ensemble that also comprises the necessary components to apply the technical artifact to a given socio-economic activity (Kling and Dutton, 1982; Illich, 1973). Among these components, we find commitment, additional resources such as training, qualified personnel, organizational agreements, the political and reward systems. In short, we find all that is necessary to promote the effective management of systems (Kling and Scacchi, 1982). The ensemble view of telehealth systems entails at least three things. First, the necessity to consider these systems as embedded in a dynamic and complex social context and the examination of the manner in which different social influences contribute to model its deployment along with how different user groups integrate them (Orlikowski and Iacono, 2001). Second, the structural potential of IT on the rules and resources and the spirit of these systems (Giddens, 1984; DeScantis and Poole, 1994). Finally, it is necessary to consider uncertainties and consequently the interpretation problems due to the diversity of the technologies involved, the organizational agreements they require and changes into organizational schemas and procedures for everyday action (Barley, 1986).

The previous developments lead us to understand that, not only does the assimilation of telehealth systems entail that we proceed with shared social representations of these systems but also that they are susceptible to become influenced by factors related to these systems' attributes, to characteristics of the institutional context, and to interactions between technological innovation and the organizational milieu.

Understanding Assimilation

Assimilation is often conceptualized as a learning process (Attewell, 1992; Fichman and Kemerer, 1997, 1999). Our conceptualization, though, differs slightly as we model assimilation as two processes: technological routinization and infusion. Routinization refers to the fact that as time goes by; the system ceases to be perceived as a novelty and becomes taken-for-granted (Saga and Zmud, 1994; Ritti and Silver, 1986; Zucker, 1977). Infusion refers to the system's embeddedness into organizational procedures and work architectures as it links different organizational elements such as roles, formal procedures, and emerging routines (Cooper and Zmud, 1990; Kwon, 1987). As telehealth systems combine diverse technologies their development and implementation, like that of complex systems, become a continual process (Weick, 1990).

Underlying Mechanisms of Assimilation

Making sense of telehealth systems is needed due to the nature of the system and because telehealth constitutes a new form of health services delivery.

Telehealth systems are complex, a reality that is not only due to the institutional agreements that their deployment requires but also to their technological constituents. For example, the Sores Care Tele Assistance Project (SCTAP) implemented by the Sherbrooke Integrated Health University Network deploys seventy three (73) information technologies within sixty five (65) points of care. The deployment comprises eight phases each including the organization of new clinical services and the elaboration of a deployment strategy of new virtual clinics, etc. (RUIS de Sherbrooke, 2007).

Given their complexity, systems in healthcare can create problems never-before seen by managers or by health care professionals (Weick, 1990). Given they are exogenous to the organization context, their introduction is likely to create a certain hiatus between existing meaning, legitimization and domination systems and the new exigencies related to the organization's daily actions (Barley, 1986). Therefore, these new technologies affect organizational members' capacity to reason on telehealth systems structures because technologies in general, and new technologies in particular, are interpretively flexible (Weick, 1990), they allow for different possible and plausible interpretations by diverse social groups and can be misunderstood, uncertain, and complex (Pinch and Bijker, 1987; Weick, 1990; Orlikowski and Gash, 1994).

This interpretive flexibility results from the presence of information technology artifacts as well as from cognitive schemas (Orlikowski and Iacono, 2001; Chae, 2002). While artifacts are made up of material resources like equipment, applications (Kling, 1987), non-material resources, networking capacity, programming languages (Chae, 2002) as well as structural elements built-into technology (DeSanctis and Poole, 1994), schemas point to generalizable procedures that take root in the context or pre-existing institutions (Chae, 2002). Within the context of implementation and utilization, procedures can be associated to the social organization of computerization (Kling and Iacono, 1989). Further, since telehealth systems often involve several organizations and individuals, this may even lead to equivocalities in meaning. For example, the SCTAP project regroups thirteen

(13) Health and Social Services Centers (Centres de Santé et des Services Sociaux, CSSS), spreading through three of Quebec's geographical regions and calling up ninety nurses. Consequently, schemas can be considered complex, numerous and embedded into multiple structures.

Precedent arguments stress both the participants' perception of ambiguity regarding the nature of telehealth systems and users' need to make sense of these technologies for using and integrating them in their daily practice. Following Orlikowski and Gash (1994), participants develop hypotheses and expectations to build their comprehension about what the technology is and what it is good for and their interpretation of the technology often dictates how he/she will use it. Hence, sensemaking is essential for assimilating the technology into work practice. Further, sensemaking clarifies the system's rationale and the development of its underlying philosophy or, in other words, its spirit (De Sanctis and Poole, 1994). It helps understanding the nature of the technology and its consequences within a given context (Orlikowski and Gash, 1994).

In our view, sensemaking is also a process that modifies the user's cognitive structure (mental models) which could be described as: "a built-up repertoire of tacit knowledge that is used to impose structure upon, and impart meaning to otherwise ambiguous social and structural information to facilitate understanding" (Gioia, 1986, p.56).

Technology Routinization and Infusion

In early research, IS implementation is viewed as a final step in which a new system is configured and installed. Since the work of Kwon and Zmud (1987), the process research stream in IS innovation implementation has instead focused its attention on post-implementation organizational behaviors (Saga and Zmud, 1994). Expanding the work of Kwon and Zmud (1987), Cooper and Zmud (1990) introduced a model of implementation that comprises the following stages: initiation, adoption, adaptation, acceptance, routinization, and infusion. This stream of research studies system implementation from a perspective inside the organization and conceptualizes implementation as a change effort to ensure successful implementation of a new system (Lucas, 1981). Indeed, Cooper and Zmud's model drew upon Lewin's (1952) planned change theory. As adaptation reflects the "changing state", acceptance, routinization, and infusion mirror the "refreezing state" (Saga and Zmud, 1994). Accordingly, inside this stream some scholars have later moved away from the planned change perspective. Their studies focused either on issues arising from implementation process or on how to manage the group along with the interpersonal process to make changes happen. IS implementation literature has later proposed a complementary view to the planned change perspective. According to this view, IS implementation is better thought of as a dynamic process of mutual adaptation between technology and organization (Leonard-Barton, 1988). Further contributing to this line of reasoning, Orlikowski (1992/1993) as well as Orlikowski and Gash (1994) proposed a situated change perspective. Central to this view is the subtle, smooth, and significant way through which organizational transformation is enacted. Such an organizational transformation is grounded in the organization's routines or work systems (Alter, 2003) and then in the ongoing work practices of organizational actors. These organizational changes are enacted as users accommodate to contingencies, exceptions opportunities, breakdowns, and even unintended consequences they face in their task (Barley, 1990). Scholars in this view widely acknowledge that new technologies always trigger changes in organizational routines (Barley, 1986; Tyre and Orlikowski, 1994) and this disruption in routines has been found to be largely associated with cognitive and interpersonal changes (Barley, 1986; Orlikowski, 1993).

Adopting this line of reasoning, moving away from studies that focus on the process through which managers alter routines, we take the perspective that when a new technology is implemented, the organizational actors engage in a sense making process and develop new frames about the technology. In so doing, they make cognitive, interpersonal, and organizational adjustments that allow the new technology and the corresponding new routines to become ongoing practice (Edmonson et al., 2001). Accordingly, routinization, in our view, follows Hall and Loucks' (1977) theory of cognitive adaptations. Individuals go through several understandings (meanings) of the technology as they first make sense of it before using it. Through their use of the technology, their sharing of their experiences with others and their coordinating of their activities with those of others, they refine their understandings (meanings) of it. Users confront their meanings with those of others and refine their understanding of the nature of the technology and of what it is good for though at times conflicts could arise that would lead to a new system's social representation (Lauriol, 1998).

Coordinating their activities with other users is an important means of assimilating the technology because it is the very nature of organizational learning, whose main outcomes are routinization and infusion. Coordination helps users build up new cognitive coordinations, to memorize them, to repeat them and to transpose them to new situations. Coordination also implies norms and rules and can promote the incorporation of technology into organizational routines. As long as the organization evolves in its understanding of the system and its possibilities, it tends to modify its workplace architecture to increase the extent of systems' use, to integrate the systems' usage and to accomplish activities not previously considered feasible (Saga and Zmud, 1994).

In summary, assimilation starts as an individual learning process through which participants later develop new schemas and scripts to represent the system. Afterwards, through interaction and coordination, an organizational learning process occurs by which individuals' schemas and scripts evolve leading to a shared understanding which initially blends into their routines but ends up being integrated into their daily practices and organizational beliefs, transcending the individuals who were at the beginning of the process.

DEVELOPMENT OF THE CONCEPTUAL MODEL

Figure 1 illustrates the conceptual model for this exploration of the factors that are likely to influence the assimilation of telehealth systems. Through this model we contend that systems innovation attributes, institutional environment properties, and interaction between technology and organizations are important determinants of telehealth systems assimilation. The different elements of the model are discussed below.

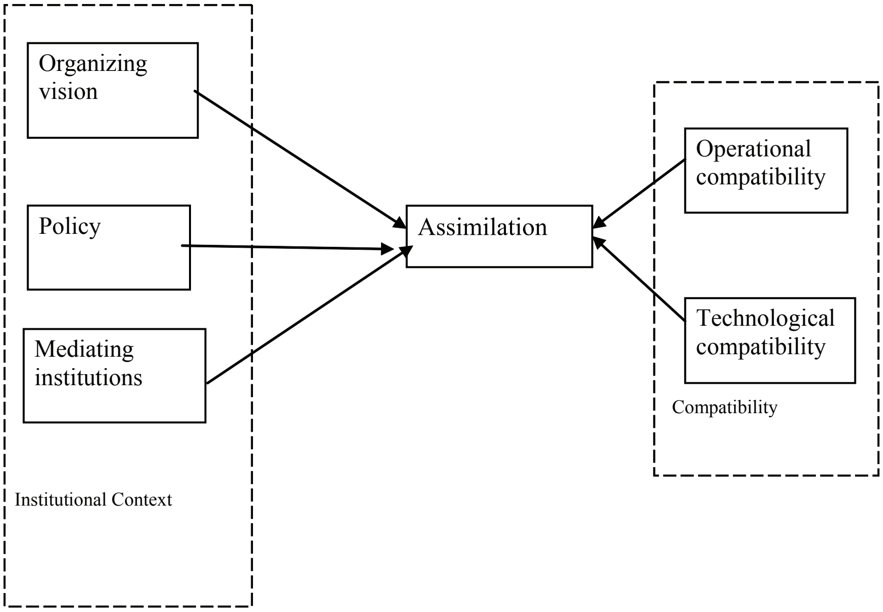
The Organizing Vision

In the case of technological innovations like telehealth systems, institutional processes come into play from the beginning of the diffusion process. A heterogeneous network of parties creates and employs an organizing vision that contributes to reduce uncertainties surrounding the systems along with their applications (Swanson and Ramiller, 1997). This organizing vision allows members of this network to make sense of the innovation. An organizing vision aims at making the spirit of the technology explicit, namely the underlying philosophies of the IT artifacts as well as the motives for its development (Chae, 2002)

Therefore, users do not rely exclusively on their own interpretations of the technology during the early phase of sensemaking as they can use the organizing vision as a starting point. From their original understanding, they will seek to search, probe and confirm meanings with others (Swanson and Ramiller, 1997). They will assess interpretations that exist within their own organization, yet consistent with those of partner organizations due the presence of an organizing vision. There are, however, some pitfalls and limitations that may arise during the process of sensemaking.

Telehealth projects vary in nature and objectives. They may vary in configuration (same technologies but configured differently). Sometimes, some of the system components are immature technologies or prototypes. Those system

Figure 1. Factors of organizational assimilation of telehealth systems



components are ill-defined and their applications are not well understood (Swanson and Ramiller, 1997). Meanings assigned to such technologies reflect incompleteness and instability (Rosemberg, 1994). An organizing vision is warranted to provide a structure that helps users understand the very nature of telehealth systems as well as their role given social, technical and economic contexts (Klecun-Dabrowska and Cornford, 2002). It also provides for reducing equivocalities and creating shared understandings of the system.

The sociocognitive theory of organizational learning, however, suggests that for a given technology, each group is likely to develop a specific set of shared understandings thus forming a technological frame. This frame emerges from interactions among group members through the coordination of their interdependent activities (Schein, 1985; Strauss, 1978) and also through the way the group's specific norms influence its members (Porac et al., 1989; Grégory, 1983; Van Maanen and Schein, 1979).

By formulating expectancies, assumptions and knowledge about key aspects of telehealth systems, the organizing vision contributes to make congruent the groups' technological frames. Therefore, organizations are likely to experience fewer difficulties or conflicts linked to systems' implementation and use (Orlikowski and Gash, 1994 p.180). Consequently, we make the following hypothesis:

Conjecture 1: *A compelling organizing vision is likely to positively influence the assimilation of telehealth systems.*

The organizing vision also provides a structure of legitimization that complements and reinforces the structure of interpretation by including in its discourse aspects directed toward justifying the technological innovation. Discourse pointing to the systems' legitimacy deals with technical and functional arguments with political, organizational and business arguments. This discourse is not just formulated in terms of the low-cost associated with electronically delivered services; it also includes dominant social values and principles like improving the quality of citizens' life (Klecun-Dabrowska and Cornford, 2002). This dimension of the organizing vision is dedicated to communicating not only the expected benefits of the innovation but also its spirit. To illustrate, by promoting telehealth as a means to bring specialized care services to remote regions and to recruit and maintain physicians in those regions, the organizing vision capitalizes on current norms and social values of our society. In so doing, it legitimates telehealth and mobilizes resources needed for its successful deployment (Orlikowski and Gash, 1994, Swanson and Ramiller, 1997). The preceding development suggests the following conjectures:

Conjecture 2: *An organizing vision that promotes telehealth on the basis of the health system's current values and social norms is likely to positively influence the assimilation of telehealth systems.*

Conjecture 3: *Perceived social benefits are likely to positively influence the assimilation of telehealth systems.*

Policy Making

Many barriers have been identified with respect to the diffusion of innovations, two of which are particularly relevant here: lack of reimbursement and legal liability. In the domain of reimbursement for instance, few public or private payers reimbursed healthcare services provided through advanced ICT in the USA during the early years of ICT. Some improvements have been made but are still deemed too restrictive. The Balance Budget Act expanded the coverage to telemedicine services but at the same time introduced new requirements that keep people from using telemedicine under current Medicare conditions (DHSS, 2001). Likewise, Gagnon et al. (2001) reported that the reimbursement system made some services less available and less accessible in the telehealth project implemented in Iles-de-la Madeleine one remote region in the Province of Québec, Canada.

Legal liability is an important issue in the diffusion of telehealth. Medical errors account for some 44000 to 98000 deaths every year in the US and errors are attributable in great part to the decentralized, fragmented, complex nature of the US healthcare delivery system (IOM, 1999). According to IOM, the relationship between the complexity of the healthcare system and medical errors can have serious adverse effects on the diffusion of telehealth. For instance, who is accountable for a medical error, the referent of the referring physician? There is no clear answer. Yet, specialists may be reluctant to give medical advice through ICT. We hence propose:

Conjecture 4: *Policy making directed toward facilitating the reimbursement of telehealth services is likely to positively influence the assimilation of telehealth systems.*

Conjecture 5: *Policy making directed toward establishing the liabilities of telehealth professionals when an error is reported is likely to positively influence the assimilation of telehealth systems.*

Mediating Institutions

Telehealth shares the properties of both technological and administrative innovations (Robinson et al., 2003). As such, deployment issues stem from their incorporation in the organizational and clinical routines (Paré and Sicotte, 2004). Partnerships with mediating institutions like knowledge generating organizations (consulting, universities) specialized in advanced technologies know-how could help lower knowledge barriers associated with technology integration (Attewell, 1992).

Conjecture 6: *Collaboration with some intermediating institutions is likely to positively influence the assimilation of telehealth systems.*

COMPATIBILITY

Operational Compatibility

Telehealth systems are deployed in healthcare organizations with well-defined values, norms and institutional practices. These institutional elements are instantiated in rules, work procedures, protocols and even current technologies which can influence their assimilation. It has been reported that social structures could serve either as constraints or as enablers to the implementation of systems (Kling and Iacono, 1989). Systems in turn have the capability to introduce a new organizational dynamic that modifies social and hierarchical relationships as well as the balance between institutional arrangements and the organization's daily life (Gosain, 2004). Then, telehealth systems not only trigger a structuration process, but also create the potential for misalignment between the incumbent institutional regime (installed social base) and the institutional logics embedded in telehealth systems. Indeed, telehealth systems are best conceptualized as complex social objects (Kling and Scacchi, 1982) embodying traces of human intentions that resurface as they are put in use (Chae and Poole, 2005). This raises a question of compatibility between telehealth systems and the adopting healthcare organization's work systems.

Conjecture 7: *compatibility between telehealth systems and the adopting healthcare organization's work systems is likely to positively influence their assimilation.*

Technological Compatibility

Information systems present a unique combination of human, material and disciplinary agency (Chae and Poole, 2005; Pickering, 1995). Agency refers to the capacity of a thing or person to act purposefully. While human agency involves self-reflexive monitoring and adjustment of action in order to achieve desired ends, material agency refers to the things the physical and biological world does (Chae and Poole, 2005 p.22). Disciplinary agency is the shaping and channeling of human action by conceptual and cultural systems. These differing agencies emerge when IS are put in use or when said differently through interactions with the adopting organizations. This raises a question of compatibility between telehealth systems and the adopting healthcare organization's work systems and technological infrastructure.

Conjecture 8: *compatibility between telehealth systems and the adopting healthcare organization's technological infrastructure is likely to positively influence their assimilation.*

CONTRIBUTIONS

This article developed a theoretical perspective for understanding the assimilation of telehealth systems on the grounds of their very nature and the issues raised by their deployment. In so doing, it contributes to research in pointing to the value of grounding the theorizing of assimilation of telehealth systems in the fundamental characteristics of the technological artifact like its interpretive flexibility as well as the complex organizational arrangements necessary to its deployment. Further, unlike in prior studies of assimilation of IS innovations (Chatterjee et al., 2002; Purvis et al., 2001; Gallivan, 2001; Meyer and Goes, 1988), assimilation is conceptualized as an organizational phenomenon that has its theoretical origins in individual interpretation. Second, the model uncovers the interplay between the institutional context and cognitive regulations. In so doing, it makes more salient the fact that assimilation of telehealth systems is essentially a multilevel phenomenon.

Our study also carries implications for practice. Particularly, it points to the importance of examining the assimilation process within the continuum of IS phenomena surrounding the deployment of telehealth systems. As such, it helps understand why managerial actions directed toward facilitating the assimilation process should be employed as early as the adoption phase. For instance, issues related to compatibility between the systems and the organization's work infrastructure should be managed during the development phase. Briefly, even though routinization and infusion are post-implementation behaviors, factors that are likely to influence them should be taken under consideration before systems acquisition.

FUTURE WORK

Given that the goal of this article is theory development, additional work is needed to fully operationalize the constructs and empirically test the model. Nevertheless, it builds a sound foundation for better understand assimilation of telehealth systems.

Our future work will focus on extending the current model of assimilation of IS and on addressing related open research issues. Indeed, despite the fact that we take individual sense making as the starting point of routinization, we focus on examining the assimilation of telehealth systems at the organizational level. As prior studies, our exclusive focus on the organizational level ignores more micro and meso explanation of the phenomenon (House et al., 1995). A more detailed account is then needed to explicit both the structure (Kozlowski and Klein, 2000) and the functional relationships of the phenomenon (Morgesson and Hofmann, 1999). In other words, it is necessary to account for how individual, group and organizational characteristics interact to structure the process of assimilation. Therefore, approaching this phenomenon from a socio-cognitive viewpoint will lead us to a multilevel perspective that will result in a more integrated understanding of how the assimilation process unfolds across levels in organizations and may add depth and richness to our theoretical model. In fact, the first reflections in this direction has already provided new insights and pointed to some key factors we would never supposedly think of.

This new research direction is likely to enhance the managerial significance of this work. Indeed, a more comprehensive and integrative multilevel model of assimilation, by making explicit the functional relationships at individual, group and organizational levels, will highlight the range of managerial interventions required to secure the IS assimilation and consequently the telehealth systems effectiveness. In addition, the model will provide, beyond policy, a better understanding of the locus of authority for each specific managerial intervention. In so doing, it will be helpful in enhancing the effectiveness of managerial actions and also in smoothing the IS governance aspects regarding telehealth systems. Finally, next in our agenda, we will test the model in an empirical, real-life, setting. This will provide for a test of the model and will allow us to identify additional contributing factors to better understand assimilation of telehealth systems into the workplace.

REFERENCES

Amy C Edmondson, Richard M Bohmer, and Gary P Pisano. (2001). Disrupted routines: Team learning and new technology implimentationin hospitals. *Administrative Science Quarterly,* 46 (4), 685.

Attewell, P. (1992). Technological Diffusion and Organizational Learning:The Case of Business Computing. *Organization Science, 3* (1), 1.

Barley, S. R. (1986). Technology as an Occasion for Structuring: Evidence from Observations of CT Scanners and the Social Order of Radiology Departments. *Administrative Science Quarterly, 31* (1), 78.

Barley, S. R. (1990). The Alignment Of Technology And Structure Through Roles And. *Administrative Science Quarterly, 35* (1), 61.

Bishop, J. E., O'Reilly, R. L., Daddox, K., et Hutchinson, K. (2002). Client Satisfaction in a faisability Study Comparing face-to-face Interviews with Telepsychiatry. *Journal of Telemedicine and Telecare, 8* (4).

Chae, B. (2002). *Understanding information systems as social institutions: Dynamic institutional theory.* Unpublished doctoral dissertation, Texas A&M University, United States -- Texas.

Chae, B., et Poole, M. S. (2005). The surface of emergence in systems development: agency, institutions, and large-scale information systems. *European Journal of Information Systems, 14*, 19-36.

Chatterjee, D., Grewal, R., and Sambamurthy, V. (2002). Shaping up for e-commerce: Institutional enablers of the organizational assimilation of web technologies. *MIS Quarterly, 26* (2), 65.

Chatterjee, D., and Segars, A. H. (2001). Transformation of the Enterprise through E-Business: An Overview of Contemporary Practices and Trends. *Report to the Advanced Practices Council of the Society for Information Management,* (July).

Cohn, J. R., and Goodenough, B. (2002). Health Professionals Attitudes to Videoconferencing in Pediatric Heathcare. *Journal of Telemedicine and Telecare, 8* (5).

Cooper, RB., and Zmud, R. W. (1990). Information Technology Implementation Research: A Technological Diffusion Approach. *Management Science, 36* (2), 123.

DeSanctis, G., and Poole, M. S. (1994). Capturing the Complexity in Advanced Technology Use: Adaptive Structuration Theory. *Organization Science, 5* (2), 121-147.

DHSS. (2001). *Report to Congress on Telemedicine*: Secretary of Health and Human Services.

Duplantie, J., Gagnon, M.-P., et al. (2007). Telehealth and the recruitment and retention of physicians in rural and remote regions: a Delphi study. *Canadian Journal of Rural Medicine,* 12(1), 30.

Eveland, J. D., and Tornatzky, L. (1990). The Deployment of Technology. L. In Tornatzky, et M. Fleischer (Eds), *The Processes of Technological Innovation* (p.Chapter 6). Lexington: Lexington Books.

Fichman R.G , and Kemerer C. F. (1997). The assimilation of software process innovations: An organizational learning perspective. *Management Science, 43* (10), 1345.

Fichman R.G, and Kemerer C.F. (1999). The illusory diffusion of innovation: An examination of assimilation gaps. *Information Systems Research, 10* (3), 255.

Gagnon, M.-P., Fortin, J. P., and Cloutier, A. (2001). La télémédecine au service d'une région: Recherche évaluative sur le projet des Iles-de-la-Madeleine. *Ruptures, 8*, 53-70.

Gallivan, M. J. (2001). Organizational adoption and assimilation of complex technological innovations: Development and application of a new framework. *Database for Advances in Information Systems,* 32 (3), 51.

Giddens, A. (2005). *La Constitution de la Société: éléments de la théorie de la structuration (traduit de l'anglais par Michel Audet)*. Paris: Quadridge PUF (1čre édition).

Gosain, S. (2004). Enterprise Information Systems as Objects and Carriers of Institutional Forces: The New Iron Cage. *Journal of the Association for Information Systems, 5* (4), 151-182.

Gregory, K. L. (1983). Native-View Paradigms: Multiple ultures and culture conflicts in organization. *Administrative Science Quaterly, 28* (3), 359-376.

Grémy, F., and Bonnin, M. (1995). Evaluation of Automatic Health Informations Systems. What and How? E. In Van Gennip, and J. Talmon (Eds.), *Assessment and Evaluation of Information Technologies in Medicine* . Amsterdam: IOS Press.

Hall, G., and Loucks, S. (1977). A developmentla Model for Determining Wether the Treatment is Actually Implemented. *American Educational Research Journal, 14* (3), 263-276.

Lucas, H.C. (1981). An Experimental Investigation of the Use of Computerized –Based Graphics in Decision Making. *Management Science (Pre-1986),* 27 (7), 757.

Hu, P., andChau, P. (1999). Physician acceptance of telemedicine technology: an empirical investigation. *Topics in Health Information Management, 19* (4), 20-35.

Illich, I. (1973). *Tools for conviviality.* New York: Harper and Row.

Institute of Medicine (IOM). (1999). *To Err Is Human: Building a Safer Health System*. Washington, DC: National Academic Press.

Keen, P., and McDonald, M. (2000). *The eProcess Edge: Creating Customer Value and Business Wealth in Internet Era.* Berkeley, CA: McGraw Hill.

Klecun-Dabrowska, E., and Cornford, T. (2002). The Organizing Vision of Telehealth. *ECIS, Gdansk Poland*.

Kling, R., and Dutton, W. H. (1982). The computer package, dynamic complexity. J. N. Danziger, D. W. H. , R. Kling, et K. L. e. Kraemer *Computers and Politics: High Technolgy in American Local Governments.* (p.22-50). New York: Columbia University Press.

Kling, R., and Iacono, C. (1989). The Institutional Character of Computerized Information System. *Office Technology & People, 1* (1), 24-43.

Kling, R., and Scacchi, W. (1982). The Web of Computing: Computer technology as Social Organization. *Advances in Computers,* (21), 1-90.

Kozlowski, S. W. J., and Klein, J. K. (2000). A Multilevel Approach to Theory and Research in Organizations: Contextual, Temporal, and Emergent Process. J. K. Klein, et S. W. J. Kozlowski ((Eds.)), *Multilevel Theory, Research, and Methods in Organizations* (p.3-90). San Francisco: Jossey-Bass.

Kwon, T. H. (1987). *A Study of the Influence of Communication Network on MIS Institutionalization.* Unpublished dissertation, The University of North Carolina at Chapel Hill, United States -- North Carolina.

Kwon, T. H., and Zmud, R. W. (1987). Unifying the fragmented models of information systems implementation. In Boland and Hirscheim (Eds), *Critical Issues in Information Systems* . New York: John Wiley.

Lauriol, J. (1998). Les représentations sociales dans la décision. In H.Laroche, et J-P. Nioche (dir.), *Repenser la stratégie* . France: Vuibert.

Leonard-Barton, D. (1988). Implementation as Mutual Adaptation of Technology and Organization. *Research Policy,* 17 (5), 251.

McKee, J. J., Evans, N. E., and Owens, F. J. (1996). Digital Transmission of 12-Lead Electrocadiograms and Duplex Speech in the Telephone Bandwith. *Journal of Telemedicine and Telecare, 2* (1).

Mitchell, B. R., Mitchell, J. G., and Disney, A. P. (1996). User adoption Issues in Renal Telemedicine. *Journal of Telemedicine and Telecare, 2*(2).

Nordal, E. J., Moseng, D., Kvammen, B., and Lochen, M. (2001). A Comparative Study of Teleconsultation versus Face-to-Face Consultations. *Journal of Telemedicine and Telecare, 7* (5).

Orlikowski, W. J. (1992). The Duality of Technology: Rethinking the Concept of Technology in Organizations. *Organization Science, 3* (3), 398-427.

Orlikowski, W. J., and Gash, D. C. (1994). Technological frames: making sense of information technology in organizations. *ACM Transactions on Information Systems, 12* (2), 174-207.

Orlikowski, W. J., and Iacono, C. S. (2001). Research commentary: Desperately seeking «IT» in IT research - A call to theorizing the IT artifact. *Information Systems Research, 12* (2), 121.

Orlikowski, W. J. (1993). Learning from notes: Organizational issues in groupware implementation. *Information Society,* 9 (3), 237 .

Paré, G., and Sicotte, C. (2004). Les technologies de l'information et la transformation de l'offre de soins. *Cahier Du GReSI,* (04-04).

Pickering, A. (1995). *The Mangle of Practice*. Chicago: The University of Chicago Press.

Picolo, D., Smolle, D., et al. (2000). Teledermoscopy: Results of a Multicentre Study on 43 Pigmented Skin Lesions. *Journal of Telemedicine and Telecare, 6* (3).

Pinch, T., and Bijker, W. (1987). The social connstruction of facts and artifacts. W. In Bijker, T. Hughes, and T. Pinch (Eds.), *The Social Construction of Technological Systems* (p.159-87). Cambridge, Massachussets: MIT Press.

Porac, J. F., Thomas, H., and Baden-Fuller, C. (1989). Competitive groups as cognitive communities: The case of Scottish knitwear manufacturers. *Journal of Management Studies, 26* (4), 397-416.

Purvis, R. L., Sambamurthy, V., and Zmud, R. (2001). The assimilation of knowledge platforms in organizations: An empirical investigation. *Organization Science, 12* (2), 117.

Putnam, J. M. (2007). Combining Telehealth and E-Learning: A Case Study in Smoking Cessation Programming. *American Journal of Health Studies,* 22 (3), 130.

Ritti, R., and Silver, J. (1986). Early Processes of Institutionalization: The Dramaturgy of Exchange in Interoganizational Relations. *Administrative Science Quaterly, 31*, 25-42.

Rosemberg, N. (1994). *Exploring the Black Box: Technology,Economics and History.* Cambridge: Cambridge University Press.

Ruis de Sherbrooke. (2007). La téléassistance en soins de plaies, orientée vers une amélioration continue de la qualité des soins. *Manuel D'Organisation De Projet,* 1-63.

Saga, V., and Zmud, R. (1994). The nature and determinants of information technology acceptance, routinization and infusion. In Levine. L. (Ed.), *Diffusion, Transfer, and Implementation of Information Technology* (p.67-68). Noth-Holland, Amsterdam.

Schein E. (1985). *Organizational Culture and Leadership.* San Francisco, California: Jossey-Bass.

Shore, J. H., Brooks, E., et al. (2007). An Economic Evaluation of Telehealth Data Collection With Rural Populations. *Psychiatric Services,* 58 (6), 830.

Strauss, A. (1978). A Social World Perspective. *Stud. Symb. Interaction, 4*, 171-190.

Swanson, B. E., and Ramiller, N. C. (1997). The Organizing Vision in Information Systems Innovation. *Organization Science, 8* (5), 458.

Van Maanen, J., and Schein, E. (1979). Toward a theory of organizational socialization. *Research in Organizational Behavior, 1*, 209-264.

Weick, K. (1990). The vulnerable system: an analysis of the Tenerife Air disaster. *Journal of Management, 16.*

Zmud, W. R., and Apple, L. E. (1992). Measuring Technology Incorporation/Infusion. *Journal of Production Innovation Management,* (9), 148-155.

Zucker, L. (1977). The Role of Institutionalization in Cultural Persistence. *American Sociological Review, 42* (5), 726-743.

This work was previously published in International Journal of E-Services and Mobile Applications, Vol. 1, Issue 2, edited by A. Scupola, pp. 20-37, copyright 2009 by IGI Publishing (an imprint of IGI Global).

Chapter 8.2

Mobile Health Applications and New Home Telecare Systems:

Critical Engineering Issues

Žilbert Tafa
University of Montenegro, Montenegro

ABSTRACT

This chapter describes the very actual issues on mobile health (M-H) and home care (H-C) telecare systems, reviewing state of the art as well as theoretical and practical engineering issues crucial for designing these applications. The purpose, advantages and overall information and communication technology (ICT) architectures of M-H and H-C telecare systems are firstly presented. There are several engineering fields involved in the design of modern M-H and H-C applications. Making the optimal application-specific choice in each engineering aspect and achieving the right balance between complementary coupled technological requests are of crucial meaning so the main critical engineering issues (weighted at sensing node's design and the wireless communications) are presented in details as well. Systematic theoretical review and accentuation of the design and realization problems given in this chapter can contribute in better understanding of crucial engineering issues and challenges on this topic as well as in giving the proper direction lines to approaching the practical realization of M-H and H-C telecare systems.

DOI: 10.4018/978-1-60566-002-8.ch021

FROM DESKTOP TELEMEDICINE TO THE NEW WIRELESS SOLUTIONS

For more than 30 years, the achievements in IT, electronics, telecommunications and biomedical engineering have been used to facilitate the quality of health care delivery. This kind of approach has provided great benefits in improving the health of population generally, especially by assuring the timely diagnostics and therapeutic treating of patients. Taking the historical view of the technologies that have been used in classical telemedicine applications, one can notice that these applications mainly were designed for fixed-based infrastructure remote monitoring, professional teleconsultations and in providing medical help to remote patients treatment. These applications were concentrated on transferring biomedical and video signals, as well as the medical images and sounds, with the main aim of providing the remote health care service. But, the main drawbacks of the early health delivery systems are contained in the fact that they were not designed to provide the mobility, autonomy of measured subject and health care delivery integrated into patient's everyday life.

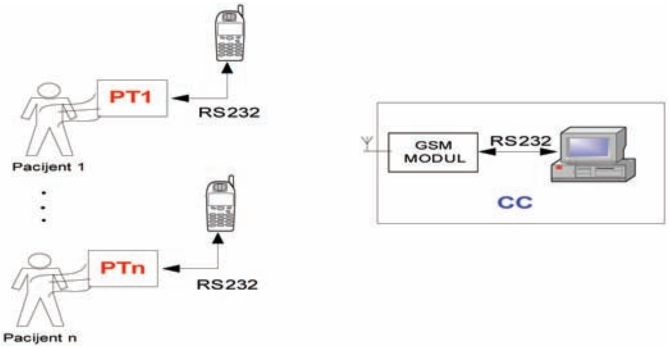
Current and emerging developments in microelectronics and wireless communications integrated with developments in pervasive and wearable technologies will have a radical impact on future health care delivery systems (Istepanian, Jovanov, and Zhang, 2004). The results of these developments make possible the realization of the wireless medical sensors with networking capability. Such medical sensor networks greatly enhance the ability of physicians to timely examine and treat complex biological systems at a distance and effectively reduce the infrastructure cost at hospital side and the travel expense at the patient side. The use of new wireless technologies in health delivery systems, offers many advantages, especially in continuous remote monitoring of patient vital signs. The most important improvements are achieved in earlier illness detection enabling timely medical intervention as well as in the treatment of chronic diseases . The integration of emerging wireless technologies in health delivery applications today is separated in two new engineering challenged disciplines – **mobile health** and **home care telecare** systems. Newer concepts represent M-H as a form of e-health evolution from traditional desktop telemedicine to wireless mobile configurations. M-H provides remote medical service delivery (especially the monitoring of biomedical signals) even while patient is in a move and regardless of geographical location of the patient. Home care systems, on the other hand, provide usually more functionality but these systems have the reduced range of mobility. In this case, the mobility range is usually limited to the level of the house, hospital or office. So, the main functional difference between M-H and H-C telecare systems is related to the mobility area. By using small-scale sensing and processing hardware attached to the patient's body or embedded into patient's everyday life ambience, both M-H and H-C systems make possible: more often or continuous inspection of patient's health condition generally, the monitoring of daily variable medical parameters (ECG, SpO2, blood pressure, glucose level, EEG etc.) which variations can point to specific medical conditions and illness etc. The advantages of using the modern m-health and home care applications can be summarized as follows:

- Medical treatment even when the patients are not situated in medical institution,
- Continuous, "real time" or store-and-forward insight into patient's health parameters
- Mobility and comfort of patients while medically treated
- Intelligent monitoring systems with the ability to generate alarms
- Multi-parameter and multi-user health care delivery
- Tele-consultations and flexibile access to expert opinion and advice at the point of care without delay
- Easy integration into greater telemedicine systems.

M-HEALTH AND HOME CARE APPLICATIONS

Applications related to the applying of wireless concept in medicine, usually have been realized for portable teletrauma systems (Chu & Gantz, 2004) and in systems designed for remote medical monitoring of mobile or "semi-mobile" patients (Lin et al, 2005, Anliker et al 2004, Fadlee et al 2005, Boquete, 2005). In the case of teletrauma systems, realized applications provide the transmission of medical parameters as: biomedical signals, images, video signals and voice assuring better understanding of the problem by medical professionals residing at remote location and, consequently, better assistance to the medical

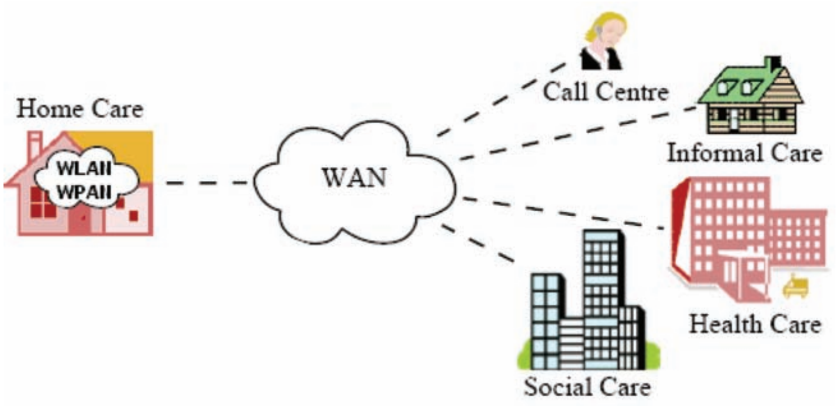
Figure 1. Example of a typical M-H application architecture



trauma team. On the other hand, systems designed for continuous remote monitoring of physiological parameters, usually are dedicated to the treatment of patients with chronicle disease as well as in case of post-hospital home care and also in cases when monitoring of some parameter's daily variability are of crucial meaning. Teletrauma and similar systems along with systems for remote continuous long term health monitoring are today known as M-H and H-C telecare systems, respectively. The first ones primarily aim to provide the ubiquitous health delivery while the second ones provide the home environment for patients while medically treated, which can be very impotant for the recovery process. Beside the main, medical advantages, the usage of these systems have economical meaning (especially when applied for longer patient-to-hospital distances) and social meaning too (in elderly population care). Health parameters which are often monitored using these systems are: ECG (electrocardiogram), HR (heart rate), SpO2 (arterial oxygen saturation), and blood pressure which are usually named as vital signs. But, signals as EEG (electroencephalograph), patient's physical activity, respiration, blood glucose etc. are also often included in these applications. Besides the basic meaning of these parameters, when monitored together, their inter-relational meaning can extend the range of the diseases that can be detected. For example, SpO2, heart beat, blood pressure, and respiration can form together an indicator of the oxygenation of the patient's brain in trauma care (Hailiang, 2006), or, when temperature and humidity sensors are used along with ECG sensor, the correlation between environment conditions with heart conditions can be derived. In all of these applications, the intention is to provide health care delivery not affecting significantly (or not affecting at all) the patient's everyday life and activities. For example, in home care applications, sensors can be embedded in bed and wrapper (Seo, J.Choi, B.Choi, Jeong, and Park, 2005), chair and computer mouse (Kim, J., Park, J., Kim, Chee, Lim, and Park, K., 2007) and so on. On the other hand, the main benefit of using M-H monitoring system is contained in fact that the patient can be medically monitored while being in car, office, or generally, anywhere else in the area of M-H network coverage. The patient's data can be send using mobile phone (GSM, GPRS, 3G etc). An example of a step-by-step application developing process is given in (Boquete, 2005). Functional modules of the system are shown in Figure 1.

In this figure, PTn is abbreviation for the *patient terminal n* (which does the sensing and signal conditioning tasks and transfers data to the mobile phone thought RS232 interface), and CC is the abbreviation for the *control center* (which does the data storing and screening). The transmission here is done in "RS232 over GSM" manner. Typical H-C system organization is given in Figure

Figure 2. A typical H-C telecare system



2 (Turner J. Kenneth, Gemma A., Campell and Feng Wang, 2007).

The main drawback of M-H system is the link capacity and the resource capacity fluctuation within the mobile environment while the main H-C system's limitation is contained in the mobility range. So, M-H and H-C systems overlap regarding the purpose – remote monitoring of human health parameters and remote health care delivery generally, but the mobility range and the wireless link capacity seems to make the main border on choosing between M-H and H-C systems in general.

ARCHITECTURAL ISSUES

The choice of the adequate technology for each sub module of the system for wireless remote medical monitoring and the way in which various technologies are implemented and integrated into these systems are still application-dependent. Some applications are designed for long term monitoring so they are limited to low power consumption technologies and design. Others are primarily constrained with the mobility range or link capacity, extended functionality etc. The view on typical M-H and H-C telecare system's position into a global Telemedicine system is shown in Figure 3.

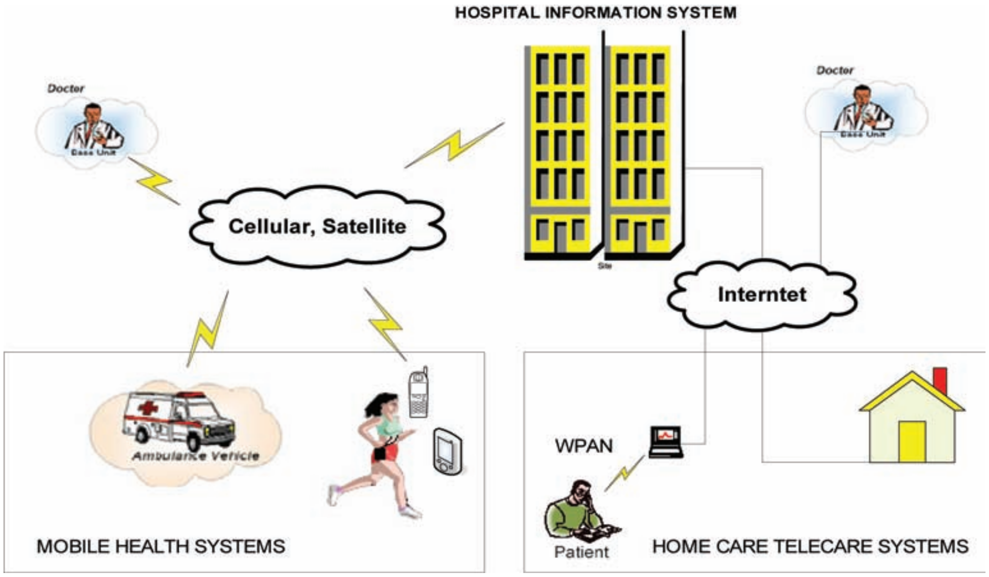
It becomes obvious that there are 3 main architectural parts either in M-H and H-C systems:

- Hospital core information system (servers, core network, database organization etc.)
- Communication infrastructure (wired and wireless)
- Mobile subsystem (hardware and software modules)

Hospital core Information system is the framework where different kind of applications are attached to and integrated into. Modern Telemedicine networks support various kind of data flow. M-H and H-C systems are just a part of these networks. Modern telemedicine IT system enables the hardware and software for storing the biomedical, financial and social data. It enables the distributed connectivity, offering various levels of authorized access to the patient's data. Patient and medical professionals can access needed information through secured Telemedicine network (or Internet) links.

Communication infrastructure depends on various factors as: the location and the level of access, the type of transferred data, etc. It is based on standardized networking devices and technologies and does not basically differ from ordinary general purpose computer network infrastructure. In architectural sense, the differences are only

Figure 3. The view on the position of the M-H and H-C modules in telemedicine architecture



noticeable at the level of the remote data upload, specific for M-H and H-C applications, and regarding the end-user networking devices.

A module specific to all wireless medical systems (as new M-H and H-C telecare systems are) is **mobile subsystem** or **personal server.** In case of H-C systems, mobile subsystem contains sensors (along with signal conditioning electronics), digital processing unit and the radio-device. In M-H systems, mobile subsystem contains the gateway device too, which is one additional difference in architectural sense between M-H and H-C systems. In modern wireless H-C applications data are sent through short range wireless links to the fixed wireless ADSL router or some other wireless / cable-based gateway device though Wireless wide area networking (WWAN) links are sometime used as well. Generally, sensing module, equiped with the wired or wireless interface, sends medical information to the gateway device. This module is attached to the monitored patient and is supposed to transmit medical data while the patient is on the move. M-H or H-C applications differ in the way the gateway device achieve the connection to the medical server. home care applications make WAN connections using fixed non-movable or semi-movable gateway devices while M-H applications use WWAN cellular links as GSM, GPRS, 3G, satellite communications etc. The information flows to the medical server which actually represents secure and authorized access point for accessing the data by medical expert from the remote locations (usually Internet).

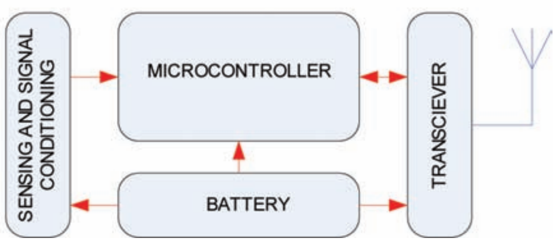
Sensors assure the conversion of biomedical signals into electrical equivalent and can be of various types (optoelectronic, ion-to-electronic, mechanical, magnetic, temperature sensors etc.). These signals are then conditioned (using analog front ends), converted into digital form and post-processed. The analog signal shaping and A/D conversion is realized in the so-called **acquisition / processing unit**. Some applications, as a part of this unit or the gateway device functionality, provide the possibility for directly viewing the data and generating alarms. Signals are further transferred to the communication module which is used to communicate with gateway device. **Gateway device**, if designed for only transferring the data, can be of miniature dimensions. In case of M-H applications, it is usually mobile phone, PDA or Laptop PC. In these cases, for communication with gateway, the processing unit uses wired connections or some of WPAN technologies (usually Bluetooth or some other widely used technology). In some applications the processing unit and gateway device can be integrated in one, in form of PDA or laptop computer. These systems usually have extended functionality (but greater physical dimensions and weight too). For example, sensors can directly be connected to laptop computer (as it is often case in emergency care applications) and the laptop computer can act as a processing and gateway device, offering direct data screening, data storage capabilities and providing expert system as well.

CRITICAL ENGINEERING ISSUES ON MODERN M-H AND H-C TELECARE SYSTEM'S DESIGN

Both M-h and H-C systems are considered to be multidisciplinary engineering areas. The design of wireless medical applications integrates sensing, processing, communications, computing and networking together into a reduced volume for wearable devices that reliably processes, transmits and represent medical parameters and data. In this sense, various aspects of design should be considered. It is very important to point that these technical issues and performances are often complementary coupled. For example, a longer range in wireless communication often means the higher output power of the transmitter, which implies the higher power consumption which further shortens the battery life or enlarges the overall system costs and the implementation complexity. As it can be concluded, main engineering aspects that are specific to the M-H and H-C application's design, can be summarized in:

- Electronic, electrophysiological, and electromechanical design of sensor nodes - sensing

Figure 4. Block diagram of a typical sensing node



- Wireless communications and networking
- Software engineering

Sensing in M-H and H-C Applications

To monitor human health constantly without disturbing the user's normal daily activities, the wearable sensors and devices for physiological data collection should be designed to be compact, durable, accurate, small, and noninvasive, to have a fast response time, and provide disturbance rejection capability. It is not always easy to meet all these requirements because, beside the accuracy, electrical, processing/software, mechanical, and practical aspects, communication aspect of these modules should be treated as well. Block diagram of typical sensing/acquisition unit is shown in Figure 4.

Because of the uniqueness of telemedical applications, non-invasive M-H and H-C measuring nodes should strictly follow some special limitations as in:

- Adequate sensing, signal shaping and digital signal processing capability, compared to the predefined medical standards
- Miniature physical dimensions
- Low power consumption
- Multi-functionality
- Resistance to various sources of noise (electrical, electromagnetic, chemical, mechanical, ambient noise etc.)

- Must be non-intrusive, acceptable for most patients, and have easy-to-use interface
- Must have the adequate wireless communication performances.

Medical signal recognition begins at **sensor's** end. Generally speaking, biomedical sensors are a subset of specialized sensors responsible for sensing physiological or biological measurands (Yeow, 2006). The biomedical measurands are used as indicators for clinical diagnosis or in therapeutic purposes. Most often, a biomedical sensor node is used as a diagnostic tool.

Many different kind of medical sensors are now available on the market, ranging from conventional sensors based on piezo-electrical materials for pressure measurements to infrared sensors for body temperature estimation and optoelectronic sensors monitoring SpO2, heart rate, HRV, and blood pressure.

In the sense of achieved measuring functionality, biomedical sensing is based on one of the three principles:

- Direct measuring of the electrical activities of organs (heart, brain, muscles, etc.) – bio potentials
- Measuring the influence of physiological processes on some external source of energy (light, ultrasound etc.)
- Injecting substances and detecting their flow by special detectors (as in case of the detection of injected radioisotopes by gamma cameras).

M-H and wireless H-C systems are typically dedicated to non invasively measuring of basic physiological signals (ECG, SPO2, heart rate, blood pressure, etc.). In some special cases, images and video signals are transmitted too (as, for example, in mobile emergency care diagnostic systems). So, It is very important for the designer to be aware of electrophysiological and other (electronics, mechanical) measurement aspects of sensor's node design.

ECG sensor's functionality is based on electrical activity of the heart. As a result of cell's depolarization and repolarization, ionic current is spread over human body. This current can be detected (and transformed into electronic current) using various types of sensors, so called electrodes. Very important issues when using these sensors are: good electrical contact with the body of the measured subject and mechanical stability, the number of used leads, and the position of the leads. The number and the position of the leads determine the range of measure sophistication – the number of the diseases that could be detected. Good electrical contact and mechanical stability directly influence the quality and accuracy of measurement. Bad contact means higher signal attenuation and noise while mechanical instability (vibrations and other mechanical movements) usually introduce so called artifact. An efficient low-noise transducer design can often reduce the need for extensive subsequent signal processing and still produce a better measurement (Semmlow, 2004).

Pulse rate, SPO2, HRV (heart rate variability), and blood pressure are usually derived from the measuring method called PPG (photoplethysmography). PPG is non-invasive method for the detection of cardiovascular pulse waves propagated around the human body based on the determination of optical properties of vascular tissue using light source and photo detector. It is also the mostly used sensing method to monitoring the physiological signals in M-H and H-C applications. There are two PPG approaches based on transmission or reflection of the light (**transmission mode** and **reflection mode**, respectively). Transmission mode is limited to areas such as finger, earlobe or toe, since the light emitter and receiver should be positioned on opposite side of tissue but should also be in close distance to each other. On the other side, reflective mode can be used virtually on any skin area, because the emitter and the receiver are positioned in parallel (and close) to each other. Experience in using PPG sensors in wearable sensor applications for wireless data transmission shows that the finger-base PPG may be most acceptable to users and provides excellent access to an arterial blood signal. PPG is based on the fact that, when directing the light on tissue, the light absorption (and consequently reflection) depends on the concentration of blood in vessels, which is generally given by Beer-Lambert law (Ward, 2001). Using this technique, usually pulsating current is measured and conditioned on the detector side and this pulsating current corresponds to pulse rate. PPG signal has two components: DC and AC component. DC component is relatively constant because it represents the absorption/reflection of the light by constant values as: skin, bones, venal blood, and a non-pulsating arterial blood. AC component represents pulsatile component of arterial blood and is usually 1 to 2% of the DC value. Beside the use in directly determining the pulse rate and shape (HRV), PPG signals are often used in deriving SpO2 – the level of oxygen saturation in hemoglobin. The measurement is based on the fact that deoxyhemoglobin (Hb) is more absorbed by red (R) then infrared (IR) light and on the other hand oxygenated hemoglobin (HbO2) is more absorbed by IR than by R light. Saturation of hemoglobin is estimated by the following formula:

$$S_pO_2 = 110 - 25R \tag{1}$$

where

$$R = \frac{AC_{RED} / DC_{RED}}{AC_{IR} / DC_{IR}} \tag{2}$$

where alternated current (AC) and direct current (DC) components are firstly calculated.

SpO2 is a very important physiological parameter which gives information about respiration. On healthy subjects, the SpO2 values should be above 96%. This parameter is often monitored during anesthesia but is also used in M-H and H-C applications alone or together with other parameter's monitoring.

Blood pressure is also one of the basic physiological parameters which are often monitored in typical M-H and H-C applications. There are few standard methods for blood pressure monitoring such as: invasive canola based monitoring (which is never used in M-H and home care systems), sphygmomanometer, oscilloscopic method, and lately some efforts are made in the direction of using pulse transit time (PTT) derived from PPG measuring sensors. Cuff -based method (oscilloscopic) is most popular for classical home but is also used in M-H and H-C applications (Anliker et al, 2004). The PTT based method measures the time distance between R or Q wave of the ECG and point of 50% of the pulse magnitude. Consequently, ECG and PPG sensors should be used together in order to derive the PTT value, but since most of M-H and H-C applications already monitor ECG and PPG signals, the PTT calculation may extend the application functionality without any additional hardware. It should be noted that PTT based measurement of blood pressure is not well correlated to the absolute value of blood pressure at the given moment. PTT actually enables the prediction of the blood pressure variations for short time intervals.

As can be concluded, PPG method offers the creation of multifunctional non invasive sensor nodes and as such is very suitable for use in M-H and H-C applications. Signal sampling is often based on so called chopper mode – when sampling is triggered by some external source (microcontroller, oscillator etc.), making the module low power consumer. The main drawback of PPG sensing method is noise: **ambient light and artifact**. In order to reduce ambient noise, instead of usually used LED-PIN (light emitting diode – P type intrinsic N type) configuration, a LEDs in reverse bias mode are lately being used as photo detectors. This measuring process assures greater immunity to ambient noise since LED detector operates as band-pass filter. In order to face the artifact, many methods are being proposed. They are usually based on mechanical modeling of sensor node (Booho Yang, Harry H. Asada, S. Rhee, 1999) or on using accelerometer which enables the use of active noise cancellation algorithms based on adaptive filtering (Shaltis P., Wood L., Reisner A. & Asada H., 2005).

Along with transducers, **signal conditioning sub module** is the most important part in achieving the needed quality of the signal for further processing and transmission. Output signal from sensor can be in digital or analogue form. In order to achieve the needed quality of the signal (satisfying magnitude level and low noise influence), it is always necessary to make some further signal conditioning as amplifying, filtering etc. The tradeoff is usually made between the complexity (the size and the price) of **front-end** and the accuracy. For example when using higher filtering degree, higher quality of output signal can be achieved but this implies bulkiest hardware and some more power consumption as well as greater overall physical dimensions. When designing this part of the system, it is important to do some quantitative observations, comparing the achieved results to some professional widely used instrument. It is crucial to know the all technical (electrical) characteristics of measured physiological parameters, and the most important ones being: the signal magnitude and the frequency range. Depending on these parameters and the way the physiological signals are electrically represented (as current, voltage or frequency), proper amplifying and filtering should be realized. For example, when conditioning ECG signal, designer should keep in mind that the voltage derived from electrodes is in range of 1-5 mV and that the frequency band of ECG signal is between 0.02 Hz and 150 Hz (though 1 KHz limit is often used at hospital devices). Although ECG is specified to have a wider frequency band, when monitored using low cost, low power wearable devices, usually only the band from 0.02 Hz to 50 Hz is treated and this quality is very satisfying since the main energy concentration of ECG spectrum belongs to this band.

Summarizing, in biomedical measurements and consequently in M-H and H-C applications, unwanted signal variability has four different origins: physiological variability, environmental noise or interference, transducer artifact, and electronic noise.

As mentioned previously, one of the main limiting factor to be considered in wireless sensor node's design is **power consumption**. In M-H and H-C applications, mobile subsystem is battery supplied. Bearing in mind that these systems are dedicated for long term continuous monitoring, it is obvious that this parameter directly affects most of the system's performances. Duty cycle reduction in conjunction with the so-called power save modes of the MCU and RF transceiver, are often used in order to reduce the power consumption. For example, when using CC1000 transceiver supplied by idealized AA batteries, with duty cycle of 2%, the autonomous battery supply is expected to last up to about a year. But this power consumption reducing method can be used only where the real time monitoring is not a primary limiting factor. In the sense of power consumption, most important sub module is radio device. As it will be described further, many telecommunication and architectural aspects affect the overall power consumption (such as operating frequency, modulation technique, output power, etc). Actually, radio device usually consumes more than 70% of overall power consumption of the sensing node. Processing units (microcontrollers) today are designed to be ultra low power devices. Their current consumption is expected to be in the range of 0,5 to few mA. Some other (but much lower) power consumption is expected from the rest of signal conditioning electronics (voltage regulators, etc.)

Processing unit enables A/D conversion, digital signal processing, and transmission of the signal to the communication module. In multifunctional applications where the data are needed to be screened from the sensing module directly, more powerful microcontrollers would be needed. Sometime this means some more external memory modules which, on the other hand, can enlarge the overall physical dimensions. Processing unit is not a critical part of the system because developments in today's microelectronic device's design offer very high performance products with: high processing speed, large memory space, low power consumption, high resolution, small physical dimensions, power saving modes, many I/O lines etc.

In the next section, special weight is given to the wireless communication's characteristics and performances since these communications make M-H and H-C applications differ from classical approaches in medical monitoring.

Wireless Communication Issues and the Emerging Wireless Technologies for M-H and H-C

Emerging wireless communications open new solution to health care delivery systems. The appliance of wireless communications in medical systems for remote monitoring such as M-health and home care telecare systems have the potential to transform the way health care is currently provided. Regarding the wireless communications, most important parameters that are considered when designing the M-H and H-C applications are:

- Range
- Data rate
- Resistance to the noise and disturbance
- Power consumption (of the radio-device)
- Physical dimensions (of the radio devices and antennas)
- Networking issues
- Security issues
- Easiness of implementation (the cost) and the ability to integrate smaller communication systems into larger systems (as larger networks or Internet) etc.

There is no actual wireless technology optimized on each of given parameters. These parameters depend on telecommunication aspects as well as the radio-technique architectures of used radio devices and usually are complementary coupled. In this sense, most important issues to be considered are:

- Operating frequency and the bandwidth
- Transmitter power, antenna gain, receiver sensitivity
- Modulation and multiplexing techniques
- Networking topology
- Higher networking protocols.

Although some wireless applications are based on using visible or near-visible optical spectrum, RF communications are mostly used (especially in wireless telemedicine systems). RF section of electromagnetic spectrum lies between the frequencies of 9 kHz and 300 GHz. The RF bands which are used for most wireless networking (including short range telemedicine modules) are the unlicensed ISM (instrument, scientific and medical) bands as: 314 MHz, 433 MHz, 868 MHz (for Europe), 915 MHz (for North America), 2,45 GHz and 5 GHz. Unlicensed in this sense means that the band is free for use and it is up to users to resolve any interference problems, while when dealing with licensed bands, the FCC and similar bodies have a role to play in resolving interference. The choice of **operating frequency** is directly correlated to some very important parameters as: range, power consumption of the radio device and (indirectly) the influence of electromagnetic noise and disturbance. Free space loss is the most important factor affecting the received signal strength. It depends on the signal frequency and transmission distance according to the formula:

$$Lfs = 20 \log (4\pi D \backslash \lambda) \tag{3}$$

Where D is the transmitter to receiver distance in meters and λ is the wavelength of the radio signal in meters which can also be expressed as:

$$\lambda = c / f \tag{4}$$

As can be noted from the given formulas (3) and (4), losses are larger when higher operating frequency is used. This is a very important conclusion, especially for the outdoor communications (as this calculation assumes the clear line-of sight between transmitting and receiving antennas). Lower frequencies better penetrate the walls but, in practical indoor situations, the differences in losses due to the difference between used frequencies are small compared to other environmental effects. The most important factor here is the material of the indoor construction and sometime the thickness of walls. Losses are in range from 2-4 dB for non tinted glass, wooden door, cinder block wall, or plaster to over 15 dB in case of metal and silvering (mirrors). Lower losses consequently imply typically lower energy consumption, so, generally, lower frequency transmissions mean lower consumption too. One drawback of using lower frequency is greater antenna length ($l \sim \lambda \backslash 4$). On the other hand, much higher operating frequencies (70 GHz) are sometime used as suitable for very short distances at the order of centimeters but they are not widely used in medical applications. When choosing the operating frequency, it is also important to choose the one which will not interfere with other networks at the same environment. This helps in preventing and minimizing the influence of the interference and noise.

Regarding the transmission frequency band, RF communications are often categorized as: **narrowband** and **wideband**. Data rate, as very important communication parameter, is directly correlated to the bandwidth: the greater the bandwidth, the higher capacity of the communication link. Narrowband devices generally have lower overall power consumption though some wideband systems can be highly effective in the sense of power consumption per transmitted bit (UWB). In order to avoid the interference and eavesdropping, today’s technologies often use some of the Spread Spectrum (SS) techniques. Most important spread spectrum techniques are DSSS (direct sequence spread spectrum) as used by ZigBee networks, and FHSS (frequency hopping spread spectrum) as used by Bluetooth technology. It is important to note generaly that the choise in **operating frequency** and the **bandwidth** directly influence data rate and the range. Higher data rates require more spectrum. But, more spectrum can only be found higher in the frequency band. Using higher frequency band, on the other hand means greater propagation losses, which implies the lower propagation range.

Beside telecomunication aspects of the wireless links, some radio-technique characteristics are also very important as: **output transmitter power, antenna gain, and the receiver sensitivity**. Along with losses, these factors make so-called **link budget** - the balance of power plus gain required to compensate for losses in the link so that sufficient signal strength is available at the receiver to allow data decoding at an acceptable error rate (Webb, 2007).

Output transmitter power is one of the most important characteristics of the radio device because, along with other parameters, it often directly determines the range of RF communications. For the radio devices operating at ISM bands, some strict regulations exists regarding the output signal strength. For example, in Europe, at frequency of 2,4 GHz, oputput power is limited to maximum 100 mW.

Antenna shape and the directivity can have great impact on strength and the quality of transmittet signal and sometime can influence the link security too. Directive antennas are more effective but in M-H and H-C applications they can not be used because the factor of mobility. In implementation process, in order to avoid losses and reflection, it is important to match antenna impedance with the output impedance of the radio device. The higher directivity of the antenna, the lower possibility to eavesdropping the data.

Receiver's sensitivity is the lowest limit of the signal strength that can be detected by the receiver. Typical values for receiver's sensitivity of the low power WPAN devices (which are usually used in H-C and M-H applications and in wireless sensor systems generally) are < - 85 dBm.

The bit stream must be **modulated** in order to be sent by the radio waves. It can be modualated onto either a single or multiple carrier frequencies but also can be modified regarding the position or shape of the signal. Right choice on modulation technique has impact on some important communication parameters as:

- Spectral efficiency (achieving the desired data rate within the available spectral bandwidth),
- BER (Bit Error Rate) performance – achieving the required error rate given the particular factors of the degradation (interference, multipath fading etc.),
- Power efficiency – particulary important in mobile health applications,
- Implementation complexity – wich direcly influences the cost of the hardware though some aspects of the modulation can be implemented in software (not influencing the cost of implementation).

On these parameters some tecniques can be more or less efficient and usually the choise depends on the purpose and on which parameter is application more limited to. For example, constant envelope of modulated signal, practically means higher efficiency of the output power amplifier (even to 50%) achieved by using nonlinear part of the transfer function in contrast to other types where efficiency can be up to 10%, so in the sense of power efficiency, these techniques can be more appropriate where power consumption is the primary limitation factor.

For combining multiple analog message signals or digital data streams into one signal, **multiplexing techniques** are used. These techniques define the way multiple users access the common medium and can be of types as: TDMA (time division multiple access), FDMA (frequency division multiple access) or OFDMA (orthogonal FDMA), SDMA (space DMA) and CDMA (code DMA). The combination of two techniques is used as well. For example, GSM uses FDMA/TDMA with eight time slots available in each 200 KHz radio channel.

Networking topology is one of the first issues that are considered in the process of M-H and H-C application's design. At the beginning of the project, the designer usually determines some basic architectural parameters as: wireless coverage, number of sensing nodes, redundancy, extendibility, connectivity to higher level Telemedicine networks etc. All these aspects more or less depend on the choice of the networking topology. For example, when designing simple typical home care application for only one user (e.g. in continuous monitoring of ECG, SpO2, blood pressure etc.), a simple **point-to-point** link can be used without the need for wireless networking in the sense of dealing with greater number of nodes and considering medium sharing and addressing. When dealing with smaller size network (for ex. in ambulatory monitoring of few patients), usually the simple **star topology** can be appropriate. The main advantage of star topology is the simplicity. The drawbacks are: a simple central node (which, in case of error, can break down the whole network), relatively small range and bandwidth sharing. Central node can be: PC, PDA, WiMAX base station, Wi-Fi access point, Bluetooth master, ZigBee PAN coordinator, embedded Web server etc. Typical indoor range of wireless short-range star topology networks (as in Home/Office/Hospital Care low power communications) is 30 m. **Tree topology** (extended star) is very popular and mostly used one because of: extended range (usually using wired infrastructure partially), simplicity and more efficient in using the overall bandwidth. **Mesh topology** enables greater functionality of the network. The main advantages are the redundancy and roaming. The data routing function is distributed throughout the entire mesh rather than being under the control of one or more dedicated devices. These networks are also known as mobile ad hoc networks (MANET) in which nodes are mobile and communicate directly with adjacent nodes not needing any central controlling devices. Distributed control and continuous reconfiguration allows for rapid re-routing around overloaded, unreliable or broken paths, allowing mesh networks to be self-healing and very reliable (Rackley, 2007). It is clear that for the network to be really meshed and mobile, routing protocols should be implemented in each node. This implies the increased node's complexity, since more processing power should be implemented also affecting the overall power consumption of the nodes which can be a critical factor in most Telemedicine applications. Wireless mesh networks are rarely used in typical M-H and H-C applications, mostly because of their complexity. When ubiquitous monitoring is needed (as in mobile health applications), cellular networks are used.

Higher communication and networking protocols are important in achieving wider network functionality and more reliable data transfer as well as in accomplishing better efficiency in sending different types of data. Generally, there are five categories of medical data that can be transferred: biological signals, live scene images, administrative data (e.g., access control, device configuration signals, etc.), control commands for remote devices, and warning signals (Polley, 2006). Because the telemedicine applications use different interconnected networks, protocols as TCP (transmission control protocol) and UDP (user datagram protocol) are usually used. TCP is connection-oriented reliable protocol with flow control and congestion control mechanism, whereas UDP uses a simple datagram with no congestion control. TCP is more suitable for transferring data which require small portion of bandwidth and high reliability. Very imprtant issue here is setting the various priorities for various data types. As an example, ECG, PPG and other vital signs, should be sent via high priority TCP link. On the other hand, bandwidth-hungry images transfer quality will satisfy the purpose by using low priority UDP protocol, since congestion control mechanism of the TCP protocol with retransmitting (especially in a wireless environment) would cause extra delays.

In M-H and H-C systems, security issues have to be considered as well. This factor should be treated as the priority one, since medical data are very sensitive so the data integrity is very important. Different technologies offer different mechanisms in this sense. Higher protocols (as encryption algorithms and others) are usually integrated into a technology-specific protocol stack. For example, Bluetooth technology uses integrity check system SAFER+ and the 128 bit E0 encryption. Some extension in security issues can be achieved by appropriate software development at the application level.

Engineering aspects mentioned previously are very important in choosing adequate technology which would be optimal for a given purpose. Some of standardized technologies are often used. Knowing their technical characteristics, the designer should be able to make the choice of the appropriate one.

Generally, today's wireless communication systems can be categorized as (Webb, 2007):

1. **Mobile:**
   - 2G
   - 3G
   - WiMax
   - 4G
2. **Private mobile radio (PMR):**
   - Analogue
   - Digital
   - Mobile mesh

  - Emerging technologies including cognitive radio and software defined radio (SDR)
3. **Fixed wireless:**
   - Point-to-Point
   - Point-to-multipoint
   - Fixed mesh
4. **Short range:**
   - WLANs (802.11)
   - WPANs (Bluetooth, ZigBee, UWB)
   - RFID (Passive and Active devices) – WBAN.
5. Conventional analogue and digital broadcasting

Since applications designed for continuous monitoring of physiological parameters mostly use some of standardized cellular or short range (WLAN and WPAN) technologies, these technologies will be described in some more details.

As mentioned, M-H application's primarily advantage is the network coverage which enables ubiquitous mobile health care delivery. Consequently, these systems use cellular networks as 2G (and the extensions as GPRS, MMS, HSCSD, WAP, EDGE etc.), 3G, and (in future) 4G networks. Beside the coverage, the advantage of these networks is contained in the fact that they are very much present in cellular phones, so their integration into telemedicine systems is easy. 2G systems, through EDGE for GSM, can provide (in "ideal" occasions) the data rate of up to 300 kb/s. In typical practical use, data rates are much lower. On the other hand, 3G systems were designed against criteria of delivering 2 Mb/s but they practically can achieve data rates up to 400 kb/s which open a wide range of opportunities for use as: video calls, video streaming, real time monitoring (with very satisfying data rate and coverage) etc. As such, they are very appropriate for use in M-H systems when sending medical data in real time manner such as video signal, images and other measured medical parameters. The problem with 3G is that this technology is still not widely deployed. 4G technology, beside cellular character, is expected to integrate other short range technologies as: Bluetooth, ZigBee, UWB etc. Very high data rates are expected to be achieved, even up to 100 Mbps.

Indoor data and voice traffic transmission, however, converge to short range communications systems because these systems generally have some important advantages over cellular (and other long-range) networks when integrated into telemedicine applications as: lower price, higher data rate, networking capabilities (supporting ad-hoc networking), longer battery life, smaller device's dimensions etc. New home care telecare systems are supposed to assure the mobility in range of ambulance, hospital sector, office or house. So, there is no need for the only advantage which mobile cellular networks offer over short range communications – the outdoor coverage. That's why, in these systems, short range communications are mostly deployed. On the other hand, in typical M-H applications, short range communications (for communication of sensor node with the gateway device) are often used too. For example, cellular phone can communicate with sensor node using Bluetooth technology and, at the same time, can act as a gateway device transferring data to some medical server or directly to some other mobile phone using cellular networks.

Almost all **WLAN** networks are covered with IEEE standard 802.11. Most popular versions are: "a", "b", and "g". Greatest advantage of 802.11 is data rate which can theoretically go up to 54 Mbps. Technically, IEEE 802.11 use ISM frequency 2,4 GHz (versions "b" and "g") and 5 GHz (version "a"). Version "a" is under the lower influence on disturbance because a small number of technologies use this frequency, but, on the other hand, this shortens the range, which can be up to 7 times shorter compared to standards "b" and "g". For collision avoidance, CSMA/CA (Carrier Sense Multiple Access / Collision Avoidance) is used and, on physical layer, techniques as DSSS (at version "b") and OFDM (at versions "a" and "g") are used too. Indoor range is typically 50 m while outdoor links can be in rage of km using special antennas. Another sdvantage of IEEE 802.11 devices is very good Internet connectivity which makes this networks suitable for use as backbone (in conjunction to UWB or other short range technology). On the other hand, typical WLAN devices are not suitable for the integration into wearable medical nodes, primarily because of their power consumption and physical dimensions. WLAN technology can be very appropriate in ambulatory/hospital monitoring where sensor node can be wired to Laptop PC or PDA or can be wirelessly connected using some WPAN link, while the transmission to the medical server can be accomplished by WLAN link.

UWB technology uses very wide frequency band, between 3.1 GHz and 10.6 GHz. Because of the bandwidth, power limitations are regulated and very strict. UWB is designed for short range communications (typically 10-20 m) of very high data rates (few hundred Mbps). This technology is most suitable for PC connectivity and wireless connection of home devices (DVD players and plasma screens etc). UWB transmission has the lowest consumption per bit but overall power consumption is typically higher than at Bluetooth or ZigBee devices. This technology could be a good choice when transferring larger medical data loads at short distances as when transferring medical images and video signal.

Bluetooth was initially designed to serve as cable replacement technology for data communications between mobile phones. When new improved versions appeared, it became clear that Bluetooth will do much more than that. Today, Bluetooth devices, beside their initial purpose, are used in creating wireless sensor networks and especially in forming WPAN (Wireless Personal Area Networks) for mobile health and home care telecare applications. From the technical point of view, Bluetooth works at frequency range 2,402 – 2,480 GHz using FHSS, GFSK modulation and TDMA multiplexing. Bluetooth defines 3 power classes: class 1 (maximum output power of 20 dBm), class 2 (maximum output power of 4 dBm), and class 3 (maximum output power of 0 dBm). Networking architecture is of type master/slave and usually forms star topology called **piconet**. Bluetooth network can be extended into **scatternet** – set of two or more piconets. Main characteristics of Bluetooth technology can be summarized as:

- Data and voice transfer at typical distances 1-100 m
- Various networking topology supported
- Data rates can be up to 723 Kbps (versions 1.x) and up to 3 Mbps (version 2.0)
- Small current load (typically from few mA to 30 mA) and usage of power saving modes as *sniff, hold*, and *park*.
- Robustness
- Miniature radio devices (typically 20mm x 20mm or smaller)
- Great presence in mobile telephone devices.

These characteristics make Bluetooth technology a good choice when simple short range star topology is needed, with solid data rate and small power consumption. As such, Bluetooth is often found in M-H applications as a communication method between wearable sensor and mobile phone, PDA or Laptop. At home care applications, fixed cable based gateway can be used and the communication between gateway and sensor node can be done using Bluetooth links.

ZigBee is another WPAN technology which works at 3 frequency ranges: 2,4-2,4835 GHz (with 16 channels and maximum data rate of 250 Kbps), 902-928 MHz in North America (with 10 channels and maximum data rate of 40 Kbps), and 868-868,6 MHz (only one channel and maximum data rate of 20 Kbps). The first one uses OQSK (Offset Quadrature Shift Keying) modulation technique and the other two use BPSK (Binary Phase Shift Keying). ZigBee uses DSSS and, for collision avoidance, CSMA/CA. Performances of ZigBee technology can be summarized as:

- Ultra low power consumption
- Miniature radio devices
- Capability of creating large ad hoc networks
- Ranges 10-75 m

Because of the mentioned characteristics, especially power consumption, ZigBee technology tends to become optimal choice in wireless sensor networks where power consumption is most critical parameter, while the high data rates and advanced capabilities of Bluetooth are not needed. In Telemedical applications, ZigBee would be an optimal solution in long term continuous monitoring of some slow changing signals (i.e. PPG) or in the case of implants and signal acquisition from different parts of human body (forming wireless body area network).

Critical Issues on Software Design

As mentioned before, the design of systems for remote monitoring of medical data belongs to so-called middleware engineering which, beside some physiological and electrophysiological aspects, includes the knowledge on hardware design, communications, and the software design. Most of the hardware and device's communications should be supported by appropriate software modules. Software design in M-H and H-C systems is related to the microprocessor / sensor unit programming, network programming, and the user graphical user interface (GUI). Also, some software integration into a hospital core information system are needed as transferred data need to be correlated to other patient's data. Sensor units for continuous monitoring of biomedical signals as used in M-H and H-C systems contain programmable units such as microcontrollers or microprocessors with the extensions (memory modules, etc.). There are different software platforms on which the functionality of these units is based. For example, C programming is often used as very efficient with high speed processing capabilities. Some sensors are programmed using the operating system called TinyOS, which is currently the industrial standard for wireless sensor network operating system. TinyOS also provide well-defined set of API's for programming the Motes and some on-board data processing. It supports the execution of multiple threads and provides a variety of additional extensions like virtual machine and the database (TinyDB). Typical software modules implemented into a microcontroller unit contain routines as: ports and timer's initialization, I/O initialization and communication routines, A/D routines, storage of digitized sampled data, interrupt routines, often CRC calculation routines etc. Beside this, some application-specific communication protocol is usually needed. For example, sensor initialization is usually made by the healthcare provider at the remote site. After that, the protocol might include some frames either for synchronization or for identification. To ensure the link security, some applications include special coding techniques. Into a software design, node control and administration often should be included in order to configure devices for various uses.

Generally, most important issues on remote health monitoring system software design can be summarized in following limitations:

- The ability for real time processing and (sometime) data compression
- User friendly GUI
- Security issues (authentication, authorization, encryption)
- Networking scalability and multi user platform
- Multi-functionality
- Database store and access for various types of patient's data as: medical, financial, insurance, etc.

The sensor node's software has to be able to efficiently capture and process data as well as to transmit them to the wireless radio device's interface. There are two ways of data processing storing and transferring at mobile subsystem's end*: real time* and *store and forward*. In order to achieve efficient and, for the purpose of the particular application, satisfying level of data processing and the transfer, it is very important to calculate and treat some parameters as: needed sampling period, duty cycle, etc. Depending on the fact if the data processing means buffering or not, some memory calculations sometimes are needed too. For example, if 4-Mb SRAM (static random access memory) is available and 10 min ECG signal buffering is needed, knowing the sampling rate (typical of 128 Hz or 250 Hz) and the resolution (typical 8-16 bit), leads to the calculations for the memory space. If the values are 14 bit resolution, 250 Hz sampling, and 10 minute recording of the ECG signal, then the amount of memory needed is *sampling rate x number of bits per sample x duration* = 250 x 14 x 10 x 60 = 2.1 Mb (Fadlee, 2005). This is about half of the SRAM capacity. Therefore there is a scope to alter the sampling rate, quantization level, and duration of the data according to the clinical need. It is also important to take into account the real transmission capacity of the system. For example, in order to transmit 2, 1 Mb of data through 32kb/s GPRS link, 66 seconds would be needed, so when programming the A/D conversion and buffering, it is important to make appropriate space between transmissions in order to avoid frame overlapping. In case when data are shown directly to user (as when using PDA or Laptop connection to the sensor node), the user friendly interface with easy and secure configurability should be designed. There is no practical limitation on which programming platform to use. The platform can be important mostly in the sense of portability.

At the core information system's end, software architecture is often comprised of a set of user-friendly software modules, which can receive data from the remote Telemedicine devices, transmit information back to it and store important data in local database. Authorized user (i.e. doctor) should be able to access patient's data either directly (while being logged on local hospital network), or through secured remote connection (i.e. using Virtual Private Network). These software modules should be flexible and integrated into the user-friendly GUI's functionality comprising together encircled software architecture for remote health care delivery.

CONCLUSION

M-H and H-C systems are new concepts that, beside classical integration of microelectronic design and computing in medical telecare application, include wireless communications as well. Biomedical signals are captured using sensors. They are further conditioned and processed using signal conditioning front-ends and the microprocessor unit, respectively. After digitally represented, medical data are sent to the medical server, partly or fully, using wireless communications. Medical server deals with remote connections, medical databases, networking etc. This approach assures continuous access to the patient's health parameters even when the patient is in move and usually regarding the geographical location. The benefits of this kind of health care delivery are shown in much aspects (medical, social, economical), but the essential one is facilitating the health condition of population which is already improved in countries and medical systems where these approaches are applied.

REFERENCES

Anliker, U., Ward, J. A., Lukowiez, P., Tröster, G., Dolveck, F., Baer, M., et al. (2004, December). A wearable multiparameter medical monitoring and alert syste. IEEE Transactions on Information Technology in Biomedicine, 8(1), 415–425. PubMeddoi:10.1109/TITB.2004.837888doi:10.1109/TITB.2004.837888

Boquete, L., Bravo, I., Barea, R., Ascariz, J. M. R., & Martin, J. L. (2005, May). Practacal laboratory project in telemedicine: Supervision of electrocardiograms by mobile telephony. IEEE Transactions on Education, 48(2). doi:10.1109/TE.2004.842892doi:10.1109/TE.2004.842892

Chu, Y., & Gantz, A. (2004, December). A mobile teletrauma system using 3G networks. IEEE Transactions on Information Technology in Biomedicine, 8(4), 457–461. doi:10.1109/TITB.2004.837893doi:10.1109/TITB.2004.837893

Fadlee, M., Rasid, A., & Woodward, B. (2005, March). Bluetooth Telemedicine Processor for Multichannel Biomedical Signal Transmission via Mobile Cellular Networks. IEEE Transactions on Information Technology in Biomedicine, 9(1), 35–43. PubMeddoi:10.1109/TITB.2004.840070doi:10.1109/TITB.2004.840070

Istepanian, R. S. H., Jovanov, E., & Zhang, Y. T. (2004, December). Guest editorial introduction to the special section on m-health: Beyond seamless mobility and global wireless health-care connectivity. IEEE Transactions on Information Technology in Biomedicine, 8(4), 405–413. PubMeddoi:10.1109/TITB.2004.840019doi:10.1109/TITB.2004.840019

Kim, J., Park, J., Kim, K., Chee, Y., Lim,Y., and Park, K. (2007). Development of nonintrusive blood pressure estimation system for computer users. *Telemedicine and e-Health,* 13(1).

Lin, Y., Jan, I., Ko, P., Chen, Y., Wong, J., & Jan, G. (2005, December). Wireless PDA based physiological monitoring system for patient transport. IEEE Transactions on Information Technology in Biomedicine, 8(4), 443–447.

Mei, H., Widya, I., van Halteren, A., & Erfianto, B. (2006, December). A flexibile vital sign representation framework for mobile healthcare. I*nternational Conference on Pervasive Computing Technologies for Healthcare*. Innsbruck, Austria.

Polley R. Liu, Max Q.-H. Meng, Peter X.Liu, Fanny F.L. Tong, M.Phil, and X.J. Chen, M.Phil, (2006). A telemedicine system for remote health and activity monitoring for the elderly. *Telemedicine and e-Health, 12(6)*.

Semmlow, J. L. (2004). *Biosignals and biomedical image processing*. New York: Marcel Dekker.

Seo, J., Choi, J., Choi, B., Jeong, D., and Park,K. (2005). The development of a nonintrusive home-based physiologic signal measurment system. *Telemedicine and e-Health, 11(4)*, 487-495.

Shaltis, P., Wood, L., Reisner, A., & Asada, H. (2005, September), Novel design for a wearable, rapidly deployable, wireless noninvasive triage sensor. *27th Annual International Conference of the IEEE/EMBS*. Shanghai, China.

Turner, J. Kenneth, Gemma A., Campell and Feng Wang (2007, June). Policies for sensor networks and home care networks. In *Proceedings of 7th Int. Conf. on New Technologies for Distributed Systems*, pp. 237-284.

Ward, T. (2001), *The Photoplethysmograph as an instrument for physiological measurement*. Department of Electronic Engineering, NUI Maynooth.

Webb, W. (2007). *Wireless communications: The future*. West Sussex, England: John Wiley & Sons Ltd. Key Words Key Terms

Yang, B., & Asada, H. H. S. Rhee, (1999, October). Design of an Artifact-Resistive, Finger-Ring Plethysmographic Sensor. *MIT Home Automation and Healthcare Consortium*, Progress Report No.2-4.

Yeow, J. T. W. (2006). Biomedical sensors. *Wiley Encyclopedia of Biomedical Engineering*. University of Waterloo.

KEY TERM

Home Care: Home care is health care provided in the patient's home by healthcare professionals (often referred to as home health care or formal care; in the United States, it is known as skilled care) or by family and friends (also known as caregivers, primary caregiver, or voluntary caregivers who give informal care).

Mobile Health: M-health can be defined as emerging mobile communications and network technologies for healthcare. This emerging concept represents the evolution of e-health systems from traditional desktop telemedicine platforms to wireless and mobile configurations.

Physiological Signals: Physiological signals are acquired and processed to form psycho-physiological measures. These measures affect game play both through team understanding and altered game mechanics.

Sensor: A sensor is a device which measures a physical quantity and converts it into a signal which can be read by an observer or by an instrument. For accuracy, all sensors need to be calibrated against known standards. Sensors are used in everyday objects such as touch-sensitive elevator buttons and lamps which dim or brighten by touching the base. There are also innumerable applications for sensors of which most people are never aware. Applications include automobiles, machines, aerospace, medicine, industry, and robotics.

Telecare: Telecare is the term given to offering remote care of elderly and vulnerable people, providing care and reassurance needed to allow them to remain living in their own homes. Use of sensors allows the management of risk and as part of a package which can support people with dementia, people at risk of falling or at risk of violence and prevent hospital admission.

Vital Signs: Vital signs are measures of various physiological statistics often taken by health professionals in order to assess the most basic body functions. Vital signs are an essential part of a case presentation.

Wireless Communication: Is the transfer of *information* over a distance without the use of electrical conductors or "wires". The distances involved may be short (a few meters as in television remote control) or very long (thousands or even millions of kilometers for radio communications). When the context is clear the term is often simply shortened to "wireless". Wireless communications is generally considered to be a branch of telecommunications.

This work was previously published in Handbook of Research on Distributed Medical Informatics and E-Health, edited by A. Lazakidou & K. Siassiakos, pp. 305-324, copyright 2009 by Medical Information Science Reference (an imprint of IGI Global).

Chapter 8.3

Paediatric Telepsychiatry as Innovation in Healthcare Delivery

Katherine M. Boydell
University of Toronto, Canada

Tiziana Volpe
The Hospital for Sick Children, Canada

Antonio Pignatiello
University of Toronto, Canada

ABSTRACT

Although a great deal has been written about the potential for telemedicine to increase access to care, applications in paediatrics are sparse. This chapter details how one paediatric telepsychiatry program has facilitated the creation of integrated healthcare solutions in patient psychiatric care for children and youth in remote and rural communities. It demonstrates how the telepsychiatry model of healthcare service delivery has improved access, enhanced capacity, and promoted knowledge exchange in rural communities. A case study is used to highlight theoretical and empirical research on the value of televideo information technology in mental healthcare and its impact on the healthcare stakeholders who utilize this technology. An overview of the clinical, education, and evaluation components of the program is outlined, with a focus on knowledge translation and exchange as the underpinning foundation to the success of the program.

BACKGROUND

The recent proliferation of live interactive videoconferencing technology has made it possible for two or more individuals to interact in real time, sharing information through electronic media. Telepsychiatry is a specific term designating psychiatric applications employing live interactive televideo (ITV) communication (The Work Group on Quality Issues, 2008). In fact, telepsychiatry (Brown, 1998; Ruskin, Reed, Kumar, et al., 1998) is emerging as

DOI: 10.4018/978-1-60566-356-2.ch050

one of the most successful uses of this technology. Telepsychiatry has important implications for accessing paediatric subspecialty services, determining future health care workforce requirements and their distribution, improving communications with parents of sick and chronically ill children, and extending the boundaries of the medical home (Spooner & Gotlieb, 2004).

The Canadian Standing Senate Committee on Social Affairs, Science and Technology (Kirby & Keon, 2006) recommended that telepsychiatry be utilized in rural and remote communities for consultations, education and training of mental health practitioners. This is a prudent recommendation, because children and families in rural and remote areas may face more obstacles to obtaining services and support that those in urban areas (Cutrona, Halvorson & Russell, 1996; Starr, Campbell & Herrick, 2002). The problems of service access often result from geographic, economic and cultural factors (Kelleher, Taylor & Rickert, 1992; Letvak 2002). Canada is a vast, sparsely populated country, with a varied and sometimes harsh climate and geography. In thinly populated areas, travel expenses increase the costs of both providing and obtaining care. Furthermore, it is difficult to recruit and retain specialists and allied health care workers, who tend to concentrate in larger urban areas (McCabe & Macnee, 2002). The geographic and professional isolation makes rural communities less attractive to mental health workers. In addition, the shortage of resources and support services in rural communities means that children requiring urgent care often must be placed in residential care outside of their community (Sheldon-Keller, Koch, Watts, et al., 1996).

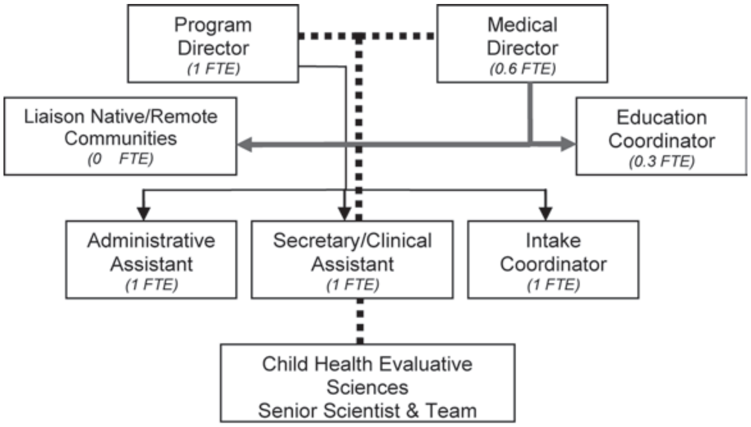
The problems associated with the mental health service system in rural areas (access, delivery, recruitment, retention) are exacerbated because, within the health research community, rural issues are often overlooked or dealt with generically. When rural perspectives are examined, it is frequently within the context of urban-rural differences, rather than as the sole focus of attention (Pong, Atkinson, Irvine, et al., 2000). Thus, providing psychiatric services to children and their families in rural and remote regions must address geographic barriers to access (Boydell, Pong, Volpe, et al., 2006) as well as the cultural context of individual communities, and the distribution, attraction and retention of psychiatrists and other mental health professionals.

THE TORONTO PAEDIATRIC TELEPSYCHIATRY PROGRAM (TPTP)

In the province of Ontario, Canada, the problem of access to specialty mental health care in rural communities is particularly problematic. In Canada, 20 percent of children and youth have a diagnosable mental health problem, yet only 1 in 6 receive any treatment (Offord et al., 1987). The ratio of child psychiatrists to children with mental health needs is approximately 1:6,148 (Steele & Wolfe, 1999). Furthermore, approximately 2% of child psychiatrists practice primarily in areas with populations of less than 20,000 while approximately 18% of the population resides in rural areas (Steele & Wolfe, 1999). Northern Ontario alone is the size of France and England combined.

To begin to address this need for service and support, in 2000 the Ontario Ministry of Community and Social Services (currently the Ministry of Children and Youth Services) (MCYS) funded the Division of Child Psychiatry, University of Toronto, operating through The Hospital for Sick Children (SickKids), in Toronto, to create The Toronto Paediatric Telepsychiatry Program (referred to as TPTP in the remainder of this chapter). The mandate of this program is to provide bilingual (English and French) psychiatric consultations and education to under-serviced children's mental health community agencies and their clients, utilizing ITV. As an academic site within the Division of Child Psychiatry at the University of Toronto,

Figure 1. Toronto Paediatric Telepsychiatry program hub site organization



SickKids is also required to fulfill clinical, teaching, and research mandates.

Funding by the MCYS compensates for capital and operating expenses, and remuneration of clinical and administrative staff at the SickKids "hub" site. TPTP functions under three distinct components: clinical (individual consultations, program consultations and special initiatives), education, and research.

The Clinical Component

Currently fifteen primary ("far") sites, along with their satellite locations[1] are connected to the SickKids hub site via an Integrated Service Digital Network (ISDN) carried on a maximum of three lines (maximum bandwidth 384 kbits/second) or via Internet Protocol (IP). Core hub site staff (as per Figure 1) and a designated telepsychiatry coordinator at far sites provide the necessary infrastructure. Seventy-five faculty members (almost exclusively child psychiatrists) within the Division of Child Psychiatry at the University of Toronto are available to provide consultations. Of those, approximately 40 participate with varying degrees of regularity.

TPTP is funded by the Ministry responsible for children's mental health (MCYS). Referrals are accepted from clinicians at community children's mental health agencies, who act as overall case managers, and not directly from physicians; however, participation from treating physicians is highly welcomed and encouraged. Agency clinicians are required to complete a mental health assessment prior to requesting the consultation. Consent is obtained for the youth and family to participate in the consultation and to release a copy of the report to the treating physician, with whom responsibility ultimately lies in facilitating any further medical/pharmacological interventions. Supporting documentation and referrals are triaged by presented urgency and matched to compatible consultants. It is a requirement that the child's case manager/primary clinician be present during the consultation to bridge culture, language, formulation, recommendations, and so forth between client and consultant, and for medical/legal prudence (Broder, Cheng, Cooke, et al., 2002). In the true spirit of a consultee-centred consultation (Lambert, 2004), the presence of the case manager and others involved in the care of the child/youth also serves to enhance capacity and facilitate collaborative care. Impressions and recommendations are provided verbally, immediately following the consultation, and a written report follows shortly thereafter. Follow-up consultations are not a mandate of the program and not routinely provided; however, are available if necessary and/

or requested. The program maintains a database derived from standard referral and summary sheets completed by all consultants.

From May 1, 2000 to March 31, 2007 a total of 4,382 clinical consultations were provided, of which close to one quarter (22.5%) were follow-ups. The most frequent diagnoses based on clinical impressions include Attention Deficit Hyperactivity Disorder (47%), Mood Disorders (21%), Anxiety Disorders (29%), Learning Disabilities (17.5%), Relational Problems (17%), Problems Related to Abuse/Neglect (12%), Conduct Disorder (11%), Attachment Disorder (8%), Pervasive Developmental Disorders (7%), and Psychosis (1%). These diagnostic categories are in keeping with other similar programs (Myers, Sulzbacher, & Melzer, 2004; Elford, White, Bowering, et al., 2000). Recommendations made, in decreasing order of frequency, have addressed (1) medication (2) counselling (3) focused assessment and testing (i.e. psychological/psychometric, neurological, etc.) (4) school-based interventions (5) day/residential treatment, and, (6) out of home placement.

In addition to individual consultations, program consultations are also offered. Of the 27 primary and satellite sites, 17 site-based programs (i.e. school-based day treatment programs, residential and foster homes, specialized programs working with children of military families, etc.) receive regular, monthly consultation where agency staff meet with a dedicated consultant(s) to discuss clinical, program-wide, and community issues. Topics for discussion have focused on individual youth and their behaviour, diagnosis, medication formulation and management, program, systems and community issues, transference and counter transference.

The clinical component of TPTP has created a variety of special initiatives to respond to the unique needs of the various partner communities: Native outreach, youthful fire setting, and military families. One of the early challenges recognized in TPTP was the difficulty engaging with Native communities. More active outreach and attention was clearly required to appreciate the cultural, spiritual, and traditional nuances of the Native populations. As a result, a core staff position, Liaison Native/Remote Communities, was created at the hub site to provide ongoing communication, education, and consultation between the hub site and remote site staff. The success of this position is evidenced by the increased referrals and participation by agencies dedicated to Native children and their families.

Another specialty area recognized as requiring attention was the problem of youthful fire setting. In response, TPTP introduced a specialized tertiary level consultation for youth involved in fire setting. Modelled after The Arson Prevention Program for Children (MacKay, Henderson, Root, et al., 2004), where fire setting behaviour is addressed within the context of a comprehensive mental health assessment, this service is offered conjointly by a specialist in the area of youthful fire setting and a generalist child psychiatrist.

A more recent special initiative has been the creation of ongoing program consultation to support and enhance the capacity of agency staff working with children whose military parent(s) are at various stages of deployment to the Canadian mission in Afghanistan. Dedicated staff specializing in war-related trauma issues, such as separation, loss, post-traumatic stress disorder, and grief, provide telepsychiatric consultations to children and youth living on military bases.

The Education Component

TPTP has used televideo technology for a wide variety of educational purposes, including continuing education and supervision (Broder, Manson, Boydell, et al., 2004; Hilty, Marks, Urness, et al., 2004). Seminars are delivered via ITV to multiple and diverse distant sites according to principles of effective continuing education. TPTP has primarily focused on providing exposure of telepsychiatry to trainees at the hub site and continuing education to professionals at the far sites. As part of their training at the University of Toronto, it is mandatory for psychiatry residents to attend two clinical consultations during their core six month rotation in child psychiatry. Evaluations completed by residents completing their core training in child psychiatry indicate that the experience is interesting and enjoyable, that their knowledge about providing psychiatric services to under serviced communities is increased, and that they would recommend the experience to others. Such exposure is ideal for residents wishing a diverse general child psychiatry community experience, and in particular for those who will be practicing in rural and remote regions. Research has shown that early exposure to telepsychiatry results in increased numbers of trainees who choose to locate their practice in rural communities (Hodges, Rubin, Cooke, et al., 2006). In such situations, efforts are made to connect the resident with the community in which they will likely be establishing professional practice upon graduation. This also allows for ongoing liaison and support for the resident in their future career. For example, child psychiatrists practicing in remote communities have the opportunity to connect into psychiatry Grand Rounds at SickKids via ITV on a regular basis.

The continuing education program for community mental health professionals at the far sites was developed on the basis of a detailed needs assessment completed by recipients of educational sessions. Continuing education is delivered in the format of multiple seminars in a series, using a range of interactive teaching methods. This format is based on evidence that suggests it is more likely to lead to changes in practice and patient outcomes (Davis, Thomson, Oxman, et al., 1995; Davis, O'Brien, Freemantle et al., 1999). Each seminar series is delivered to multiple sites at once, and cover a wide range of child mental health topics. In response to participants' requests, a calendar of educational events is prepared for six month blocks to facilitate planning for attendance. Feedback from attendees indicates that the content and teaching methods are valued by participants, and useful in their everyday practice. In addition, the seminars have had a noticeable impact on client understanding of mental health issues, resulting in increased confidence and competence. Providing continuing education in this way is very cost-effective: depending on the number of participants during any one session, the delivery cost is calculated to be as low as $21.66CDN per attendant, per session.

The Research Component

As TPTP represented a relatively new and evolving modality for the provision of psychiatric services, evaluative research was deemed critical to inform program delivery, clinical practice, and policy development. Consequently, within the first year of TPTP's establishment, an independent research team was engaged to devise and implement a comprehensive program of research. As a first step in the process, a critical review of the extant literature was conducted and an annotated bibliography generated. As well, the research team asked representatives from all the stakeholder groups (funder, hub site, and far site) to identify the key issues that the evaluation of TPTP should focus on, via a survey, focus group and individual interviews. An important finding from this design phase was that the resulting research evaluation must be inclusive of all stakeholders, and take into account the unique context (geographical, cultural, and social) of each telepsychiatry site and its community (Boydell, Greenberg & Volpe, 2004).

From this participatory process, a qualitative research program was developed to evaluate TPTP.

Various priority research areas were identified and to date four studies have been completed or are underway: (1) a study of the perspectives of service providers and family members (Greenberg, Boydell & Volpe, 2006); 2) a study of the opinions of consulting psychiatrists and community general practitioners and paediatricians; 3) a case study of recommendations made in a telepsychiatry consultation and whether or not they were successfully implemented (Boydell, Volpe, Kertes et al., 2007); and, 4) a study of the perspectives of young people who have received a telepsychiatry consultation (currently in progress).

Study 1: Service Provider and Caregiver Perspectives of a Paediatric Telepsychiatry Program

The study focused on the perspectives and experiences of family caregivers and service providers in rural children's mental health agencies. Focus groups with rural mental health service providers and interviews with family caregivers of children receiving a telepsychiatry consultation were conducted. The purpose of this research was to evaluate the benefits and limitations of providing pediatric psychiatric services via video-technology to inform future program development and health policy. While study participants indicated that their experiences with the telepsychiatry program had been overwhelmingly positive, they identified a number of barriers to accessing telepsychiatry services and implementing treatment recommendations.

The results of this study identified a fundamental need for follow-up consultations for particularly complex or unusual cases. Originally, the program's mandate did not allow for follow-up consultations. In response to the study's findings, the Ministry funder expanded the program's mandate to include and reimburse for follow-up consultations. Currently, follow-up consultations are viewed as an important element of the service, and consistently account for almost 25% of all referrals. Additionally, the research revealed the importance of program consultations that focus on discussion of specific challenges arising from individual cases or program-based issues. As with follow-ups, program consultations were not part of the program's original mandate but the policy was modified when research results revealed the multiplier effects of program consultations in rural communities, with service providers reporting increased comfort and confidence in dealing with complex mental health issues and competence in identifying future problems and potential solutions.

Research results also highlighted attention to cultural context as a key ingredient to the program's success, resulting in a number of program modifications and improvements. Originally, program funding did not provide for travel between the hub site and the various community agencies receiving telepsychiatry services. Following this study, the funder established a travel budget for Toronto-based staff to visit TPTP communities, build relationships with agency staff, and develop a knowledge base of each community's unique characteristics. In addition, telepsychiatry referral forms were scrutinized to ensure that they were user-friendly, culturally sensitive, and attentive to the nuances and heterogeneity of each community. For example, terminology specific to Native and military clients was incorporated.

Study 2: Physicians Weigh In - Medical Perspectives on Paediatric Telepsychiatry

This study focused on the perspectives of physicians (general practitioners and paediatricians) practicing in TPTP rural communities, as well as of child psychiatrists delivering consultations from the hub site. Physicians, selected from a random sample of TPTP sites, were interviewed via telephone. Many physicians were either unaware of the paediatric telepsychiatry program or lacked information about the ways that they could be involved. Recognizing that in over 60% of consultations a recommendation for further medical investigations and (or) intervention was made, requiring implementation by the local primary care physician, the telepsychiatry mandate was adjusted to allow physicians more direct involvement in the program as well as to make referrals. Physicians identified the factors that would facilitate their involvement in the program, including remuneration issues and education regarding the prescribing of newer psychotropic medications. To remedy the issue of the need for physician education, medication information sheets were created and widely distributed. Allowances are being made to the program's education component to expand the target audiences of professional development seminars, to include, for example, community physicians. Additionally, to allow physicians to benefit from the educational events at SickKids, an interactive link via videoconference was established between the hospital's weekly psychiatry Grand Rounds and the rural sites.

The interviews with hub-site psychiatrics were conducted face-to-face and provided direct feedback about the effectiveness and challenges of providing psychiatric consultations via televideo. In particular, psychiatrics appreciated their role of consultant as it meant that they were able to provide services without being burdened with an ongoing caseload. This clearly facilitated buy-in to the program and provided a strong directive to maintain a consultative model of service delivery. Research findings also revealed some difficulties in identifying non-verbal cues and facial nuances during telepsychiatry consultations. These results informed purchasing decisions by program managers regarding the type and quality of video equipment.

Study 3: Recommendations Made During Paediatric Telepsychiatry Consultations

Little is known about whether or not the recommendations resulting from telepsychiatry consultations are actually implemented, specifically, the barriers and facilitators associated with implementation. In study 3, 100 telepsychiatry consultations were selected randomly from TPTP program files and reviewed for information relating to the presenting problem, reason(s) for referral to the program, and treatment recommendations of the consulting psychiatrist. The majority of the recommendations revolved around monitoring, changing, starting, continuing and stopping medication. In addition to the case reviews, agency case managers assigned to each of the cases were interviewed to determine whether the recommendations had been implemented and examine the barriers and facilitators to implementation. Case managers indicated that the successful implementation of recommendations was often related to the value placed on the authority and expertise of consulting psychiatrists by case managers, family members, school personnel and physicians. Other facilitators to the implementation of recommendations included specific and clear treatment directives, the successful engagement of the young person and their family, the timeliness of scheduling a consultation following a referral request, and the availability of follow-up sessions for complex cases. Barriers to implementation of recommendations included the lack of cooperation or willingness on the part of family members and/or youth, the one time nature of the consultation, and the lack of community resources.

Study 4: TeleViews - Young People's Perspectives on Receiving Services via Televideo

The fourth study in the TPTP program of research, currently in progress, is focused on an important gap in our knowledge base of paediatric telepsychiatry: the views of young people themselves. Traditionally, the perspectives and experiences of young people are obtained by proxy, through the voice of parents, health care professionals, and other adults. This research seeks to hear the voice of young people themselves, and involves both focus groups and individual interviews. Preliminary results from the focus groups were shared with psychiatric consultants, who were easily able to incorporate some of the suggestions into their day-to-day televideo practices. For example, young people indicated that they would like to know something about the psychiatrist as a person. This was important to "break the ice" and enhance their comfort level before discussing sensitive and private information. The physical environment was also identified as being very important to young people. They highlighted many simple strategies that would improve the actual room in which the telepsychiatry consultation takes place. For example, youth noted that a table typically separates them from the television screen; this was seen as a barrier and its removal was recommended.

In the overall program of research, great efforts were made to ensure that all stakeholder groups were included in every aspect of the research, including design, participant recruitment, data collection and analysis, with a particular emphasis on knowledge translation and exchange. Research has demonstrated that interactions of clinicians and researchers are essential for successful knowledge generation and translation (Goering, Boydell & Pignatiello, in press; Golden-Biddle, Reay, Petz, et al., 2003). As a result, from the very beginning, members of the research team participated in monthly administration meetings with hub site staff and quarterly steering committee meetings with executive directors of the far site mental health agencies. The research team challenged commonly accepted views of health communication with their one-way transfer of information based on a one-sided relationship between communicator and receiver. Instead, information exchange based on a dialogue was highlighted (Lee & Garvin, 2003) and all members of the TPTP community encouraged to network, exchange ideas, and discuss priorities and issues. To facilitate this process, the bi-annual telepsychiatry newsletter, *Short Circuit*, originally created as a medium to communicate program news to psychiatric consultants was expanded to disseminate research findings to both hub site and far site staff. These initiatives ensured that regular input and feedback could be incorporated into the ongoing research. They also ensured the greatest buy-in to study results by all stakeholders, thus increasing the likelihood that the study findings would result in positive changes in clinical practice and service provision.

FUTURE DIRECTIONS

The Toronto Paediatric Telepsychiatry Program has moved far beyond the pilot phase, and is now an established program within the services and supports provided by the Ontario Ministry of Children and Youth Services. This solid base has allowed the TPTP group to think about expanding in a number of critical ways, in the clinical, education and research components.

In the clinical realm, multiple opportunities have presented themselves in terms of potential expansion. For example, in response to a demonstrated need for more input regarding specialized mental health care on the part of primary care physicians, the team is currently exploring the provision of support to this stakeholder group directly. The potential also exists to consider expanding the program to other service sectors that deal with children, youth and their families, such as recreation, health, criminal justice, education, and child protection.

Educational sessions are being planned for a service that is not currently offered by TPTP; education about key mental health issues targeted to the general public. This is particularly important as stigma and discrimination feature largely in help seeking efforts, and the general public - particularly in rural areas - has expressed a need for basic knowledge about mental health issues (Boydell, Stasiulis, Barwick, et al., in press). The scope and number of educational sessions offered to community mental health agencies in rural areas have also been targeted for future expansion.

With respect to research of telepsychiatry programs, the field needs to move beyond feasibility and pilot work and the tendency to focus on the technology itself and instead move toward examination of the impact and effectiveness of the intervention. The experience of using the technology for research purposes has also led the research team to begin to explore the methodological implications of conducting focus groups and individual interviews via televideo. Our early experiences using the technology in this way have proved successful, yet, it requires empirical study to enhance the knowledge base regarding the efficacy of qualitative research methodologies. The challenges of doing research with rural and remote communities must be acknowledged – especially the very real issue of lack of resources. The research team found that even when stipends were available to enable agencies to participate, it was difficult to engage rural service providers. Strategies that may facilitate research participation in meaningful ways without jeopardizing service delivery need to be examined further.

CONCLUSION

In a children's mental health system described as fragmented, under funded, and with a critical shortage of mental health professionals, telepsychiatry offers the promise of sharing existing limited resources. (Kirby & Keon, 2006). This must be viewed within a wider system of care that acknowledges that a basic level of mental health services should be in place, in order that recommendations made can be implemented. Telepsychiatry is well positioned to enhance the delivery of health care, reduce professional isolation and improve distribution of clinical expertise. The practice of psychiatry, which employs assessment via history taking, observation and collateral information gathering, lends itself well to the videoconferencing medium. Limitations imposed by catchment areas virtually disappear, and seamlessness and continuity of care are facilitated. Care can remain within the local communities of children and their families, critical masses can be achieved in communities which would otherwise be relatively isolated. The consultee-centred consultation model and the provision of continuing education, often to multiple sites simultaneously, contribute to the multiplier effect. This mode of service delivery offers solutions to some of the most difficult challenges to service access and utilization in rural areas due to geographic, economic and cultural factors.

The consultation model itself may pose its own challenges for those unfamiliar with it. The consultant is challenged to derive almost immediate formulation and recommendations. Once again, the importance of building relationships and exchanging information prior to the actual consultation assists with this challenge. Community and agency cultural issues and provision of recommendations that are feasible, locally relevant and available, require consideration.

The described program has facilitated the research and knowledge translation experience for researchers, policy makers, front line workers, community organizations and community members in rural and remote communities. Building local clinical and research capacity has increased by involving rural health care providers as collaborators in the clinical, education and the research components of TPTP.

The telepsychiatry program represents an important initiative to confront the serious challenge of shortage of specialized resources in rural and remote communities. It is an efficient, likely cost-effective (O'Reilly, Bishop, Maddox, et al., 2007; Elford, White, Bowering, et al., 2000; Mair, Haycox, May et al., 2000; Persaud, Jreige, Skedgel, et al., 2005) and user-friendly method (Ermer, 1999) providing increased paediatric mental health knowledge and training to distant and under-served areas. Early intervention through this program for children and youth and their families who are experiencing mental health problems can reduce the strain on family members, front line workers, physicians, community institutions, including schools, which will ultimately improve long term outcomes.

Mental health begins in childhood and investments in children's mental health are surely among the most important investments that any society can make. If we are to make a difference to the health of the population, new innovations in health care delivery such as TPTP to ensure optimal social and emotional development in children and to prevent mental disorders should have a prominent role. Integrated health care solutions provided by TPTP offers a comprehensive, critical initiative to confront the shortage of child and adolescent mental health resources in rural and remote Ontario.

REFERENCES

Boydell, K. M., Greenberg, N., & Volpe, T. (2004). Designing a framework for evaluating a paediatric telepsychiatry program: A participatory approach. *Journal of Telemedicine and Telecare*, *10*, 165–169. doi:10.1258/135763304323070823

Boydell, K. M., Pong, R., Volpe, T., Tilleczek, K., Wilson, E., & Lemieux, S. (2006). The rural perspective on continuity of care: Pathways to care for children and youth with emotional and behavioral disorders. *The Journal of Rural Health*, *21*(2), 182–188. doi:10.1111/j.1748-0361.2006.00029.x

Boydell, K. M., Stasiulis, E., Barwick, M., Greenberg, N., & Pong, R. (2008). Challenges of knowledge translation in rural communities: The case of rural children's mental health. *Canadian Journal of Community Mental Health*, *27*(1), 49–63.

Boydell, K. M., Volpe, T., Kertes, A., & Greenberg, N. (2007). Recommendations made during pediatric telepsychiatry consultations. *Journal of Telemedicine and Telecare*, *13*, 277–281. doi:10.1258/135763307781644889

Broder, E., Cheng, A., Cooke, R., Ghandi, J., Hodges, B., McCabe, L., et al. (2002). *Telepsychiatry guidelines and procedures for clinical activities.* Toronto, ON: University of Toronto.

Broder, E., Manson, E., Boydell, K. M., & Teshima, J. (2004). Use of telepsychiatry for child psychiatric issues: First 500 cases. *Canadian Psychiatric Association Bulletin*, *36*(3), 11–15.

Brown, F. W. (1998). Rural telepsychiatry. *Psychiatric Services (Washington, D.C.)*, *49*, 963–964.

Cutrona, C. E., Halvorson, M. B. J., & Russell, D. W. (1996). Mental health services for rural children, youth, and their families. In C. A. Heflinger & C. Dixon (Eds.), *Families and the mental health system for children and adolescents.* Thousand Oaks, CA: Sage.

Davis, D., O'Brien, M. A., Freemantle, N., Wolfe, F., Mazmanian, P., & Vaisey-Taylor, A. (1999). Impact of formal continuing medical education: Do conferences, workshops, rounds, and other traditional continuing education activities change physician behavior or healthcare outcomes? *Journal of the American Medical Association*, *282*(9), 867–874. doi:10.1001/jama.282.9.867

Davis, D., Thomson, M., Oxman, A., & Haynes, B. (1995). Changing physician performance: A systematic review of the effect of continuing medical education strategies. *Journal of the American Medical Association*, *274*(9), 700–705. doi:10.1001/jama.274.9.700

Elford, R., White, H., Bowering, R., Ghandi, A., Madiggan, B., & St. John, K. (2000). A randomized, controlled trial of child psychiatric assessments conducted using videoconferencing. *Journal of Telemedicine and Telecare*, *6*, 73–82. doi:10.1258/1357633001935086

Ermer, D. J. (1999). Experience with a rural telepsychiatry clinic for children and adolescents. *Psychiatric Services (Washington, D.C.)*, *50*, 260–261.

Goering, P., Boydell, K. M., & Pignatiello, A. (2008). The relevance of qualitative research for clinical programs in psychiatry. *Canadian Journal of Psychiatry*, *53*(3), 145–151.

Golden-Biddle, K., Reay, T., Petz, S., Witt, C., Casebeer, A., Pablo, A., & Hinings, C. R. (2003). Toward a communicative perspective of collaborating in research: The case of the researcher-decision-maker partnership. *Journal of Health Services Research & Policy*, *8*, 20–25. doi:10.1258/135581903322405135

Greenberg, N., Boydell, K. M., & Volpe, T. (2006). Pediatric telepsychiatry in Ontario: Service provider and caregiver perspectives. *The Journal of Behavioral Health Services & Research*, *33*(1), 105–111. doi:10.1007/s11414-005-9001-3

Hilty, D., Marks, S. L., Urness, D., Yellowlees, P. M., & Nesbitt, T. S. (2004). Clinical and educational telepsychiatry applications: A review. *Canadian Journal of Psychiatry*, *49*(1), 12–23.

Hodges, B., Rubin, A., Cooke, A., Parker, S., & Adlaf, E. (2006). Factor predicting practice location and outreach consultation among University of Toronto psychiatry graduates. *Canadian Journal of Psychiatry*, *51*(4), 218–225.

Kelleher, K. J., Taylor, J. L., & Rickert, V. I. (1992). Mental health services for rural children and adolescents. [Special issue: Child and Adolescent Mental Health]. *Clinical Psychology Review*, *12*(8), 841–852. doi:10.1016/0272-7358(92)90005-S

Kirby, M., & Keon, W. (2006). *Out of the shadows at last: Transforming mental health, mental illness, and addiction services in Canada*. Ottawa, ON: The Standing Senate Committee on Social Affairs, Science, and Technology.

Lambert, N. M. (2004). Consultee-centred consultation: An international perspective on goals, process, and theory. In N. M. Lambert, I. Hylander & J. H. Sandoval (Eds.), *Consultee-centred consultation–improving the quality of professional services in school and community organizations* (pp. 3-19). NJ: Lawrence.

Lee, R. F., & Garvin, T. (2003). Moving from information transfer to information exchange in health and healthcare. *Social Science & Medicine*, *56*, 449–464. doi:10.1016/S0277-9536(02)00045-X

Letvak, S. (2002). The importance of social support for rural mental health. *Issues in Mental Health Nursing*, *23*, 249–261. doi:10.1080/016128402753542992

MacKay, S., Henderson, J., Root, C., Warling, D., Gilbert, K. B., & Johnstone, J. (2004). *TAPP-C: Clinician's manual for preventing and treating juvenile fire involvement* (Version 1.0). Toronto, ON: Centre for Addiction and Mental Health.

Mair, F. S., Haycox, A., May, C., & Williams, T. (2000). A review of telemedicine cost-effectiveness studies. *Journal of Telemedicine and Telecare*, *6*(1), 38–40. doi:10.1258/1357633001934096

McCabe, S., & Macnee, C. L. (2002). Weaving a new safety net of mental healthcare in rural America: A model of integrated practice. *Issues in Mental Health Nursing*, *23*, 263–278. doi:10.1080/016128402753543009

Myers, K. M., Sulzbacher, S., & Melzer, S. (2004). Telepsychiatry with children and adolescents: Are patients comparable to those evaluated in usual out patient care? *Telemedicine Journal and e-Health*, *9*(1), 278–285. doi:10.1089/tmj.2004.10.278

O'Reilly, R., Bishop, J., Maddox, K., Hutchinson, L., Fisman, M., & Takhar, J. (2007). Is telepsychiatry equivalent to face-to-face psychiatry? Results from a randomized controlled equivalence trial. *Psychiatric Services (Washington, D.C.)*, *25*(6), 836–843. doi:10.1176/appi.ps.58.6.836

Offord, D. R., Boyle, M. H., Szatmari, P., Rae-Grant, N. I., Links, P. S., & Cadman, D. T. (1987). Ontario child health study II: Six-month prevalence of disorder and rates of service utilization. *Archives of General Psychiatry*, *44*, 832–836.

Persaud, D., Jreige, S., Skedgel, C., Finley, J., Sargeant, J., & Hanlon, N. (2005). An incremental cost analysis of telehealth in Nova Scotia from a societal perspective. *Journal of Telemedicine and Telecare*, *11*, 77–84. doi:10.1258/1357633053499877

Pong. R. W., Atkinson, A. M., Irvine, A, MacLeod, M., Minore, B., Pegoraro, A., Pitblado, J. R., Stones, M., & Tesson, G. (2000). *Rural health research in the Canadian Institutes of Health Research.* A position paper prepared for Canadian Health Services Research Foundation and Social Sciences and Humanities Research Council.

Ruskin, P. E., Reed, S., Kumar, R., Kling, M. A., Siegel, E., Rosen, M., & Hauser, P. (1998). Reliability and acceptability of psychiatric diagnosis via telecommunication and audiovisual technology. *Psychiatric Services (Washington, D.C.)*, *49*(8), 1086–1088.

Sheldon-Keller, A. E. R., Koch, J. R., Watts, A. C., & Leaf, P. J. (1996). The provision of services for rural youth with serious emotional and behavioural problems: Virginia's Comprehensive Services Act. *Community Mental Health Journal*, *32*(5), 481–495. doi:10.1007/BF02251047

Spooner, S. A., & Gotlieb, E. M. (2004). Telemedicine: Pediatric applications. *Pediatrics*, *113*(6), 639–643. doi:10.1542/peds.113.6.e639

Starr, S., Campbell, L. R., & Herrick, C. A. (2002). Factors affecting use of the mental health system by rural children. *Issues in Mental Health Nursing*, *23*, 291–304. doi:10.1080/016128402753543027

Steele, M. M., & Wolfe, V. V. (1999). Child psychiatry practice patterns in Ontario. *Canadian Journal of Psychiatry*, *44*(8), 788–792.

The Work Group on Quality Issues. (2008). Practice parameter for telepsychiatry with children and adolescents. *Journal of the American Academy of Child and Adolescent Psychiatry*.

KEY TERMS AND DEFINITIONS

Knowledge Exchange (formerly knowledge transfer): Knowledge exchange is collaborative problem-solving between researchers and decision makers that happens through linkage and exchange. Effective knowledge exchange involves interaction between decision makers and researchers and results in mutual learning through the process of planning, producing, disseminating, and applying existing or new research in decision making.

Paediatric Telepsychiatry: The use of electronic communications technology to provide and support health care for infants, children, adolescents, and young adults when distance separates the practitioner from the patient, parent, guardian, or referring practitioner. This definition specifically excludes from discussion the use of ordinary telephone communication between practitioners and patients and the use of communications technology for education of practitioners.

Stakeholders: Stakeholders refer to all individuals involved in/having an interest or stake in paediatric telepsychiatry. They include the funders of the program, the administrative staff, psychiatric consultants; mental health service providers in rural communities, and young people and their families.

Telepsychiatry: The use of electronic communications technology to eliminate or reduce geographic barriers to receiving psychiatric services.

ENDNOTE

[1] Big Trout Lake, Chatham, Fort Frances (satellite site: Atikokan), Kapuskasing (satellite sites: Hearst, Cochrane), Kenora (satellite site: Lake-of-the-Woods), Moosonee, Owen Sound, Parry Sound, Pembroke (former site), Sault Ste. Marie, Sioux Lookout (satellite sites: Dryden, Red Lake), Thunder Bay (satellite sites: Geralton/Longlac, Marathon, Nipigon), Kirkland Lake, Bracebridge (satellite site: Huntsville), North Bay (satellite site: Sundridge), Timmins.

This work was previously published in Handbook of Research on Information Technology Management and Clinical Data Administration in Healthcare, edited by A. Dwivedi, pp. 814-826, copyright 2009 by Information Science Reference (an imprint of IGI Global).

Chapter 8.4

Emerging Approaches to Evaluating the Usability of Health Information Systems

Andre W. Kushniruk
University of Victoria, Canada

Elizabeth M. Borycki
University of Victoria, Canada

Shige Kuwata
Tottori University Hospital, Japan

Francis Ho
University of Victoria, Canada

ABSTRACT

It is essential that health information systems are easy to use, meet user information needs and are shown to be safe. However, there are currently a wide range of issues and problems with health information systems related to human-computer interaction. Indeed, the lack of ease of use of health information systems has been a major impediment to adoption of such systems. To address these issues, the authors have applied methods emerging from the field of usability engineering in order to improve the adoption of a wide range of health information systems in collaboration with hospitals and other healthcare organizations throughout the world. In this chapter we describe our work in conducting usability analyses that can be used to rapidly evaluate the usability and safety of healthcare information systems, both in artificial laboratory and real clinical settings. We then discuss how this work has evolved towards the development of software systems ("virtual usability laboratories") capable of remotely collecting, integrating and supporting analysis of a range of usability data.

DOI: 10.4018/978-1-59904-792-8.ch001

INTRODUCTION

A wide variety of health information systems have appeared in healthcare (Shortliffe & Cimino, 2006). Although, such innovation promises to revolutionize healthcare there are a number of critical problems and issues related to their development, deployment and acceptance by end users that are related to human-computer interaction (HCI). Usability of health information systems refers to the degree to which they are useful, effective, efficient and enjoyable (Sharp, Rogers, & Preece, 2007). Lack of system usability has been a major impediment to adoption of health information systems. Indeed, perhaps in no other field have issues related to HCI come more to the fore when attempting to introduce information technologies than in healthcare. It has been previously argued that issues of HCI may be the most serious barrier to successful implementation and adoption of information technologies in healthcare (Kushniruk & Patel, 2004). Strenuous demands are placed on healthcare professionals and end users of health information systems making the need for usable systems critical in healthcare. Health information systems must be designed to consider not only technical aspects but also the complex information needs, cognitive processing and limitations of human users of such systems.

One of the main areas of concern revolves around the following question: how can we ensure that the health information systems we develop are usable, meet user information, support work needs and are safe? The design of health information systems that are intuitive to use and that support human information processing is essential. This has become increasingly recognized as more and more complex software and hardware applications appear in healthcare. Furthermore, as the complexity and variety of healthcare situations in which this technology is deployed increases, issues related to ensuring that health information systems will support local work activities and practices in healthcare are becoming critical. Closely related to issues of usability are issues related to healthcare safety, with the need to ensure that new devices and information systems increase patient safety and facilitate healthcare work. In addition, applications targeted to health consumers (e.g., patients and lay people) are also being developed at an increasing rate. It is essential that these systems be usable and that the information and advice they provide is both understandable and safe. Improved understanding of issues related to human cognitive processes that are part of human-computer interaction in healthcare is needed so that we can develop more effective health information systems.

In order to be able to determine if systems developed in healthcare are usable and safe methods of analysis are needed that can be used to characterize the information needs and processing of users of these systems. A wide variety of techniques and methods have appeared from applied psychology that can be used in health information system evaluation. One powerful method involves application of "think aloud" protocols. This involves the recording of subjects as they verbalize their thoughts while interacting with computer systems (Ericsson & Simon, 1993). In addition, video recordings of user interactions with systems can also be collected to provide a more complete picture of the interaction between humans and health information systems, as will be described in this chapter (Kushniruk & Patel, 2004). In addition to assessing the interaction with systems such methods can also be applied to assess the information needs of healthcare workers in order to form the basis for design of systems that better match both information needs and human information processing capabilities.

This chapter describes the evolution of our work in the development of practical and efficient approaches to assessing of the use and usability of new and emerging health information systems. This chapter begins with a discussion of cognitive aspects of human interaction with health information systems. This is followed by a discussion of an approach to rapid low-cost usability engineering that can be applied in the field to conduct studies of users interacting with health information systems in real settings. The approach has been used to evaluate a variety of healthcare information systems ranging from electronic health records (EHR) to Web-based information resources designed for use by both healthcare professionals and lay persons. We then follow this with discussion of our most recent work in extending the concept of usability testing to conducting studies of system usage and usability over the World Wide Web (WWW) remotely.

BACKGROUND

The Study of Human-Computer Interaction

The study of human-computer interaction (HCI) is concerned with the human, social, organizational, and technical aspects of the interaction between human and machines. It is a broad area of study that deals with a broad range of phenomena, including the design, evaluation and social implications of computer systems (Sharp, Rogers, & Preece, 2007). Research in HCI lies at the intersection of a number of disciplines including: cognitive and social psychology, computer science, anthropology, sociology, design sciences, and engineering. In this chapter we will illustrate how interdisciplinary perspectives to designing and evaluating healthcare information systems are needed in order to lead to healthcare systems that will be more effective and acceptable to their users.

Cognitive Aspects of HCI in Healthcare

There are a wide range of aspects of health information systems that are related to cognition and human information processing. One may ask "why study cognitive aspects of health information systems?" In answering this we must consider that the user interface to healthcare information systems can be defined as being the component of the overall man-machine system responsible for communication with the user of the system. Thus, HCI can be considered to be largely cognitive in that it involves processing of information by humans, in close conjunction with computer systems. Therefore, the application of ideas, theories and methods emerging from the field of cognitive psychology are highly relevant to the design and implementation of more effective healthcare information systems from the perspective of human users, for whom systems are designed to support and serve. There are a number of ways in which knowledge of human cognitive processing is important for improving healthcare information systems. These include the following: (a) providing knowledge about what typical users of systems can and cannot be expected to do, (b) identifying and explaining the nature and causes of user problems, (c) characterizing the problem solving and decision making processes of healthcare workers, (d) assessing the cognitive needs of users in designing systems and user interfaces, (e) feeding input back into system re-design and improvement, and (f) providing models and frameworks for conducting HCI research in healthcare.

TOWARDS A FRAMEWORK FOR HCI IN HEALTHCARE

In this chapter we take a broad perspective on HCI which encompasses the first three levels of human, social, and organizational aspects of health information systems, as outlined in the preface of this book: (1) Level 1—the level of the individual user interacting with a system in isolation, (2) Level 2—the level of the user interacting with an information system in order to carry out real work tasks, and finally (3) Level 3—the social and organizational level, where the interaction with an information system is considered in the context of its impact and effect on the organization as a whole. This characterization of the use of new information technologies in healthcare builds on a multi-level model of HCI which provides a useful framework for considering the complex problem of understanding how to best design, test and deploy innovative healthcare information technologies (adapted from Eason, 1991). Using this model, we can consider problems in acceptance of new technology at each of the three levels. For example, the goal of successful adoption of a health information system may fail at Level 1 if the design of the computer screens and instructions are such that users cannot easily learn how to use the system to enter patient data. Even if a system is designed to work well at Level 1, problems may occur once the system is inserted into the complex day-to-day activities and workflow of healthcare work practices, which may involve a variety of team members, contexts, environments, levels of urgency and complexity of tasks. However, careful analysis and adjustments made to provide effective systems at Level 2 does not guarantee uptake and acceptance of a new healthcare information technology, since the effect and impact of deploying such a technology at the organizational level (i.e., Level 3) may be an issue. For example, in the context of a patient record system, privacy and confidentiality issues at an organizational or political level may restrict the deployment of this technology within an organization such as a hospital. Nowhere in healthcare may careful consideration of each of these three levels of HCI be more germane than in consideration of barriers to adoption of health information systems. Health information systems span the levels of individual users of systems, from application of new technology within complex work roles and activities to issues that emerge with the increased possibilities for widespread access and dissemination of patient information along with the resulting organizational concerns regarding privacy and confidentiality.

Another perspective from which to consider health information systems relates to the extent of interaction of human users with the system. Thus, we can consider user interaction with health information systems in healthcare along a continuum from applications which require continual focus of user attention on the information technology, to applications where the technology is "invisible" or interacts to a very limited extent with the user. For example, the user interfaces of many handheld applications typically represent an extension of conventional desktop user interfaces to mobile applications. With these types of applications, users must focus considerable attention on the user interface [e.g., to enter medical values into a PDA (personal digital assistant)] at particular periods in time and explicitly insert its use within their work activities. Thus, the introduction of the technology must be understood in how it changes the work activity of the user and many aspects of human factors from the study of conventional user interfaces are applicable. However, many new applications of health information systems, including remote monitoring devices and wearable computing, are designed to be used ubiquitously *while* the user carries on their work activities (i.e., without switching their focus of attention to interacting with the technology). The implications of this new type of user-system interaction include the following (Lukowicz, Kirstein, & Troster, 2004): (1) interaction of the system with the environment is through a variety of modes that are appropriate for different contexts of use (2) the system may need to be operated with minimal cognitive awareness and effort on the part of the user, and (3) a wide range of tasks may need to be performed by the system with varying degrees of human-system interaction.

USABILITY ENGINEERING METHODS FOR IMPROVEMENT OF HEALTH INFORMATION SYSTEMS

Usability engineering is a rapidly emerging area in the field of human-computer interaction and has provided a set of methodologies for analysis of complex human interactions with computer-based systems. In this section, we will describe some of the main methods that may be employed for gaining insight into detailed aspects of HCI in the study of health information systems (Nielsen, 1993). These approaches can be considered along a continuum from experimental laboratory-based studies to the study of use of systems in naturalistic real-world settings. There is also a category of study of HCI that falls between pure experimental approaches that involves use of realistic simulations of real settings and contexts where information technologies may be used. For example, the laboratory study of a handheld application for entering medical prescriptions might involve subjects coming to a usability laboratory where their interactions with the application are recorded as they respond to artificial medical cases (e.g., they might be asked to verbalize their thoughts as they enter prescriptions from paper into the device). A simulation-based study of the same application might involve subjects (e.g., physicians) interacting with a "simulated patient" (i.e., a research collaborator playing the role of a patient) while the subject conducts an interview of the "patient." A naturalistic study of the same application might involve remote logging and tracking of user interactions with a device as the users carry out actual day-to-day activities in a medical clinic (as will be described later in this chapter). It should be noted that in-depth analysis of HCI in healthcare may involve iteration from laboratory study of user interaction with a device or application, that then lead to testing under simulated conditions and then finally in naturalistic settings. Analysis of HCI aspects of health information systems may require initial testing in artificial settings, followed by analysis involving simulated conditions, where conditions may be controlled for evaluation purposes.

USABILITY INSPECTION

Usability inspection is a cost-effective methodology adapted from study of HCI to healthcare that has emerged for improving the usability of health information systems (Nielsen & Mack, 1994; Zhang, Johnson, Patel et al., 2003). Usability inspection involves a usability analyst or inspector stepping through or "walking through" use of an interface or system in the context of some real task or activity. For example, an approach known as the cognitive walkthrough, involves the analyst (or a team of analysts) stepping through the activities that might involve use of a new health information system while recording their goals, actions, system responses and potential problems (Kushniruk & Patel, 2004). To guide such analyses, sets of principles emerging from HCI are considered. As another example, the methodology known as heuristic evaluation involves the identification of violations of principles of human factors design when a system is used to carry out a task. Jacob Nielsen (1993) has outlined a set of principles or rules to consider when conducting such analysis which include the following: (1) visibility of system status—this principle states that the state of system's processing should visible to users of a system when they so desire that information, (2) matching the system to the real world—this principle states that real world language and conventions should be used in user interfaces, (3) user control and freedom—users should feel like they are in control, (4) consistency and standards—the user interface and system operations should be consistent, (5) error prevention—designers should design interfaces to prevent errors, (6) minimize memory load—systems should support recognition (e.g., using menus) rather than recall, (7) flexibility and efficiency of use—systems should allow for customization and adaptability, (8) aesthetic and minimalist design—often the simplest and most minimal designs are the best, (9) help users recognize, diagnose and recover from errors, and (10) help and documentation—help should be available to users when needed.

These principles can be extended when considering health information systems, in particular system designed to be integrated into complex healthcare work activities. In our current work, we have developed the following heuristics for evaluation of such pervasive health information system applications: (1) unobtrusiveness—direct interaction of a user with a health information system should be limited to only parts of the task where such interaction is necessary (i.e., allowance for visibility when required), (2) privacy and security—use of a health information system must not violate privacy and security restrictions under normal conditions of use, (3) ability to provide emergency override capability—under exceptional conditions, security and access restrictions may need to be overridden, however such exceptional cases need to be identified and logged for subsequent audit, (4) appropriate context-awareness—health information systems must be able to track the context of use and respond to differing contexts in an appropriate manner, (5) failure backup—failure of a health information system or its supporting network should be made apparent to the user through some form of notification, (6) allowance for recovery and alternative modes of user interaction during failure periods, (7) information and altering prioritization—the system should appropriately prioritize and display alerting or remaindering information only at essential points in user workflow to avoid cognitive overload, (8) user control in the absence of traditional interface cues, (9) Selection of appropriate mode for system-user interaction, (10) consistency across modes of interaction, and (11) allowance for seamless modal switching.

Heuristics, such as those presented previously can be applied in a principled manner in both designing and evaluating health information systems. For example, analysts may step through the use of an information system, recording violations of any of the heuristics mentioned during such testing. In addition, the same heuristics can be used to guide the analysis of data collected from study of subjects interacting with systems under artificial conditions, simulations or naturalistic settings. These types of heuristics essentially form the basis for coding and quantifying problems observed by analysts and investigators in reviewing video data obtained from recordings of user interactions. Used in this way, the heuristics provide categories for identifying interaction problems in coding the resultant video recordings of user interactions, as will be illustrated later in this chapter.

USABILITY TESTING IN HEALTHCARE

One of the most powerful methods for understanding and analyzing usability of health information systems is known as usability testing (Nielsen, 1993). Usability testing refers to the evaluation of information systems through the in-depth analysis of user interactions with the system (under artificial or realistic conditions). Subjects in such studies are asked to carry out tasks for which the system or device was designed to support. For example, physicians may be observed while they carry out tasks that may use of a system to remotely access patient records. Typically this may involve video recording the entire interaction of users with the system (e.g., the screens of a computer application, or logs of the system's behavior as well as the physical and verbal behavior of subjects as they interact with others in their work environment and with a health information system). Usability testing may be conducted under artificial laboratory conditions, simulations, or in real-life settings. Under artificial conditions, subjects may be asked to "think aloud" while interacting with a device or carrying out a task that involves the use of an information system (e.g., interacting with a EHR system remotely while carrying out emergency procedures), while under simulated conditions use of the device might be recorded while the subject interacts with patients in a simulated clinical environment. In either case, the resultant audio and video recordings of the interaction can then be analyzed using methods involving the coding and classification of user problems, as will be described in a subsequent section.

Usability testing is closely related to on an approach to analysis of HCI known as cognitive task analysis (CTA). Cognitive task analysis emerged from the fields of cognitive science and psychology and involves the detailed analysis of humans as they carry out complex reasoning and decision making tasks (Gordon & Gill, 1997). In healthcare, CTA is concerned with characterizing the decision making, reasoning skills, and information processing needs of users (e.g., doctors, nurses, patients) of health information systems. An essential part of conducting a cognitive task analysis is to initially identify the essential tasks, or work activities, that an information system under study has been designed to support. For example, tasks might include entering a medication order into a health information system or accessing patient information about drug allergies from a health information system. Once tasks of interest have been identified, CTA typically involves observing subjects of varying levels of expertise as they carry out the tasks, identifying the skills, knowledge and problems encountered by subjects.

Our approach to usability testing, which we term "rapid low-cost usability engineering" (Kushniruk & Borycki, 2006) builds on CTA as well as usability testing and involves the following stages (Kushniruk & Patel, 2004; Kushniruk, Patel, & Cimino, 1997):

- **Stage 1.** Identification of testing objectives: As a first step the objectives of the usability test must be identified. The objectives might for example consist of testing a new health information system in order to determine what specific aspects of the user interface design might be adversely affecting its adoption by physician users.
- **Stage 2.** Selection of test subjects and computer application: Data is typically collected from a representative sample of users (e.g., physicians, nurses, patients) of the system under study. This often involves testing 10-20 representative users of a system (Kushniruk & Patel, 2004). It is important that subjects selected for the testing are representative of real users of the system under study (e.g., physician users of a patient record system).
- **Stage 3.** Selection of representative experimental tasks: Usability testing of healthcare information systems typically involves selection of several key representative tasks (that the system under study is designed to support) that will be used in the testing. For example, in analyzing the interaction of physicians with a medication order entry system, representative tasks might include the entry of specific medications into the system by physicians.
- **Stage 4.** Selection of an evaluation environment: The actual environments where usability testing will take place may vary from a fixed usability laboratory (under artificial laboratory conditions) to the recording of users interacting with real systems under real conditions (e.g., evaluation of users interacting with a health information system in an operating room or hospital ward). The approach described in this chapter is based on a portable and low-cost approach to usability engineering, where the equipment required can be brought into any healthcare environment.
- **Stage 5.** Observation and recording of users' interaction with the health information system under study: This is the stage where the users' interaction with the system under

study are observed and recorded. For example, physicians may be instructed to interact with a new patient record system while "thinking aloud." The resulting interaction is typically recorded in its entirety, for example, all computer screens are typically recorded using screen recording software, the users' physical interactions are video recorded and all verbalizations are also audio recorded (using methods that will be detailed following).

- **Stage 6.** Analysis of usability data: The data collected in Stage 5 can be analyzed using a variety of methods. In our consulting work this has often involved simply "playing back" the recordings of users interacting in order to visually illustrate type of issues and problems that users of their systems may be encountering. From our experience this can often provide extremely useful to designers of healthcare systems that will suggest improvements and modifications that might greatly improve adoption. More detailed forms of analysis (which will be described) can also be conducted. Typically, this involves coding the resultant data (which may consist of screen recordings, video recordings and transcripts of any audio recordings) to precisely identify the occurrence, type and frequency of user problems encountered. This type of in-depth analysis can also be used to characterize the cognitive processes of users of health information systems (e.g., reasoning and decision making strategies of healthcare professionals as they interact with computer technologies).
- **Stage 7.** Interpretation of findings and feedback into system improvement redesign: The ultimate objective of our work in conducting usability testing of health information systems is to understand the complex interaction between healthcare workers and computer systems in order to improve the usability of health information systems. This typically involves feeding back results obtained from the analysis of usability data (as described in Stage 6) to designers and implementers of such systems in the form of recommendations for system improvement. In general we have found that the earlier in the development cycle of health information systems that results from usability can be fed back into design, the better (Kushniruk, 2002).

We have used the approach to analyze a wide range of healthcare information systems. For example, in a recent study of a medication order entry system, subjects were asked to enter prescriptions as accurately as possible into the system. By recording their activities in doing so, we were able to identify aspects of the user interface ranging from content issues that needed to be changed to allow for accurate data entry (e.g., changing the default dosages provided to users to match dosages actually used in their hospital) to issues related to lack of consistency in the user interface (e.g., multiple ways to exit a screen leading to confusion for new users).

RAPID LOW-COST USABILITY ENGINEERING IN HEALTHCARE

In this section of the chapter we will describe our approach to usability engineering that can be applied in any type of setting (ranging from hospital rooms to the home setting) to study the use of health information systems by end users (e.g., healthcare professionals or patients). This approach to rapid usability engineering has so far been used for a number of projects, ranging from the study of nurse's information needs to the evaluation of a range of new and emerging health information systems including medication administration record systems, which are designed to allow for electronic ordering of medications

Figure 1. User interacting with a health information system while being video-recorded

(Borycki & Kushniruk, 2005; Kushniruk & Borycki, 2006).

Figure 1 shows an example of a typical user (a nurse) interacting with a health information system under study during usability testing. In this example, the subject is interacting with the system within a hospital, obtaining information about a specific patient. The subject is being video recorded while doing so. Our typical studies carried out in naturalistic clinical settings involve asking subjects (e.g., nurses or physicians) to interact with systems to carry out real tasks (e.g., to enter medications for patients or access patient reports). In many of our studies, we also ask subjects to "think aloud" while carrying out the task (which is audio recorded). The recordings of subject's "thinking aloud" while using a system can be analyzed using methods from protocol analysis (Ericsson & Simon, 1993; Kushniruk & Patel, 2004). The subject's overt physical activities are recorded using a video camera (i.e., a mini-DVD camcorder) as shown in Figure 1. In addition to recording physical activities and audio of think aloud, the actual computer screens are also recorded as digital movies (with the audio portion of each movie corresponding to subject's verbalizations). In order to do this we are currently using a screen recording program called Hypercam© which allows one to record all the computer screens (and verbalizations) as a user interacts with the system under study, and stores the resultant digital movie for later playback and in-depth analysis of the interaction.

The equipment we are currently using for many of our usability studies of health information systems is both low-cost and portable. In summary, this typically includes: (1) a computer to run the system under study on, (2) screen recording software which allows the computer screens to be recorded as movie files (with audio input of subject's "thinking aloud" captured using a standard microphone plugged into the computer), and (3) a digital DVD camcorder on a tripod or a ceiling mounted camera to video record user's physical interactions.

ANALYSIS OF USABILITY DATA

As previously mentioned, the analysis of the data collected varies from informal analysis (which consists of simply playing back the recordings of user interactions) to identifying specific usability problems and issues. The analysis can involve systematically annotating the recordings of interactions using software such as Transana© (a video annotation program that allows analysts to "mark up" and time stamp movies of user interactions with a system) as described in Kushniruk and Patel (2004). The typical result of carrying out such analyses includes identification of specific usability problems (often in a meeting setting with system developers, customers, and hospital or management staff present). For example, our work in the analysis of use of electronic health record systems has identified the following categories of problems with many health information systems we have studied: problems with lack of consistency in the user interface, lack of feedback provided by the system to the user about the status of the system, user problems in understanding information or terms displayed by the system, as well as user problems in entering information into the system in a timely and effective manner (Kushniruk, 2002).

As noted, the intent of our work is to provide feedback to system designers and implementers about system usability in order to provide useful information to improve systems. Our most recent projects have involved applying usability engineering methods to identify potential errors that may be caused by a system (e.g., inappropriate medication defaults in an order entry system), or "induced" by poor design of a user interface *prior* to release of the system in real clinical settings (Borycki & Kushniruk, 2005). This has involved conducting simulations of user interactions with systems under study as will be described below. We have also employed a similar approach to detecting and correcting potential user problems and preventing medical error in a range of systems. This has included analysis of handheld prescription writing software designed to run on handheld devices to allow physicians to record medications and obtain recommended guidelines about their use (Kushniruk, Triola, Borycki et al., 2005). More recently, we have employed a methodology based on rapid usability engineering and use of simulations of clinical activities to determine how medical workflow may be inadvertently affected by introduction of a medication order entry system, described in the case study below (Borycki, Kushniruk, Kuwata, & Kannry, 2006).

In the early stages of our work and early experimentation with usability engineering in healthcare, we employed a number of different approaches to conducting usability testing including setting up a considerably more expensive "fixed" usability laboratory (where users would interact with systems in a fixed "wired" room while being observed through one-way mirrors). However, our experience has indicated that this approach does not allow us to easily and rapidly collect data at the site where the software under study is actually installed—which often ends up being at a location that is not readily accessible (e.g., due to security restrictions) from a fixed usability laboratory. In addition, for many of our studies it is essential that we test information systems in the actual environment in which the system under study is being used (i.e., in order to determine how aspects of a particular environment may be affected and how users interact with a system) which is not realistically possible without employing a portable approach. With the advent of inexpensive screen recording software and high quality portable digital video cameras, the costs have decreased for conducting such studies along with an increase in the portability of the equipment that can be taken into any hospital or clinical environment, which also simplifies the entire process.

Based on our experiences, the approach to rapid usability engineering in healthcare typically involves the following steps: (1) familiarizing oneself with the techniques and approaches that are possible (see Kushniruk & Patel, 2004, for details) in healthcare, (2) setting up a low-cost portable usability laboratory, (3) choosing a project area that is of significance (e.g., to identify the major usability problems that users of a patient record system may be encountering), (4) working closely with clinical informatics staff, designers and management to show how system usability can be improved in an effective and cost-beneficial manner, and (5) making alterations to the information system based on feedback.

EXAMPLE: EVALUATING THE UNINTENDED CONSEQUENCES OF A MEDICATION ADMINISTRATION RECORD SYSTEM

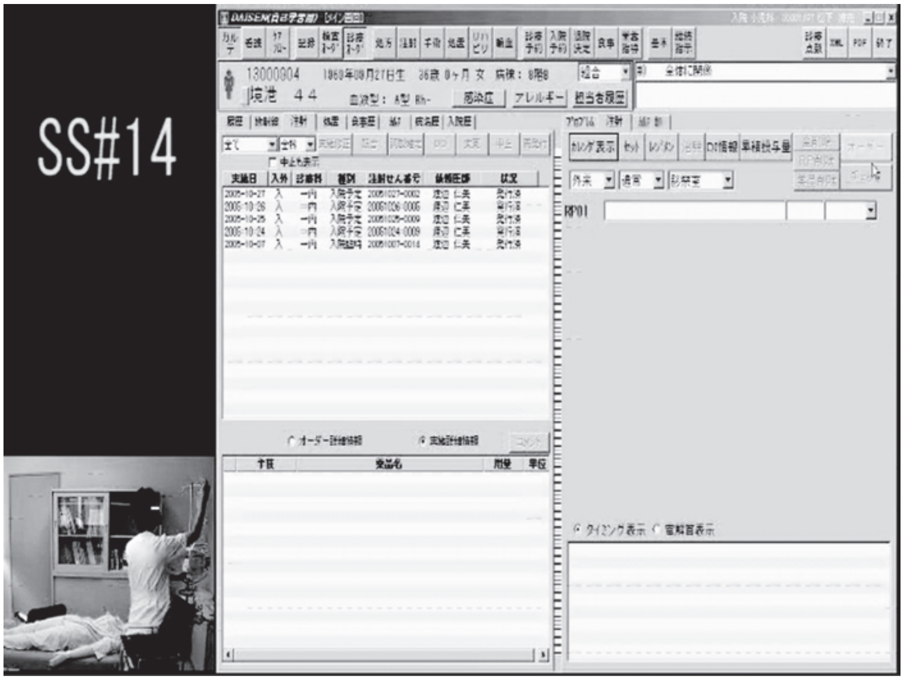
In the example described in the following, a rapid usability engineering approach (employing simulations of realistic healthcare situations) was used to assess the impact of a new medication administration system about to be deployed in a teaching hospital in Japan. The system was designed to allow users (e.g., physicians and nurses) to obtain information and instructions about medications to give to patients and to record the administration of the medication in a computer system. Thus the system is similar to many systems currently being deployed in hospitals around the world. The computer component of the medication administration system was also integrated with bar-coding technology that allows the doctor or nurse to scan the wrist band of the patient to identify the patient and to also scan the labels on medication bags. The study set up involved asking subjects to obtain information from the medication order entry system and administer medications while being video recorded (physical activities were recorded using a camcorder on a tripod, while all computer screens were automatically recorded using screen recording software).

Sixteen subjects, consisting of doctors and nurses were given written instructions for entering medications for a list of simulated patients. The subjects interacted with both the computer system as well as the "patient," which consisted of a dummy (i.e., a mannequin) with a bar coded wrist band (as shown in the bottom left-hand side of Figure 2). A typical computer screen from the system is shown on the right-hand side of Figure 2. Figure 2 shows the two video views from subject #14—the video of the subject's interaction with the patient in one window while the screen recordings of interactions with the computer system are shown in another window (supporting analysis of both "views" to identify subject actions both on and off the computer). In the study, subjects were specifically instructed to interact with the computer system and the dummy patient (e.g., to hang intravenous medication bags) just as they would be doing in a real situation. In order to record the use of the system in the study, we employed a digital video camera on a tripod to record the interactions of the subject with both the computer system and the patient.

In summary, the study design included full video recording of the subjects' interaction with the system while subjects were asked to use the computer application to enter the patient's name, obtain the list of medications to give the patient, to administer the medication (to the dummy patient) and to then record the administration in the computer application. All computer screens were recorded while subjects interactions with a dummy patient (a mannequin) were recorded using the portable camcorder. At the end of the session the subjects were also interviewed about their experience in using the system (and the interviews audio recorded).

In order to analyze the data collected, first the audio portion of the recorded sessions were transcribed in their entirety (including the interviews at the end of each session—see Figure 3 for the transcripts from one nurse subject) and then annotated by the experimenters by reviewing the video recordings of the computer screens and subjects' physical activities (e.g., actually hanging medication bags). In Figure 3 the numbers on the left hand side refer to the video counter corresponding to the actual actions of the subject. The latter portion of Figure 3 also contains the transcript of the interview with the subject (a nurse)

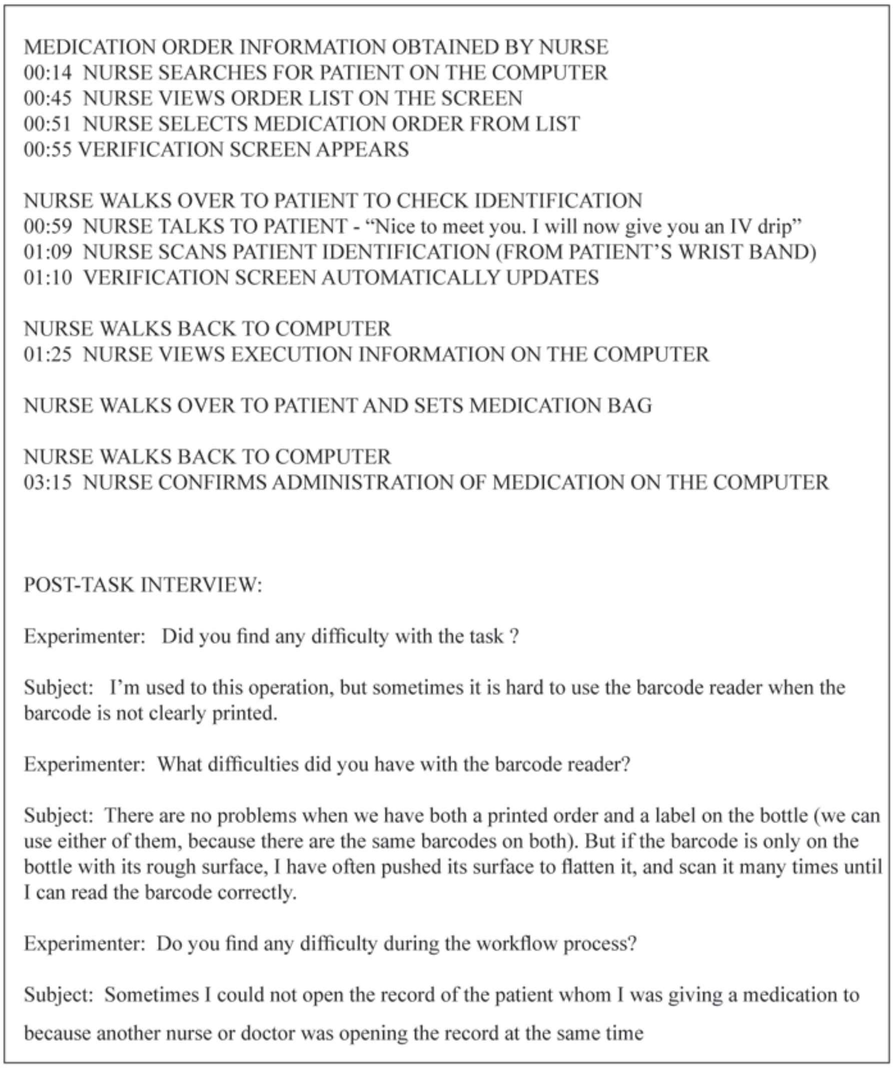
Figure 2. Video playback of 2 recorded views: the subject's physical interactions (lower left window) and the computer screens (right window)



conducted immediately following completion of the simulation task

From analysis of this data a range of usability problems were identified including the following: difficulty in physically scanning the medication bags and scanning the patient's wrist band, inability to record administration of a medication when the patient's record is "locked out" by other users of the system (who are accessing the system at the same time as the nurse or doctor is attempting to administer medication), and issues related to the slow speed of the system particularly when there were many medications to be administered. In addition to identifying potential sources of specific problems that would arise from implementation of the new system, it was also observed that introduction of the computer actually generally led to a major change in the *process* of medication administration. This was characterized by a serialization of the workflow process that could not be deviated from, for example, as shown in the annotated transcript in Figure 3, the physician or nurse would have to administer one medication at a time, first accessing the computer, physically moving to the patient, scanning the patient identification band on their wrist, moving back to the computer for details, then back to the patient to administer that drug and finally back to the computer to record the administration prior to administering the next medication (which is repeated each time for each medication). As compared to the previous workflow (i.e., the workflow before the system involving paper records), it was discovered that the new system imposed a relatively rigid order of activities for medication entry that could not be deviated from. Under normal conditions, this could lead to increased safety in medication entry by providing a structured and standardized procedure for medication entry. However, from our simulations it was also clear that under certain conditions (e.g., need to administer a number of medications under time-

Figure 3. Transcript of a Subject (a Nurse) Administering a Medication (followed by post-task interview)



MEDICATION ORDER INFORMATION OBTAINED BY NURSE
00:14 NURSE SEARCHES FOR PATIENT ON THE COMPUTER
00:45 NURSE VIEWS ORDER LIST ON THE SCREEN
00:51 NURSE SELECTS MEDICATION ORDER FROM LIST
00:55 VERIFICATION SCREEN APPEARS

NURSE WALKS OVER TO PATIENT TO CHECK IDENTIFICATION
00:59 NURSE TALKS TO PATIENT - “Nice to meet you. I will now give you an IV drip”
01:09 NURSE SCANS PATIENT IDENTIFICATION (FROM PATIENT’S WRIST BAND)
01:10 VERIFICATION SCREEN AUTOMATICALLY UPDATES

NURSE WALKS BACK TO COMPUTER
01:25 NURSE VIEWS EXECUTION INFORMATION ON THE COMPUTER

NURSE WALKS OVER TO PATIENT AND SETS MEDICATION BAG

NURSE WALKS BACK TO COMPUTER
03:15 NURSE CONFIRMS ADMINISTRATION OF MEDICATION ON THE COMPUTER

POST-TASK INTERVIEW:

Experimenter: Did you find any difficulty with the task ?

Subject: I’m used to this operation, but sometimes it is hard to use the barcode reader when the barcode is not clearly printed.

Experimenter: What difficulties did you have with the barcode reader?

Subject: There are no problems when we have both a printed order and a label on the bottle (we can use either of them, because there are the same barcodes on both). But if the barcode is only on the bottle with its rough surface, I have often pushed its surface to flatten it, and scan it many times until I can read the barcode correctly.

Experimenter: Do you find any difficulty during the workflow process?

Subject: Sometimes I could not open the record of the patient whom I was giving a medication to because another nurse or doctor was opening the record at the same time

constrained conditions) the new computer-based system could also potentially result in cognitive overload leading to the need for complete bypass of the system by users under emergency or stressful situations. It should be noted that such potential unintended consequences of implementation of the system were not anticipated by the designers of the medication order entry system and that applying an approach to usability testing where users of health information systems are recorded as they participate in simulations of real clinical activity we were able to anticipate user problems prior to implementation of the system (Borycki & Kushniruk, 2005).

TOWARDS REMOTE USABILITY ANALYSIS OF WEB-BASED INFORMATION SYSTEMS

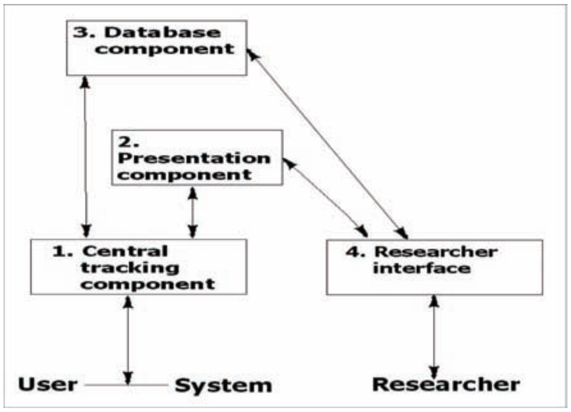
This section describes our most recent work in extending rapid usability engineering to the development of methods and approaches that will allow for remote usability testing of health information systems. The remote evaluation of the use and usability of Web-based healthcare information systems and resources is becoming recognized as being a critical area within health informatics. Many new health information system applications are being targeted towards use by not only health professionals but also by patients and lay people in an ever increasing variety of physical locations. Web sites containing digital libraries of on-line clinical information and guidelines, which provide health professionals with guidance and current evidence about the treatment and management patient cases, have appeared widely over the World Wide Web (WWW). In addition, many reputable healthcare organizations are providing similar type of information adapted to patients and lay people over the WWW. For example, the Canadian Medical Association provides guidelines on the treatment of Breast Cancer which are publicly accessible through their Web site. The assessment of such applications by varied end users (patients, physicians, nurses, etc.) from varied locations is challenging and has led us to a complementary line of work in developing and extending portable usability testing to the remote distance analysis of large numbers of users (e.g., healthcare providers or patients) interacting with health information system applications from any number of physical locations over the WWW.

As noted above, the evaluation of the use, usability and effectiveness of Web-based health information systems by end users who may vary greatly in terms of education, computer expertise and motivation, has become a major issue (Nielsen, 2000). However, the distributed nature of these systems leads to a number of challenges for system designers and evaluators. As a result in recent years an attempt has been made to conduct remote usability evaluations over the WWW. Such evaluation can involve collection of a variety of data, including remotely collecting on-line recordings of patients' and physicians' use of systems, telephone interviews, and in-depth video analysis of users interacting with systems. An example of this is a distance evaluation approach we have termed "televaluation" (Kushniruk, Patel, Patel, & Cimino, 2001). Cimino et al. (2002) describe the application of this approach to assess the use of a patient clinical information system (that allowed patients to access their own patient data from home over the WWW) based on remote logging of all user interactions with the system. This work built on and extended the work of Felciano and Altman (1996) in development of methods for remote tracking of Web users (using a program known as 'Lamprey'). By employing such a remote Web-based tracking component at the core of an evaluation system (Kushniruk et al., 2001; Kushniruk & Ho, 2004; Owston, Kushniruk, Pitts & Wideman, 2005; Kushniruk, Owston, Pitts et al., 2007) this line of work went on to extend the data collection to include results from online questionnaires and other sources of data (including remote recordings of computer screens), in an attempt to relate detailed usage logs from Web tracking with other types of data, such as user demographics, patient records etc. In the following, we describe experiences in extending the approach for evaluating a range of Web-based systems and information resources. The objective of this most recent work has been to develop an automated system to support the collection, integration and analysis of a range of remotely collected data and more specifically to extend the approach to the evaluation of Web-based information resources and health information systems targeted to both healthcare providers and patients.

METHODOLOGICAL APPROACH

Our approach to developing an evaluation tool for conducting remote usability evaluations has to involved the creation and integration of the following interacting system components (see Figure 4) to form the basis for an evaluation tool known

Figure 4. Overall VuLab architecture



as the virtual usability laboratory or "VULab":

1. A central tracking component, residing on an evaluation server (i.e., a computer located in our facilities), was designed for remotely tracking and analyzing use of Web-based information systems located at remote sites. This component can provide a customized record of all accesses by users to a system under study. For example, it can provide a log file of what Web pages within a site are accessed, the order of browsing and a time-stamped record of the users' activities in accessing a remote site. In addition, this component has recently been extended to allow for remote recording of users' computer screens (and audio) as digital movies stored on a central evaluation server allowing usability data (similar to the type of data collected described in the first part of this chapter) to be collected remotely.
2. A second component was designed for controlling the automatic presentation of online forms and questionnaires to users in order to assess the usability of Web sites remotely at point of use. The triggering of such online questionnaires can be based on a user profile created for each user of a site being evaluated. By redirecting requests for access to a Web site under evaluation through our evaluation server we are able to write programs that can trigger prompts for user information (e.g., about user satisfaction with information provided or usability) to appear at points when users enter or leave parts of a Web site of interest. For example, on first entry into a system under study a demographic questionnaire can be triggered to appear and later, when the user accesses a page of interest, e.g., a Web page containing clinical guidelines in a health Web site, an online questionnaire can also be triggered to appear automatically to query the user (e.g., about why the page is being accessed, satisfaction with information provided, perceived educational value of the content provided, etc.).
3. A database component was designed for collecting and integrating the results of remotely tracking users, screen recordings and questionnaires in an integrated database containing other information about users including demographic and illness information (using relational database tables to store and interrelate data). For example, a database table can be created containing the results of logging of users' interactions with a Web site. This type of information can be linked to other data including information about user demographics, results of pre and post test online questionnaires (that may be triggered to appear just before or after a user enters a Web page being analyzed).
4. A researcher user interface component was designed that allows evaluators of a health Web site to easily set up a remote evaluation. For example, a researcher may specify what site will be evaluated, what type of questions should appear to users (by adapting or editing questions contained in a questionnaire bank) and indicating when questionnaires/logging is to be triggered. To facilitate this process, the researcher

can choose from and modify questionnaires and prompts contained in a template bank, or alternatively choose to create their own. Finally, the researcher is prompted to indicate what type of data analysis they would like by selecting from a list of built-in types of statistical analyses. In addition, we are currently working on making a variety of data mining and knowledge discovery algorithms available to the researcher to select from in order to support computer-based automated analysis of use and usability data collected from many system users remotely (Han & Kamber, 2001).

REMOTE USABILTIY ANALYSES: EXPERIENCES TO DATE

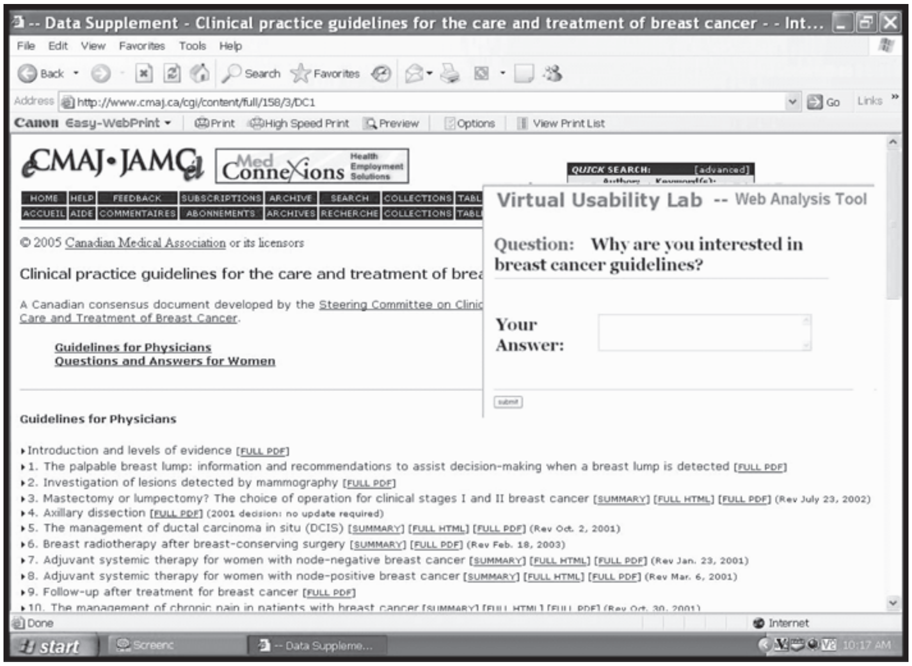
The VULab is currently being tested and deployed for a number of projects examining the use of innovative health information resources and information systems. This has included the evaluation of a Web site designed to filter patient and provider requests for health information, as well as on-going application of the approach for a project involving remote analysis of use of advanced simulation software for health education purposes. We have found that the collection of varied forms of usage data remotely is not only feasible, but additionally by storing data in consistent database format the integration and querying of varied forms of usage data can be supported for practical purposes.

A current application of the VULab is in the area of assessing the use and usability of Web-based applications and clinical guidelines designed to support physician decision making about cancer. To illustrate its use, a researcher studying use and usability of Web-based breast cancer guidelines might wish to set up a series of questions that are triggered to appear whenever a user of a system (e.g., a physician browsing through the guidelines) enters a particular part of a Web site or information system (including specifying what type of questions will be asked of users as they enter specific sections of a system under study, for example, “why are you interested in breast cancer guidelines?”). Specifically, the researcher may wish to understand when and why physicians access the breast cancer guidelines. To do this, the VULab can be set up by the investigators to automatically trigger presentation of a pop-up questionnaire to users whenever they click on the page containing the guideline (in this case the user would be queried as to why she is interested in breast cancer guidelines—see the pop-up question in Figure 5). It should be noted that this type of subjective information at point of user (regarding use, usability or usefulness of information presented) can be integrated with the logging data which records all Web pages the user had browsed through during his/her interaction with the site. Therefore we can interrelate logging data to subjective user data collected right at point of use (this combination of different types of data can be fed into data mining and knowledge discovery methods—see Han & Kamber, 2001).

In summary, the researcher interface allows the researcher/investigator to specify: (1) when and where in a remote web site questions should be automatically presented to the user, (2) what the question should be (e.g., in the example, “Why are you interested in breast cancer guidelines?”), and (3) in what format they would like user logging data to be stored. The results from the questionnaires are automatically stored in the database component of the VULab and collated with results from other users, to create a statistical summary of system usage. In addition, this information can be merged with results from other forms of data collection, such as responses from users to online demographic questions regarding their health status, as well as remotely collected screen recordings.

Another current application of the VULab is its use as a central component for evaluation in a cross Canadian network of researchers studying

Figure 5. Screen shot of the pop-up question as it appears to a user as she enters a specific Web page (within an on-line clinical guideline)



© 2005 Canadian Medical Association or its licensors

Clinical practice guidelines for the care and treatment of brea

A Canadian consensus document developed by the Steering Committee on Clinic Care and Treatment of Breast Cancer.

Guidelines for Physicians
Questions and Answers for Women

Virtual Usability Lab -- Web Analysis Tool

Question: Why are you interested in breast cancer guidelines?

Your Answer:

Guidelines for Physicians

- Introduction and levels of evidence [FULL PDF]
- 1. The palpable breast lump: information and recommendations to assist decision-making when a breast lump is detected [FULL PDF]
- 2. Investigation of lesions detected by mammography [FULL PDF]
- 3. Mastectomy or lumpectomy? The choice of operation for clinical stages I and II breast cancer [SUMMARY] [FULL HTML] [FULL PDF] (Rev July 23, 2002)
- 4. Axillary dissection [FULL PDF] (2001 decision: no update required)
- 5. The management of ductal carcinoma in situ (DCIS) [SUMMARY] [FULL HTML] [FULL PDF] (Rev Oct. 2, 2001)
- 6. Breast radiotherapy after breast-conserving surgery [SUMMARY] [FULL PDF] (Rev Feb. 18, 2003)
- 7. Adjuvant systemic therapy for women with node-negative breast cancer [SUMMARY] [FULL HTML] [FULL PDF] (Rev Jan. 23, 2001)
- 8. Adjuvant systemic therapy for women with node-positive breast cancer [SUMMARY] [FULL HTML] [FULL PDF] (Rev Mar. 6, 2001)
- 9. Follow-up after treatment for breast cancer [FULL PDF]
- 10. The management of chronic pain in patients with breast cancer [SUMMARY] [FULL HTML] [FULL PDF] (Rev Oct. 30, 2001)

advanced gaming and simulation software for educational purposes—the SAGE project (Wideman, Owston, Brown et al., 2007). The objective of this line of research is to identify and assess key aspects of games and simulations that could be incorporated in educational software, evaluate learning as a result of use of such software, and analyze use and usability of emerging gaming and simulation components being developed as part of the SAGE project. Specifically, the VULab is being used to automatically collect and collate data on usage of Web-based collaborative, and other forms of educational games and simulations aimed at improving awareness and understanding of health issues. Data being collected includes what parts of games are accessed, how often along with information about specific user impressions and results from on-line questionnaires and quizzes presented to users. In one study of users of an educational simulation, the approach was able to identify and tease apart a variety of usability problems with the software under study, ranging from technical problems with scripting to problems of usability and understandability of user instructions.

CONCLUSION

In this chapter, we discussed our work in the development and evolution of methods for the analysis of health information systems by end users. As we have described, this work has evolved from development of low-cost rapid usability engineering approaches for conducting usability testing in both laboratory and real settings (which we continue to employ to study a wide range of health information systems) to the design and development of a "virtual" usability laboratory for the analysis of use and usability of health related Web-based information systems, resources and sites. Our work has been employed for improving healthcare information systems in Canada, the United States and internationally. Using these approaches we have been able to feed valuable information back to both designers and implementers of health information systems about what aspects of the system work from the end user's perspective and what aspects need to be modified to ensure usability. From our work we have found that is essential for dissemination of these approaches that we strive to develop methods that are both practical and cost-effective. The argument for the need for such analyses extends not only to providing input to improve and refine usability of health information systems and Web applications but also to ensuring patient safety. Indeed, based on studies indicating that poorly designed healthcare systems may actually facilitate medical error we must ensure not only system usability but also equally as important we must ensure the safety of healthcare information systems. In this context, we have successfully used the approach to predict errors and problems that will occur from human-computer interaction *prior* to releasing the system for general use (Kushniruk et al., 2005). With the rapid increase in deployment of health information systems, continual development and refinement of new methods for conducting such analyses of human-computer interaction in healthcare will become even more critical.

FUTURE RESEARCH DIRECTIONS

There are a variety of future research directions in the area of usability engineering in healthcare. These include: (a) research into application of methods described in this chapter throughout the development cycle of health information systems, from system selection through to design, implementation and system testing, (b) further extension of usability engineering methods to data collection and analyses conducted remotely over the WWW, (c) development of experimental study designs that can be used to assess use of systems and cognitive issues involved in using system in real clinical conditions, (d) extension to use in the study of new and emerging health information systems, including mobile applications, (e) extension of approaches from usability engineering to include advanced simulation methods, and (f) automated analysis of usability data and application of data mining and knowledge discovery methods.

The application of scientific methods for analysis of health information system usability have been shown to be usefully applied throughout the entire process of developing health information systems. Kushniruk (2002) describes how the approach can applied from the earliest stages of system development, even including applying usability testing to assess different health information systems prior to selecting them, to the analysis of early system prototypes to provide early feedback to designers about features of systems that may enhance or decrease usability. As described in this chapter work in developing methods for remote analysis of a large number of users of systems is another area where ongoing research is being conducted, including work on tools such as the VULab. Also, the application of new study designs, incorporating aspects of ethnography and portable recording techniques, will be important to move usability engineering from being conducted in only a few fixed usability laboratories to widespread application throughout the healthcare industry. This will lead to study of new and emerging applications, including pervasive healthcare information systems, such as wearable computing and hand-held computing devices (Kushniruk & Borycki, 2007). Further work will also include incorporation of methods of simulation from other domains such as aviation and nuclear power to improve the identification and prediction of usability errors before systems are released for real use in healthcare (Borycki & Kushniruk, 2005). Finally, the application of methods from the field of data warehousing and mining will provide designers, implementers and health decision makers with improved knowledge about use and usability of health information systems.

REFERENCES

Borycki, E., & Kushniruk, A. W. (2005). Identifying and preventing technology-induced error using simulations: Application of usability engineering techniques. *Healthcare Quarterly (Toronto, Ont.)*, *8*, 99–105.

Borycki, E., Kushniruk, A. W., Kuwata, S., & Kannry, J. (2006). Use of simulation approaches to the study of user needs and error in biomedical informatics. *Proceedings of the 2006 Annual AMIA Conference* (pp. 61-65).

Cimino, J. J., Patel, V. L., & Kushniruk, A. W. (2002). The patient clinical information system (PatCIS): Technical solutions for and experiences with giving patients access to their electronic medical records. *International Journal of Medical Informatics*, *68*(1-3), 113–127. doi:10.1016/S1386-5056(02)00070-9

Eason, K. D. (1991). Ergonomic perspectives on advances in human-computer interaction. *Ergnomics*, *34*, 721. doi:10.1080/00140139108967347

Ericsson, K. A., & Simon, H. A. (1993). *Protocol analysis: Verbal reports as data* (2nd ed.). Cambridge, MA: MIT Press.

Felciano, R. M., & Altman, R. B. (1996). Lamprey: Tracking users on the World Wide Web, *Proceedings of the 1996 AMIA Annual Fall Symposium* (pp. 757-761).

Gordon, S. E., & Gill, R. T. (1997). Cognitive task analysis. In C.E. Zsambok & G. Klein (Eds.), *Naturalistic decision making* (pp. 131-140). Mahwah, NJ: Lawrence Erlbaum Associates.

Han, J., & Kamber, M. (2001). *Data mining: Concepts and techniques*. New York: Morgan Kaufman Publishers.

Kushniruk, A., & Borycki, E. (2006). Low-cost rapid usability engineering: designing and customizing usable healthcare information systems. *Healthcare Quarterly (Toronto, Ont.)*, *9*(4), 98–100, 102.

Kushniruk, A., & Borycki, E. (2007). Human factors and usability of healthcare systems. In J. Bardram & A. Mihailidis (Eds.), *Pervasive computing in healthcare*. New York: CRC Press.

Kushniruk, A., Owston, R., Ho, F., Pitts, K., Wideman, H., Brown, C., et al. (2007). Design of the VULab: A quantitative and qualitative tool for analyzing use of on-line health information resources. *Proceedings of ITCH 2007*.

Kushniruk, A. W. (2002). Evaluation in the design of health information systems: application of approaches emerging from usability engineering. *Computers in Biology and Medicine*, *32*(3), 141–149. doi:10.1016/S0010-4825(02)00011-2

Kushniruk, A.W. & Ho, F. (2004, May). The virtual usability laboratory: Evaluating web-based health systems. *Proceedings of e-Health 2004*, Victoria, B.C.

Kushniruk, A. W., Patel, C., Patel, V. L., & Cimino, J. J. (2001). Televaluation of clinical information systems: An integrative approach to assessing web-based systems . *International Journal of Medical Informatics*, *61*, 45–70. doi:10.1016/S1386-5056(00)00133-7

Kushniruk, A. W., & Patel, V. L. (2004). Cognitive and usability engineering methods for the evaluation of clinical information systems. *Journal of Biomedical Informatics*, *37*, 56–76. doi:10.1016/j.jbi.2004.01.003

Kushniruk, A. W., Patel, V. L., & Cimino, J. J. (1997). Usability testing in medical informatics: Cognitive approaches to evaluation of information systems and user interfaces. In D. Masys (Ed.) *Proceedings of the 1997 AMIA Fall Symposium*, 218-222.

Kushniruk, A. W., Triola, M., Borycki, E., Stein, B., & Kannry, J. (2005). Technology induced error and usability: The relationship between usability problems and prescription errors when using a handheld application. *International Journal of Medical Informatics*, *74*, 519–526. doi:10.1016/j.ijmedinf.2005.01.003

Lukowicz, P., Kirstein, T., & Troster, G. (2004). Wearable systems for healthcare applications. *Methods of Information in Medicine*, *43*, 232–238.

Nielsen, J. (1993). *Usability engineering*. New York: Academic Press.

Nielsen, J. (2000). *Designing web usability.* Indianapolis: New Riders Press.

Nielsen, J., & Mack, R. L. (1994). *Usability inspection methods*. New York: John Wiley & Sons.

Owston, R., Kushniruk, A., Ho, F., Pitts, K., & Wideman, H. (2005). Improving the design of Web-based games and simulations through usability research. *Proceedings of Ed-Media 2005*.

Sharp, H., Rogers, Y., & Preece, J. (2007). *Interaction design: beyond human-computer interaction* (2nd ed.). New York: John Wiley & Sons.

Shortliffe, E. H., & Cimino, J. J. (2006). *Biomedical informatics: Computer applications in healthcare and biomedicine* (3rd ed.). New York: Springer.

Wideman, H. H., Owston, R., Brown, C., Kushniruk, A., Ho, F., & Pitts, K. (2007). Unpacking the potential of educational gaming: A new tool for gaming research. *Simulation & Gaming*.

Zhang, J., Johnson, T. R., Patel, V. L., Paige, D. L., & Kubose, T. (2003). Using usability heuristics to evaluate patient safety of medical devices. *Journal of Biomedical Informatics*, *36*(1-2), 23–30. doi:10.1016/S1532-0464(03)00060-1

ADDITIONAL READINGS

Beuscart-Zephir, M. C., Brender, J., Beuscart, R., & Ménager-Depriester, I. (1997). Cognitive evaluation: How to assess the usability of information technology in healthcare. *Computer Methods and Programs in Biomedicine*, *54*, 19–38. doi:10.1016/S0169-2607(97)00030-8

Beuscart-Zephir, M. C., Elkin, P., Pelayo, S., & Beuscart, R. (2007). The human factors engineering approach to biomedical informatics projects: state of the art, results, benefits and challenges. *IMIA Yearbook of Medical Informatics . Methods of Information in Medicine*, *46*(Supplement 1), 109–127.

Borycki, E., & Kushniruk, A. W. (2005). Identifying and preventing technology-induced error using simulations: Application of usability engineering techniques. *Healthcare Quarterly (Toronto, Ont.)*, *8*, 99–105.

Cimino, J. J., Patel, V. L., & Kushniruk, A. W. (2001). Studying the human-computer-terminology interface. *Journal of the American Medical Informatics Association*, *8*(2), 163–173.

Elkin, P. L., Mohr, D. N., Tuttle, M. S., Cole, W. G., Atkin, G. E., Keck, K., et al. (1997). Standardized problem list generation, utilizing the Mayo canonical vocabulary embedded within the Unified Medical Language System. *Proceedings of the AMIA Annual Fall Symposium* (pp. 500-504).

Hackos, J. T., & Redish, J. C. (1998). *User and task analysis for interface design*. New York: John Wiley & Sons.

Han, J., & Kamber, M. (2001). *Data mining: Concepts and techniques.* New York: Morgan Kaufman Publishers.

Hix, D., & Hartson, H. R. (1993). *Developing user interfaces: ensuring usability through product & process*. New York: John Wiley & Sons.

Horsky, J., Kaufman, D. R., Oppenheim, M. I., & Patel, V. L. (2003). A framework for analyzing the cognitive complexity of computer-assisted clinical ordering. *Journal of Biomedical Informatics*, *36*(1-2), 4–22. doi:10.1016/S1532-0464(03)00062-5

Jaspers, M.W., & Steen, T., Van den, B.C., & Geenen, M. (2004). The think aloud method: a guide to user interface design. *International Journal of Medical Informatics*, *73*(11-12), 781–195. doi:10.1016/j.ijmedinf.2004.08.003

Kaufman, D. R., Patel, V. L., Hilliman, C., Morin, P. C., Pevzner, J., & Weinstock, R. S. (2003). Usability in the real world: assessing medical information technologies in patients' homes. *Journal of Biomedical Informatics*, *36*(1-2), 45–60. doi:10.1016/S1532-0464(03)00056-X

Kushniruk, A., & Borycki, E. (2006). Low-cost rapid usability engineering: designing and customizing usable healthcare information systems. *Healthcare Quarterly (Toronto, Ont.)*, *9*(4), 98–100, 102.

Kushniruk, A. W. (2001). Analysis of complex decision making processes in healthcare: Cognitive approaches to health informatics. *Journal of Biomedical Informatics*, *34*(5), 365–376. doi:10.1006/jbin.2001.1021

Kushniruk, A. W. (2002). Evaluation in the design of health information systems: Applications of approaches emerging from systems engineering. *Computers in Biology and Medicine*, *32*(3), 141–149. doi:10.1016/S0010-4825(02)00011-2

Kushniruk, A. W., Kaufman, D. R., Patel, V. L., Levesque, Y., & Lottin, P. (1996). Assessment of a computerized patient record system: A cognitive approach to evaluating an emerging medical technology. *M.D. Computing*, *13*(5), 406–415.

Kushniruk, A. W., Patel, C., Patel, V. L., & Cimino, J. J. (2001). "Televaluation" of information systems: An integrative approach to design and evaluation of web-based systems. *International Journal of Medical Informatics*, *61*(1), 45–70. doi:10.1016/S1386-5056(00)00133-7

Kushniruk, A. W., & Patel, V. L. (2004). Cognitive and usability engineering approaches to the evaluation of clinical information systems. *Journal of Biomedical Informatics*, *37*, 56–57. doi:10.1016/j.jbi.2004.01.003

Kushniruk, A. W., Patel, V. L., & Cimino, J. J. (1997). Usability testing in medical informatics: Cognitive approaches to evaluation of information systems and user interfaces. In D. Masys (Ed.), *Proceedings of the 1997 AMIA Fall Symposium* (pp. 218-222).

Kushniruk, A. W., Patel, V. L., Cimino, J. J., & Barrows, R. A. (1996). Cognitive evaluation of the user interface and vocabulary of an outpatient information system. In J. Cimino (Ed.), *AMIA Fall Symposium Proceedings* (pp. 22-26). Philadelphia: Hanley & Belfus Inc.

Kushniruk, A. W., Triola, M., Borycki, E., Stein, B., & Kannry, J. (2005). Technology induced error and usability: The relationship between usability problems and prescription errors when using a handheld application. *International Journal of Medical Informatics*, *74*, 519–526. doi:10.1016/j.ijmedinf.2005.01.003

Mayhew, D. J. (1999). *The usability engineering lifecycle*. San Diego: Academic Press.

Nielsen, J. (1993). *Usability engineering*. New York: Academic Press.

Nielsen, J., & Mack, R. L. (1994). *Usability inspection*. New York: John Wiley & Sons.

Patel, V. L., & Kushniruk, A. W. (1998). Interface design for healthcare environments: The role of cognitive science. In C. Chute (Ed.), *Proceedings of the AMIA 98 Annual Symposium* (pp. 29-37).

Patel, V. L., Kushniruk, A. W., Yang, S., & Yale, J. F. (2000). Impact of a computer-based patient record system on data collection, knowledge organization and reasoning. *Journal of the American Medical Informatics Association*, *7*(6), 569–585.

Pearrow, M. (2000). *Web site usability handbook*. Rockland, MA: Charles River Media.

Preece, J., Rogers, Y., Sharp, H., Benyon, D., Holland, S., & Carey, T. (1994). *Human-computer interaction*. New York: Addison-Wesley.

Rasmussen, J., Pejtersen, A. M., & Goodstein, L. P. (1994). *Cognitive system engineering*. New York: John Wiley & Sons.

Rubin, J. (1994). *Handbook of usability testing: how to plan, design and conduct effective tests*. New York: John Wiley & Sons.

Sharp, H., Rogers, Y., & Preece, J. (2007). *Interaction design: beyond human-computer interaction* (2nd ed.). New York: John Wiley & Sons.

Shneiderman, B., & Plaisant, C. (2004). *Designing the user interface: strategies for effective human-computer interaction* (4th ed.). New York: Addison Wesley Longman.

Staggers, N. (1995). Essential principles for evaluating the usability of clinical information systems. *Computers in Nursing*, *9*(2), 47–49.

Weiss, S. (2002). *Handheld usability*. New York: John Wiley & Sons.

This work was previously published in Human, Social, and Organizational Aspects of Health Information Systems, edited by A. Kushniruk; E. Borycki, pp. 1-22, copyright 2008 by Information Science Reference (an imprint of IGI Global).

Chapter 8.5

Adaptive Awareness of Hospital Patient Information through Multiple Sentient Displays

Jesus Favela
CICESE, Mexico

Mónica Tentori
CICESE and Universidad Autónoma de Baja California, Mexico

Daniela Segura
CICESE, Mexico

Gustavo Berzunza
CICESE, Mexico

ABSTRACT

Sentient computing can provide ambient intelligence environments with devices capable of inferring and interpreting context, while ambient displays allow for natural and subtle interactions with such environment. In this paper we propose to combine sentient devices and ambient displays to augment everyday objects. These sentient displays are aware of their surroundings while providing continuous information in a peripheral, subtle, and expressive manner. To seamlessly convey information to multiple sentient displays in the environment, we also propose an approach based on abstract interfaces which use contextual information to decide which display to use and how the information in the display changes in response to the environment. Our approach is illustrated through a hospital monitoring application. We present the design of two sentient displays that provide awareness of patient's urine outputs to hospital workers, and how contextual information is used to integrate the functionality of both displays.

INTRODUCTION

Sentient computing is an approach that allows users to naturally interact with the physical environment by becoming aware of their surroundings and by reacting upon them (López de Ipiña & Lai Lo, 2001). Awareness is achieved by means of a sensor infrastructure that helps to maintain a model of the world which is shared between users and applications – referred as Sentient artifacts (Hopper, 1999). Indeed, sentient artifacts have the ability to perceive the state of the surrounding environment, through the fusion and interpretation of information from possibly diverse sensors (Addlesee et al., 2001). However, it is not sufficient to make Ambient Intelligence (AmI) environments aware of the user's context, they must be able to find a way to communicate this information to users while becoming a natural interface to the environment (Shadbolt, 2003).

Ambient displays could be embedded in everyday objects already known and used, thus becoming the user interface of the AmI environment. This vision assumes that physical interaction between humans and computational devices will be less like the current keyboard, mouse, and display paradigm and more like the way humans interact with the physical world. For instance, a mirror augmented with infrared sensors and an acrylic panel could detect human presence and act as a message board to display relevant information when a user faces the mirror. Hence, AmI environments could be augmented with such displays that unobtrusively convey information to users without requiring their full attention, while at the same time, allowing an implicit and natural interaction. Indeed, the notion of what constitutes a computer display is changing. No longer is a display confined to the typical CRT monitor with a single user paying focused attention while interacting with virtual objects on the screen (Lund & Wilberg, 2007). Rather, computer displays are found in such diverse forms as small screens in mobile phones or handheld computers, to ambient displays that provide peripheral awareness to the presence and status of people, objects or information.

In this article, by binding the ideas of sentient computing and ambient displays we propose the concept of sentient displays to define a new and appropriate physical interaction experience with an AmI environment. Such sentient displays will be capable of monitoring users' context, promptly notify relevant events and provide users with continuous information in a subtle, peripheral and expressive manner without intruding on our focal activity. Moreover, multiple such displays could be integrated in an AmI environment, with a decision of which one to use dependent on contextual circumstances, such as the user's location, the presence of other people or the activity being performed by the user. Thus, we also discuss an approach to develop contextual interfaces for a variety of sentient displays located throughout the intelligent environment. Our approach is based on the use of abstract interfaces that are specialized to specific devices once a decision is made as to which sentient display(s) should be used. This approach facilitates the progressive integration of new sentient displays.

To illustrate the concept of sentient displays we draw upon scenarios related to hospital work. Mobility and frequent task switching cause hospital workers to occasionally miss important events, such as a catheter being disconnected due to the patient movement or the need to change a urine bag that has been filled-up (Moran et al., 2006). Consequently, hospital workers have been held liable for their failure to monitor and promptly respond to patients needs (Smith & Ziel, 1997). Sentient displays located throughout hospital premises could be used for a diverse number of hospital applications, such as notifying hospital workers of a crisis or just provide continuous awareness of the health status of patients.

SENTIENT DISPLAYS: AUGMENTING NATURAL OBJECTS WITH AMBIENT DISPLAYS AND SENTIENT TECHNOLOGIES

Research in pervasive computing has included the development of ambient devices that can become part of the background while acting as a digital interface to ambient information. As stated by Mankoff: "Ambient displays are aesthetically pleasing displays of information which sit on the periphery of a user's attention. They generally support the monitor of information and have the ambitious goal of presenting information without distracting or burdening the user" (Mankoff et al., 2003). For instance, the artist Natalie Jermijenko at Xerox Parc augmented a string with a motor and spin to convey the traffic's status to a user –the Dangling String (Weiser & Brown, 1995). The device rotates at a speed that depends on the amount of traffic in the highway captured through analog sensors. During periods of intense traffic, the string's movements are slightly audible as well. Thus, ambient displays are, unlike ordinary computer displays, designed not to distract people from their tasks at hand, but to be subtle reminders that can be occasionally noticed. In addition to presenting information, the displays also frequently contribute to the aesthetics of the locale where they are deployed (Lund & Wilberg, 2007). For instance, as part of the AmbientRoom project, several displays using light, sound or motion have been developed to augment a user's office (Ishii et al., 1998). Undeniably, ambient displays need computing devices capable of perceiving our surroundings by seeing or hearing the entities in the environment, what these entities are doing and where they are. To this aim, research in sentient computing has focused on the development of sensors that attached to today's computing and communication technology are capable of perceiving a range of contextual information such as location, traffic status, user's presence and so on (Abowd & Mynatt, 2002). The most popular sentient devices are indoor location systems (Addlesee et al., 2001; Werb & Lanzl, 1998).

While ambient displays provide a different notion of what constitutes an interface to the AmI environment, sentient technologies allow such displays to be reactive and perceptive to dynamic changes in the environment. In this article we propose the concept of sentient displays combining the ideas of ambient displays and sentient computing. Sentient displays are our everyday artifacts augmented with digital services capable of perceiving information from the environment and then using this information to extend the capabilities of such artifact. We envision a sentient artifact as an object that encapsulates the information perceived and then provides users with a new form of interaction with the environment. This interaction could be either by offering continuous, subtle and peripheral awareness or by allowing users to change the status of such object in order to affect an AmI environment.

OPPORTUNITIES FOR THE DEPLOYMENT OF SENTIENT DISPLAYS IN HOSPITALS: A CASE STUDY

For nine months, we conducted a field study in a public hospital's internal-medicine unit, observing the practices of the hospital staff, who attended patients with chronic or terminal diseases (Moran et al., 2006). Such patients are often immobile and incapable of performing the activities of daily living (ADL) by themselves. The study was conducted to understand: (1) the type of patients' information being monitored by hospital workers and (2) the problems faced by hospital workers when monitoring patients.

Hospital workers are responsible for providing integral and specialized care for patients. As part of this, nurses monitor patient's activities of daily living (ADL), such as, if a patient has taken his medicine, if he has walked, eaten, felt from the bed, evacuated, etcetera. As a part of specialized care, nurses need to monitor the behavioral patterns in the activities that put at risk the patients' health or that indicate an internal failure which might evolve into a more serious disease (e.g., pneumonia, an apoplexy or a stroke), such as, if a patient is agitated, if a patient is bleeding or if the patient has respiratory insufficiency. These behavioral patterns associated to risk activities (RA) are monitored through the vital signs. To illustrate the problems faced by hospital workers when monitoring patients we present a real-scenario that was observed in the hospital:

Nurse Rita is informed, at the beginning of her working shift, that the attending physician has changed Pedro's medication to include cyclosporine. Pedro is a 56 years old man, who has a chronic renal failure and just had a renal transplant. So, to monitor Pedro's reaction to the new kidney and to the medicine being administered to him, Rita needs to supervise the frequency and quantity of Pedro's urine. Nurse Rita starts her shift by taking care of Juan –the patient in bed 226. While she is inserting a catheter to Juan, Pedro's urine bag fills up. Unaware of Pedro's status, Rita continues taking care of Juan. After several minutes another nurse informs Rita that Pedro's urine bag spilled up. Rita moves to Pedro's room to clean him.

The problem illustrated in the scenario could be avoided if Rita knows when Pedro's urine bag is almost full. This, and similar examples, helped us identify major issues faced by hospital workers when monitoring patients. In particular, issues related to hospital workers being on the move include maintaining awareness of their patients' status, being easily accessible when an emergency occurs, and prioritizing patient care on the basis of the patient's health condition. In addition, nurses must manage the tradeoff between having expressive versus silent awareness. While nurses want to be aware of the status of all the patients they are taking care off, they don't want this awareness to intrude in their focal activity. Finally, nurses need to interpret ambient information over time and at different levels of detail. This poses interesting challenges related to how contextual information influences the importance of the information presented. For instance, while to monitor Pedro's health it is significant for Rita to know the frequency and quantity of his urine outputs, for those patients with other diseases this information might not be relevant for her. This need to monitor the status of patients in an environment already saturated with information and with hospital workers constantly on the move and switching from one task to another, inspired us to design sentient displays for the hospital.

THE ADL MONITOR: A MOBILE SENTIENT DISPLAY

The ADL Monitor is a sentient display aimed at creating a wearable ambient connection between patients and nurses (Tentori & Favela, 2008). The ADL Monitor is composed of one sentient artifact and two ambient displays. The first ambient display is a two-layered vinyl bracelet containing five buttons with embedded lights (see figure 1a). Each button represents a patient under the nurse's care. The lights turn on when a patient is executing an activity, when particular actions occur, or after a series of events take place. Nurses can press the button to consult information associated to the activity a particular patient is executing. This information is shown by the ADL assistant that runs on the nurse's smartphone (see figure 1b) –the second ambient display. Nurses can also use the ADL assistant to assign priorities by selecting colors (figure 1c) or to set contextual information to act as a trigger for the activities being monitored (figure 1d). To notify patient's urine habits the mobile ADL Monitor uses the WeightScale. The WeightScale is a sentient artifact attached to the urine bag and measures its weight.

Figure 1. The mobile ADL Monitor. (a) A nurse uses the bracelet; (b) the mobile ADL assistant shows information related to an activity being executed by a patient; (c) a nurse uses her smartphone to configure the bracelet; and (d) a nurse associates contextual information with an activity.

Going back to our scenario: Rita uses ADL assistant in her smart phone to specify that the light representing Pedro in her bracelet should turn yellow when Pedro evacuates, and red if he evacuates more than five times in six hours (Figure 1d).

Later, while Rita is preparing medicines, Pedro's light turns yellow. Rita presses the button, and her smart phone indicates what Pedro is doing (Figure 1b). Rita learns that Pedro has urinated approximately 10 milliliters (this information is calculated though the weight sensor attached to Pedro's urine bag). Rita goes to Pedro's room to update his liquid balance.

Throughout the night, Pedro's light in Rita's bracelet constantly turns yellow. A couple of hours later, while Rita is talking to Dr. Perez, her bracelet turns red. Rita consults her smart phone and realizes that Pedro has urinated seven times in six hours. She discusses this with Dr. Perez, who then decides to change Pedro's medication to avoid damaging the new kidney.

The system uses a client-server architecture as a basis for its implementation. When a nurse presses a button on the bracelet, a message is sent back to the server, specifying a patient and bracelet ID. This ID is used by the server to determine which patients' status should be displayed on which smart phone. We developed our own components to communicate the bracelet with the server. A transmitter is responsible for sending and receiving messages from the bracelet at frequencies under 27 Mhz. This transmitter is internally connected to the CPU and embeds a receptor circuit that manages the radioelectrical signals from the bracelet and translates them into pulses. In contrast, the bracelet has embedded a receptor circuit that converts radioelectrical signals into electrical pulses. In the following lines we described how the components work to support the services just described.

Providing Perceptible and Silent Awareness

The idea of this service is to adequately manage how the information will be presented to the user. An ambient display that changes too fast can distract the user whiles a display that changes too slowly can pass unnoticed (Johan et al., 2000). To balance this tradeoff, the mobile ADL Monitor modulates the information shown to the user. While the bracelet only displays the status of a patient and his identity, the smartphone shows more information, such as the quantity and frequency of urine outputs. This will allow a nurse to explicitly extend the information shown by the bracelet with the one shown in the smartphone binding both displays while unrestricting their usefulness by presenting just enough information –how much a patient has urinated.

Enabling Simple, Effortless and Seamless Interaction

Users should be able to interact with the display implicitly and naturally. Users do not have previous experience interacting with ambient displays; hence they should be intuitive. The mobile ADL Monitor uses colors analogous to a traffic light adapted from the medical model used in the emergency unit. This allows nurses to naturally discover the emergency state of a patient. In addition, nurses can press the button that represents each patient to consult more information of the state of a patient. Therefore, by embedding a light in each button of the bracelet we are extending the capabilities of an artifact without altering the traditional means of interaction with it. This will result in a reduction of the cognitive load by learning how displays work and increasing the amount of attention on content (Gross, 2003).

Enabling Unobtrusive Information Sensing

The mobile ADL Monitor requires to monitor the weight of a urine bag wore by a patient. For this, we developed a sentient artifact that measures the amount of urine in a bag and communicates this information wirelessly through a mote –the weightScale. This weightScale is attached to a urine bag wore by a patient allowing thus an unnoticeable sensing. The weightScale is made of two acrylic pieces which are separated through a spring and a push button. We calibrated the required separation between both pieces. When the urine reaches a threshold (i.e., when the urine has filled 80% of the urine bag) the button is pressed. Once the button gets pressed, the sensor generates an electronic pulse. This pulse is read by the mote that is responsible for the transmission of this information wirelessly. When the bag is replaced the button goes back to its normal position. We use motes to avoid saturating the rooms with wires that could be obtrusive to nurses and patients.

To evaluate the ADL Monitor we interviewed seven nurses, each for 30 to 60 minutes, to evaluate the bracelet's design, the system's core characteristics, the nurses' intention to use the system, and their perception of system utility. All seven nurses indicated that the bracelet will help them save time, avoid errors, and increase the quality of attention given to patients. One nurse commented,

> *this bracelet will improve the quality of attention. The work will be the same, but I will do [it] faster. ... For instance, if a patient has evacuated ... I would promptly know the patient needs and I [could] take with me the things that I would need.*

In addition, nurses noticed that the system will help them prioritize events and patients:

> *Something that we currently cannot do is identify which patient has to be attended first; a system like this one [would] help me identify the urgency with which each of my patients needs to be attended.*

Overall, the staff viewed the application as useful, efficient, and generally appealing. Nurses repeatedly expressed that this system would solve many of the problems they face and improve their work, saying that it directly assists with "patient care" rather than merely supporting "secondary tasks," as they say current systems do. Nurses validated both scenarios and provided us with additional insights and opportunities for applying our technology. For instance, nurses explained that they are used to have the technology directly attached to the patient to avoid problems and errors. Nurses explained that having the information in the smart phone might cause problems, because they might confuse the patient they are attending with another one. For instance a nurse explained:

I prefer for the bracelet to only function as an indicator, rather than consulting the information of the patient in my cell phone I would prefer to consult this information in the room of the patient. In this case I would be sure that the problem I am handling corresponds to such patient.

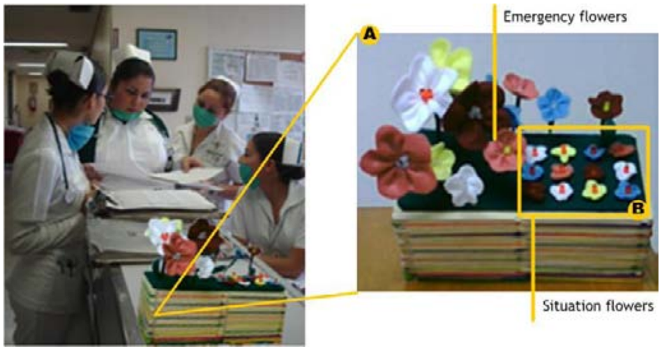
Indeed, fixed monitoring systems that allow patients to place a call to a nurse at the nurse pavilion have been successfully adopted in hospitals. What we need is to allow our sentient display to be seamlessly integrated with fixed monitoring systems.

THE FLOWERBLINK: A FIXED SENTIENT DISPLAY

In this section we describe a fixed sentient display that notifies nurses the patients' urine outputs and the status of their urine bag to be integrated with the ADL Monitor–the Flower Blink (Segura et al., 2008). The FlowerBlink is a wooden box containing twenty four artificial flowers: twelve emergency flowers with stems and twelve situation stemless flowers (Figure 2). The flowers are composed of a two-layered felt that enclose pistils covered with insulating tape. In each pistil a red or yellow led is embedded. The emergency flowers have stems with an embedded yellow light in their pistils (Figure 2a). All emergency flowers blink whenever an event or an emergency occur with a urine bag wore by a patient –if a urine bag is full. In contrast, situation flowers are flowers without stems that have a red light embedded in their pistils. These situation flowers are arranged in a matrix to represent patients' location in the unit. Each column in the matrix represents a room while a row represents a patient's bed (Figure 2b) –each room has three beds for patients. This arrangement allows nurses to quickly discover which patients' bag is about to spill. Situation flowers turn on whenever a nurse approaches the FlowerBlink or if the emergency flowers are blinking. While emergency flowers are blinking a situation flower turns on, indicating to a nurse the location of the patient related to that event.

The FlowerBlink includes two sentient artifacts and one ambient display. The first sentient artifact is the WeightScale, described in section 4. The other sentient artifact is the PrescenceDetector that is a card carried out by a nurse that detects her presence when she is in front of the FlowerBlink. The ambient display is the flower vase with a set of flowers that display the status

Figure 2. The FlowerBlink placed in the nurse pavilion. (a) The flowers that notify of emergency events (b) The flowers that personalized their color based on the nurse's presence



of the urine bag of the patient. We embedded in the box of the ambient display a communication interface which directly controls the flowers light. When the base station receives the information, it identifies the sensor that sent it, thereby identifying the location of the patient, and then turning on the red light of the corresponding flower. We use the phidgets toolkit (Greenberg & Fitchett, 2001) to implement the FlowerBlink.

One of the main challenges in integrating the FlowerBlink and the ADL Monitor is content adaptation. Binding both sentient displays will involve choosing on which device to display the information. This decision must take into account the device capabilities and its user's context. For instance, while the FlowerBlink can show patients' status, their location, their urine bag status and their frequency of urine outputs; the bracelet is only capable of displaying patients' identity and their status. Moreover, the smartphone can show a more complex representation of content because a complex interface can be displayed in such device. Adding more information in the FlowerBlink or in the bracelet could cramp both displays confusing the user on how to use them. This mismatch between rich content and constrained devices capabilities presents a main challenge in integrating multiple sentient displays (Lum & Lau, 2002).

SUPPORTING MULTIPLE SENTIENT DISPLAYS TO MONITOR PATIENT STATUS

In this section we describe our approach to seamlessly convey patient status information to multiple sentient displays. Based on contextual information our approach: (1) selects the sentient display to be responsible for showing ambient information, (2); defines a concrete interface for the selected display; and, (3) finally, adapts the information in the target display. The concrete interface is derived from an abstract, generic user interface (Braun & Mühlhäuser, 2004; Souchon & Vanderdonckt, 2003).

This is illustrated through the following version of our scenario:

Rita uses the FlowerBlink and the ADL Monitor to supervise the frequency and quantity of Pedro's urine outputs. A sensor in the urine bag detects the presence of new liquid. At this time, Rita, the nurse responsible for monitoring the patient, approaches the nurse pavilion. Thus, the system decides to notify her through the FlowerBlink sentient display located in this area. The description of the abstract notification interface is sent to the agent that acts as a proxy for the sentient display. The agent calls its interpreter to transform the abstract interface to a concrete interface that it then sends to the FlowerBlink. Rita notices that the flower base is blinking and realizes that the information relates to one of her patients. She consults her smartphone to learn that Pedro has urinated for the third time this morning and his urine bag might soon need to be replaced. The interface in the FlowerBlink will turn all lights off as its proxy agent becomes aware that Rita has consulted the information in her smartphone.

As the scenario shows, contextual information is used by the system in two stages. First, location information is used to decide which sentient display will be the most suitable to use. Since Rita is in the nurse pavilion the FlowerBlink located there would be the best display to notify the status of her patients. Once the concrete interface is executing on the sentient display it will be adapted when it is informed that the users notices the information. In the example when the sentient display realizes that Rita has become aware of the patient status it adapts its interface by turning off the lights. The presence of another person for which the information is relevant, for instance, the head nurse, might turn the lights on again.

Figure 3 and Figure 4 show the sequence diagram of the scenario. These show the main com-

Figure 3. Sequence diagram of the scenario, showing how the notification is sent through the FlowerBlink

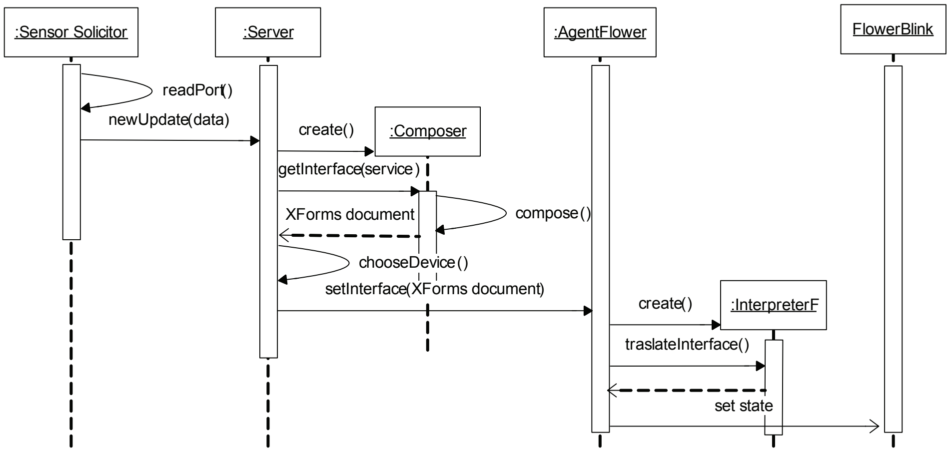
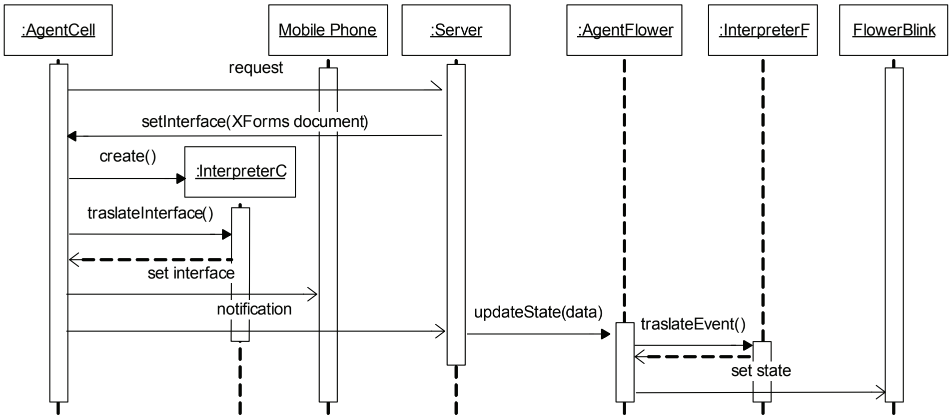


Figure 4. Sequence diagram of the scenario, showing how the FlowerBlink is turned off when its Agent becomes aware that the nurse has consulted the information in her smartphone



ponents of the architecture, which are described next. In the architecture a Server application communicates to the different sentient displays, trough their Proxy Agents, the changes notified by the Sensor Solicitor. The Sensor Solicitor is connected to a set of sensors which update the information about the state of patients' urine bags. When a notification is about to be sent the Server requests the Composer for the generic user interface to be used to inform the patient's status (patient, disease, time, urine bag level, and so on). This interface will be interpreted for each sentient display depending of its own resources. The Server decides to notify the nurse through the FlowerBlink because she is at the nurse pavilion, thus the generic user interface is sent to the FlowerBlink Proxy Agent. This agent updates the FlowerBlink state in response to the interpretation of the generic interface given by the Proxy Agent's Interpreter. In this case, the lights are turned on, to inform that the urine bag is almost full.

When the nurse notices that the FlowerBlink is blinking, she consults her smartphone for detailed information about her patient. The smartphone's Proxy Agent requests the information to the Server. This information is delivered using the same generic interface sent to the FlowerBlink. Then, the Proxy Agent invoques its interpreter to translate it to the capabilities of the smartphone, so the Agent can render the information in the smartphone using text and images. This acts as a trigger to notify the FlowerBlink that the nurse has become aware of the patient's status, so it must turn off the lights. The Server is responsible for sending to the FlowerBlink Agent the event, which in turn is passed to the Interpreter to adapt the information in the user interface. The interpreter indicates to the FlowerBlink Proxy Agent the adaptation to be performed in the display, in this case, to turn the lights off.

The generic user interface is described using a User Interface Declarative Language because it does not assume any specific interaction modality or presentation. It captures the purpose of the interface, defining what it must do and not how. Such an approach is followed by XForms (Boyer, 2007), which can separately declare the data model, the presentation, the way of binding the data model to the display elements, as well as the actions and events.

User interface elements in XForms are abstract, so that different platforms can choose to implement them in different ways, however the purpose of the tags remains the same (Rivera & Len, 2002). Inputs and outputs, events and actions that modify data element must be translated to appropriate representations for the platform. For example, an input for FlowerBlink could be given by a sensor sensitive to the light, another example is when the data model is changed and in response the output related to this data could be represented by turning off or turning on the lights through an electric pulse. In the smartphone the output could be rendered using text and images.

The XForms document is the same for each device, in consequence an XForms interpreter is required for each platform, which must implement the XForms specification, but for the purpose of the application it only needs to implement the elements of XForms that are used. In addition, the interpreter for the FlowerBlink needs to consider two cases, first it must select just the output related to the data element needed to display, in this case the amount of urine in the bag, and in the second case the amount of urine in the bag at three state alerts depending on a predefined threshold. This kind of consideration goes beyond the XForms specification, since this is specific to the application and platform. For the cell phone it is possible to display all the data in the model.

The XForms composer defines the abstract user interface in an XForms document, it contains the information related to the patient defined in the data model, an XML structure, the generic outputs bind to the data model, and the actions to perform adaptations in the data model and the user interface. All possible adaptations that data model or interface may suffer in function of the context must be considered, so the events and actions related to these adaptations must be defined in the abstract user interface. The Server must notify updates on relevant contextual information so the adaptation defined for these updates could be realized in the concrete user interface.

CONCLUSION AND FUTURE WORK

In this article, we discuss the concept of sentient displays in support of hospital work and a context-aware approach for content adaptation. We show that sentient displays are capable of becoming aware of users' context and then present continuous and expressive information in a subtle and unobtrusive way. We show that a combination of mobile and fixed displays enables a hospital smart environment to provide the type of awareness hospital workers need to promptly identify patient' needs, save time and avoid errors. We discuss that contextual information allows an

AmI environment to automatically choose the adequate sentient artifact to display information according to users' needs.

We plan to conduct an in situ evaluation of the displays developed to assess their impact within the hospital. In addition, we plan to explore a new setting where this type of technology could be useful –in particular, in nursing homes. Workers at nursing homes specialized in the care of elders with cognitive disabilities face working conditions that are similar to those in hospitals. Such workers also use common strategies to monitor patients' status. This monitoring is done manually, making it time consuming and error prone. This is another healthcare scenario in which sentient displays can prove useful.

ACKNOWLEDGMENT

This work was partially funded by CONACYT through scholarships provided to Monica Tentori, Daniela Segura and Gustavo Berzunza.

REFERENCES

Abowd, G., & Mynatt, E. (2002). The humen experience. IEEE Pervasive, 1(1), 48-57.

Addlesee, M., Curwen, R., Hodges, S., Newman, J., Steggles, P., Ward, A., et al. (2001). Implementing a sentient computing system. IEE Computer, 34(8), 50 - 56.

Boyer, J. (2007). Xforms 1.0 (third edition). Http://www.W3.Org/tr/2007/rec-xforms-20071029/.

Braun, E., & Mühlhäuser, M. (2004, May 25-28). Extending xml uidls for multidevice scenarios. Paper presented at the Workshop on Developing User Interfaces with XML of the Advanced Visual Interfaces Conference, Gallipoli, Italy.

Greenberg, S., & Fitchett, C. (2001, November 11-14). Phidgets: Easy development of physical interfaces through physical widgets. Paper presented at the 14th annual ACM symposium on User interface software and technology, Orlando, Florida.

Gross, T. (2003, June 22-27). Ambient interfaces: Design challenges and recommendation. Paper presented at the International Conference on Human-Computer Interaction, Crete, Greece.

Hopper, A. (1999). The cliord paterson lecture: Sentient computing. Philosophical Transactions of the Royal Society of London, 358(1773), 2349-2358.

Ishii, H., Wisneski, C., Brave, S., Dahley, A., Gorbet, M., Ullmer, B., et al. (1998). Ambientroom: Integrating ambient media with architectural space. Paper presented at the Conference on Human Factors in Computing Systems (CHI), Los Angeles, US.

Johan, R., Skog, T., & Hallnäs, L. (2000, January 22-24). Informative art: Using amplified artworks as information displays. Paper presented at the Designing augmented reality environments, Elsinore, Denmark.

López de Ipiña, D., & Lai Lo, S. (2001, September 17-19, 2001). Sentient computing for everyone. Paper presented at the The Third International Working Conference on New Developments in Distributed Applications and Interoperable Systems, Krakóow, Poland.

Lum, W., & Lau, F. (2002). A context-aware decision engine for content adaptation. IEEE Pervasive Computing, 1(3), 41-49.

Lund, A., & Wilberg, M. (2007). Ambient displays beyond conventions. Paper presented at the British HCI Group Annual Conference.

Mankoff, J., Dey, A. K., Hsieh, G., Kientz, J., Lederer, S., & Ames, M. (2003). Heuristic evaluation of ambient displays. Paper presented at the Conference on Human Factors in Computing Systems, Lauderdale, Florida, USA.

Moran, E. B., Tentori, M., González, V. M., Martinez-Garcia, A. I., & Favela, J. (2006). Mobility in hospital work: Towards a pervasive computing hospital environment. International Journal of Electronic Healthcare, 3(1), 72-89.

Rivera, J., & Len, T. (2002). Get ready for xforms. Http://www.Ibm.Com/developerworks/xml/library/x-xforms/.

Segura, D., Favela, J., & Tentori, M. (2008). Sentient displays in support of hospital work. Paper presented at the UCAMI, Salamanca, Spain.

Shadbolt, N. (2003). Ambient intelligence. IEEE Intelligent Systems, 18(2), 2-3.

Smith, K. S., & Ziel, S. E. (1997). Nurses' duty to monitor patients and inform physicians. AORN Journal, 1(2), 235-238.

Souchon, N., & Vanderdonckt, J. (2003, June 4-6). A review of xml-compliant user interface description languages. Paper presented at the International Conference on Design, Specification, and Verification of Interactive Systems, Funchal, Portugal.

Tentori, M., & Favela, J. (2008). Activity-aware computing for healthcare. IEEE Pervasive Computing, 7(2), 51-57.

Weiser, M., & Brown, J. S. (1995). Designing calm technology. PowerGrid, 1(1), 10.

Werb, J., & Lanzl, C. (1998). Designing a positioning system for finding things and people indoors. IEEE Spectrum, 35(9), 71-78.

This work was previously published in International Journal of Ambient Computing and Intelligence, Vol. 1, Issue 1, edited by K. Curran, pp. 27-38, copyright 2009 by IGI Publishing (an imprint of IGI Global).

Chapter 8.6

Support for Medication Safety and Compliance in Smart Home Environments

José M. Reyes Álamo
Iowa State University, USA

Hen-I Yang
Iowa State University, USA

Ryan Babbitt
Iowa State University, USA

Johnny Wong
Iowa State University, USA

Carl Chang
Iowa State University, USA

ABSTRACT

The rapid pace of new medications introduced to the market and the trend of modern healthcare towards specialization complicates doctors' prescribing process and patients' management of medications, resulting in an increase in the likelihood of unsafe prescriptions. The severity of this problem is magnified when patients require multiple medications or have cognitive impairments. The Medicine Information Support System (MISS) is designed to integrate related information systems from doctor offices, pharmacies and patients' smart homes with a universal database of medication conflicts to enable safety checks for adverse reactions among prescribed medications. MISS enhances the quality of patients' healthcare by monitoring and promoting the compliance of patients' medication intake. It also ensures patients' medical records remain private by following the privacy guidelines and regulations such as the Health Information Portability and Accountability Act (HIPAA) law in the United States.

INTRODUCTION

A Smart Home (SH) integrates and networks different technologies to provide assistance with activities of daily living. SHs, especially those designed for the elderly and persons with special needs, have gained importance as a research subject in the last few years as the baby boomer generation reaches the retirement age and begins to experience the need for assistance (Noury et al., 2003). One of the primary needs of this population is assistance in managing medications, which can be challenging due to complicated medication names, multiple simultaneous medications, or medications with differing types of dosing instructions. Two extremely important facets of medication management are the detection of possible conflicts among medications and compliance with prescriptions.

The Medicine Information Support System (MISS) presents a smart home-based solution to integrating doctor offices, pharmacies and a patient's home to assist patients in managing their medications (Reyes Álamo et al., 2008). It supports the safety of prescriptions by checking at multiple times for conflicts between medications, health conditions and foods that a patient may consume. It forwards prescription data from doctors, pharmacies, and smart home if no conflict in found and provides the mechanism for enhancing compliance with medication intake. More details of this process will be described in the following sections.

MISS is designed to transparently wrap around existing computer systems in doctors' offices, pharmacies and smart homes using Web Services (WS) to provide interoperability via standard communication interfaces. The section on system requirements and design architecture provides a detailed view of the interactions between different subsystems, as well as the data they exchange.

Additionally, because proper medication management is critical to patients' well being, a medication management system must be error free and capable of detecting various types of medication conflicts. The section on system model demonstrates the correctness of MISS. Additionally, since prescriptions and health conditions are personal health information, using telemedicine for the storage, use, and disclosure of this information between systems presents potential threats to patient privacy. As a result, privacy regulations such as the Office for Civil Rights (OCR) HIPAA (OCR, 2009) must be incorporated into the requirements and design of MISS to provide proper privacy protection for patients.

The rest of the paper is organized as follows:- the requirements, design, and detailed architecture of MISS are presented after a discussion of related work. We then describe a system model for conflict checking and compliance monitoring and illustrate MISS's prototype implementation. The last section of the paper summarizes the contributions of MISS and states future work.

RELATED WORK

Some previous efforts have been made to help individuals manage their prescriptions. For example, the Magic Medicine Cabinet (MMC) (Wan, 1999) is an Internet-enabled medication manager equipped with facial recognition software, Radio Frequency Identification (RFID) smart labels, and vital signs monitor and voice synthesis. The MMC generates personalized reminders, detects when a wrong medication is taken, and measures vital signs. However, no details are provided on the authors' claim that their system interacts with the patient's pharmacy, doctors and health care providers, and no safety checks are made for conflicts among medications. Our work bridges this gap by using WS to connect the patient's SH with the patient's visited doctors and pharmacies and to conduct multiple checks for medication conflicts. In New Zealand the ePharmacy system ("ePharmacy," 2009), connects the doctors and the pharmacies to facilitate medicine prescribing process and dispensing information among these parties. However, there is no mention if this information is shared with a Smart Home System.

The Smart Medicine Cabinet (SMC) (Brusey, Harrison, Floerkemeier, & Fletcher, 2003), and the Smart Box (Floerkemeier, M. Lampe, & Schoch, 2003; Siegemund & Floerkemeier, 2003) extend the Magic Medicine Cabinet by using passive RFID tags to identify medication containers and Bluetooth technology to synchronize the MMC with a patient's cellular phone. The SMC is automatically updated when the cell phone is brought within range. The major drawback of these two systems is that the patient must remember to carry the cell phone to the pharmacy as well as near the MMC. Our system presents a more user-friendly solution, especially for those with cognitive impairments, in that it does not require special user interaction or a cell phone.

Technology for automatic dispensing of pills also exists ("e-pill Medication Reminders: Pill Dispenser, Vibrating Watch, Pill Box Timer & Alarms," n.d.; Testa & Pollard, 2007), typically, manual configuration is needed to set notifications and dispensation schedules. Also, the medications have to be manually removed after a reminder is generated.

These proposed solutions certainly facilitate the task of taking medications by assisting with prescription compliance (Floerkemeier et al., 2003; Matthias Lampe & Flörkemeier, 2004), generating reminders to the patient (Szeto & Giles, 1997; Denis Vergnes, Sylvian Giroux, & Daniel Chamberland-Tremblay, 2005), and detecting missed doses. However, they do not provide a solution integrated with a patient's home system and still require significant manual input, which would be difficult for patients with cognitive impairments. This limitation is addressed in Fook et al. (2007) where a system for patients with dementia is presented. Our system is similar in making use of related technology to help patients with prescription compliance, but our work is more comprehensive as it transparently networks the smart home with existing systems in doctor offices and pharmacies thus require no manual data entry from the patients.

In addition to these systems, several software applications have been developed to assist with the medication prescribing process and the management of patients' medical records. For example the Computerized Physician Order Entry (CPOE) (Koppel et al., 2005) allows a physician to enter instructions for the treatment and communicate them to other parties such as nurses, pharmacies and laboratories. CPOE can significantly reduce medication errors and delays in process and treatments since instructions are communicated over a computer network, but this application is more targeted to health specialists. Other applications target mobile devices such as cell phones, smart phones, and PDAs ("WebMD Mobile for Apple iPhone," 2009). Nevertheless, they are intended for people familiar with these devices and do not always provide support for safety checks for conflicting medications or assistance in monitoring compliance with a prescription. Recently, many solutions have been proposed by the industry to provide electronic medical records (EMR),, such as Google Health ("Google Health," 2009), Microsoft Health Vault ("HealthVault: Home," 2009), and MediConnect (IT Strategic Projects, 2009). However, it remains to be seen if patients will be comfortable storing personal information in remote enterprise or government environments. The crucial added values provided by MISS, such as safety checking and compliance monitoring, are equally applicable whether data is stored in distributed subsystems or a centralized EMR database. Pervasive spaces like SHs can be used to assist patients in performing activities of daily living (ADL) (Helal, 2005), including the management of their medications (Reyes Álamo et al., 2008; Nugent et al., 2005; Noury et al., 2003). A well integrated system should integrate all these independent solutions to provide a comprehensive management of medications.

SYSTEM REQUIREMENTS, DESIGN AND ARCHITECTURE

A successful medication management system must have a set of well defined requirements and a well planned design. The requirements and design of MISS are discussed below.

System Requirements

A step-by-step description of how a patient acquires a prescription and takes a medication reveals important system requirements. Based on our observations, obtaining a prescription usually involves the following steps:

1. The patient visits the doctor.
2. The doctor prescribes medications.
3. The patient visits the pharmacy and gets the medications.
4. The patient intakes the medications at home.

Medication intake can be further broken down into the following steps:

4.1 Wait for the next dosage time
4.2 Locate the medication container
4.3 Open the container
4.4 Extract the appropriate amount of medication
4.5 Intake the medication
4.6 Close the prescription container
4.7 Return the container to the medication cabinet

The aforementioned related work helps to automate some of these steps. For instance, the Smart Box or Smart Cabinet can automate steps 4.1 and 4.2, while automatic pill dispensers address steps 4.3 and 4.4. Cognitive impaired patients might forget when the next dosage time is (Fook et al., 2007), hence a system that automatically sets up the dosing schedule using the prescription's data, generates the reminders and notifies if a dosage is missed, will help to improve the compliance with medication intake (Nugent et al., 2005). SH can also help to locate the medications container by incorporating unique identifiers using RFID tags (Ni et al., 2004).

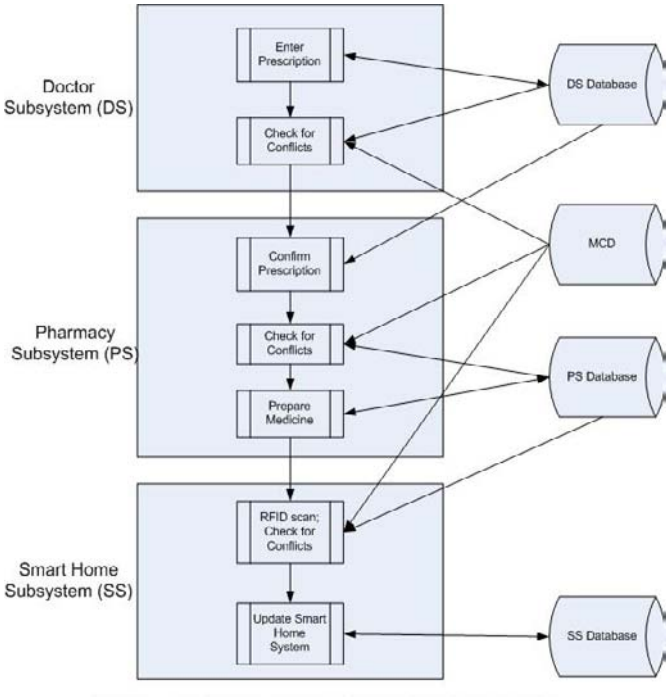
Manual entering of prescription information is often unreliable due to inexperience and frequent human error, therefore the prescription information should be entered by an expert and automatically forwarded without repeated manual entries at various locations. In MISS, prescription information is automatically forwarded between doctors, pharmacies, and homes.

Human behavior can be unpredictable, and there might be variations to the aforementioned steps when obtaining or intaking medications. The design of MISS assumes these steps are followed by most patients, and the variations will be considered as exceptions, which would likely trigger unwarranted reminders or warnings to patients, doctors or pharmacists. The next section presents the system design and operation of MISS in greater detail.

MISS Design and Architecture

MISS consists of three main subsystems: the Doctor Subsystem (DS), the Pharmacy Subsystem (PS) and the Smart Home Subsystem (SS) and four main actors: the doctor, the pharmacist, the patient, and the SH. Each subsystem is assumed to have a local database that stores information about the patient medications and medical conditions. A global medication conflict database (MCD) exists that defines all conflicts between medications, conditions, and foods. The MCD is maintained by a knowledgeable and trusted third party, and is accessed remotely by MISS without replicating the data locally. The conflict checking is executed locally at each subsystem using the data retrieved from MCD and the local patient's data. The MCD and the local databases use the same database schema and medication's data for maintaining

Figure 1. Medicine information support system diagram



consistency. Figure 1 illustrates the interactions between these actors and subsystems.

The most important use cases and actors for MISS are shown in Figure 2. The UpdateSmartHome action will be responsible for updating any subsystem that might use the medication data such as medication inventory and notifications.

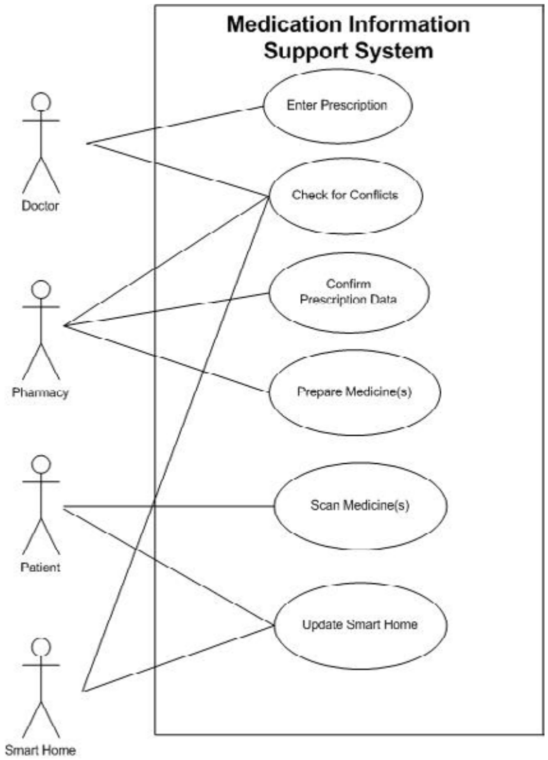
The architecture of MISS can be best presented in two tiers. The higher tier deals with the inter-subsystem communication that mimics the actual actions and interactions among patients, doctors and pharmacists. The lower tier describes the detailed structural make-up and inner operations of each subsystem.

The higher tier overview, as illustrated in Figure 3, shows that MISS includes three subsystems, DS, PS and SS which utilize the external MCD system. Each subsystem provides a human computer interface that allows interactions with users in certain role, and a system interface implemented as a WS that allows communications between subsystems.

Doctor's Subsystem (DS)

The primary owner and user of DS (Figure 4) is the doctor who after each medical examination enters any new condition c and any newly prescribed medication m into the system as needed. MISS assists the prescribing process by identifying the conflicts among new conditions and medications, helping the doctor to make better decisions. The DS uses the patient's local medical record of previous prescriptions M and the current health conditions C to determine possible conflicts and adverse side effects. The list of side effects and possible conflicts for a given medication can be retrieved from the common database, known here as the MCD, maintained by a trusted third party such as the Food and Drug Administration (FDA) ("U.S. Food and Drug Administration (FDA)," 2009), or the Physician's Desk Reference (PDR) ("The Physicians' Desk Reference (PDR)," 2009). To check for conflicts the system sends anonymized c, m, from DS to MCD, receives the conflict

Figure 2. Use cases and actors



information and checks that against the patient's M and C. If no conflicts with the new prescription are found, the prescription information is then stored into the local database. This conflict-free prescription will then, depending on the patient's preference, either be pushed immediately to the patient's selected pharmacy or pulled by the pharmacy the patient visits later. If conflicts are found, a notification is sent to the doctor, along with suggestions on alternatives.

If the data is forwarded to a preferred pharmacy, each patient must be associated with a unique ID that's shared between the DS and the PS. Using the ID, DS will check its local database for conflicts with the new prescription. If no conflict is found, the prescription's data is forwarded to the patient's preferred pharmacy through a secure channel. The doctor's office will also issue a customized printed-RFID prescription which will be used later by the pharmacy subsystem.

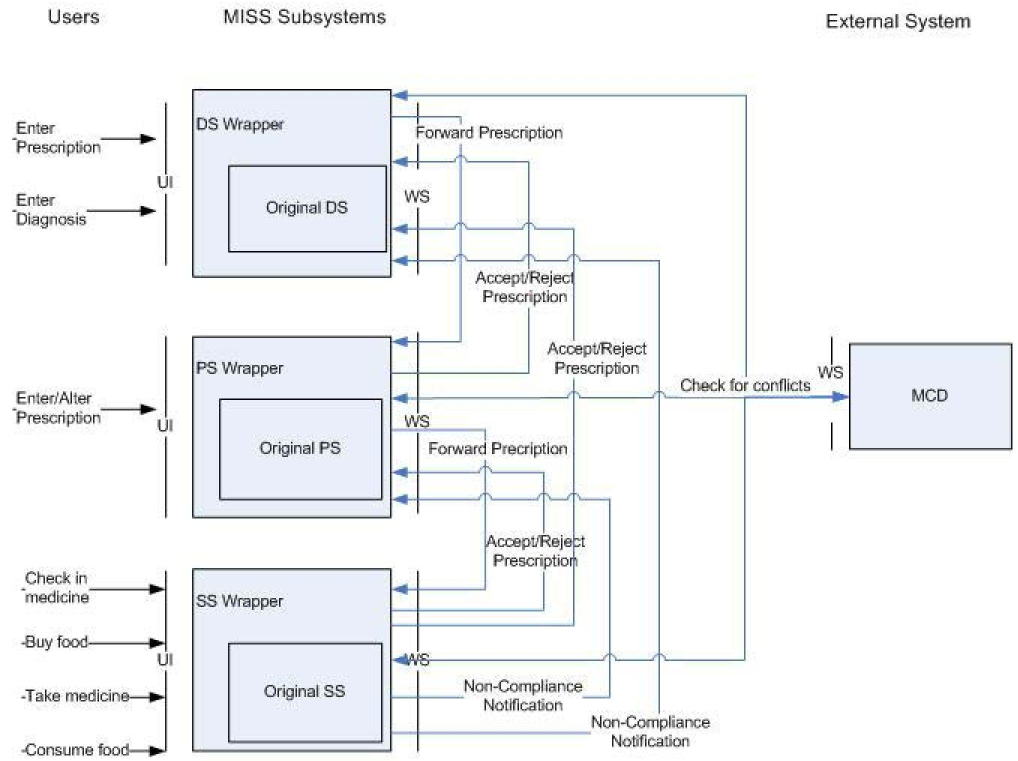
If the patient chooses a pharmacy later, the process is almost identical except the timing of when the data arrives at the pharmacy. Instead of arriving immediately, the data will be transferred only after the patient arrives at the pharmacy and the pharmacist requests the prescription information from the doctor's office.

The Pharmacy Subsystem (PS)

There are two possible starting scenarios for the PS: when the patient specifies the preferred pharmacy at the doctor's office or when the patient chooses the pharmacy later. In either case, once the new prescription information arrives at the pharmacy (Figure 5), the PS retrieves the patient's locally stored prescriptions and conditions, and checks for possible conflicts with the MCD.

In the first scenario, the pharmacy receives the prescription's data over a secure channel when the patient is still at the doctor's office, allowing

Figure 3. Communications between ISS subsystems and MCD

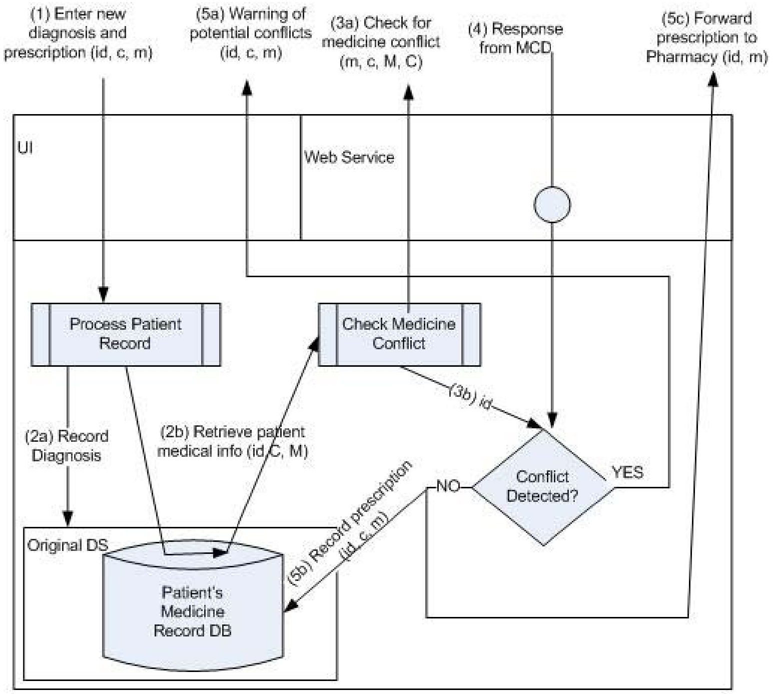


the pharmacist to start preparing the prescription before the patient arrives. The prescription is checked for conflicts with other medications that have been recently filled for the patient, similar to the check performed at the DS. However, this additional check is necessary since the patient might be receiving prescriptions from different doctors and filling them in the same pharmacy. Once the new prescription is cleared of conflicts, the pharmacist would prepare the drugs, while PS returns with a confirmation to DS and forwards the prescription's data to SS. If a conflict is found, a notification is sent to the pharmacist who might contact the doctor or take other appropriate measures. If no conflicts are found, the medication will be issued in special RFID-enabled containers that will allow the system to uniquely identify the medication in them.

In the second scenario, the patient arrives at a pharmacy with a printed-RFID prescription. The RFID prescription is given to the pharmacist as if it is a regular prescription. It is scanned and the prescription data is pulled at that moment from the doctor's office. A check for conflicts is performed between this new prescription and previous medication picked up at the pharmacy. If no conflict is found with the new prescription, the medication is dispatched into an RFID-enabled container; otherwise, both the pharmacist and doctor are notified.

The waiting time at the pharmacy can be reduced if the prescription data is forwarded ahead of the patient's arrival. This is very important to the seniors who might need their medications urgently or want to avoid long lines or repetitive trips to the pharmacy. Another benefit of our system is the extra layer of safety by checking for conflicting medications using the pharmacy's local data.

Figure 4. Doctor subsystems

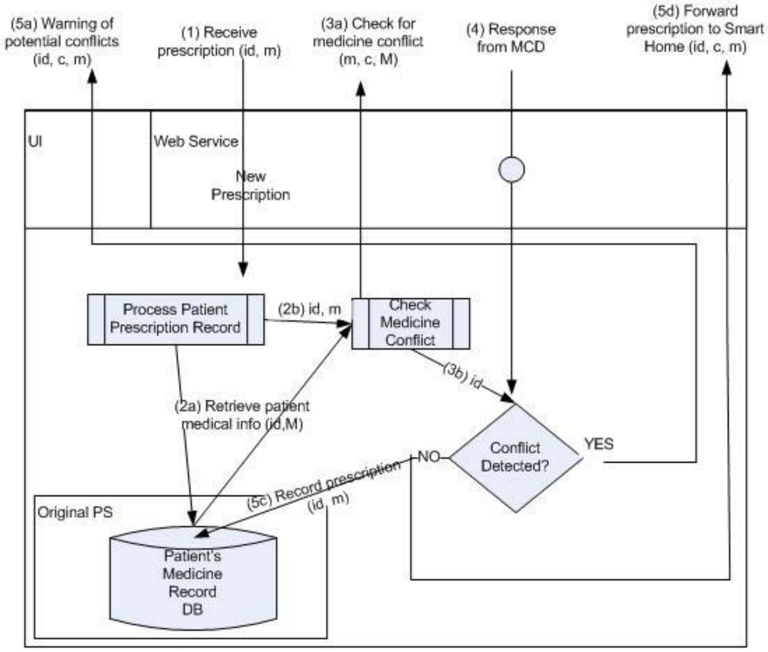


The Smart Home Subsystem (SS)

When the patient returns to the SH with the RFID-enabled prescription in hand, the local SS database is updated by scanning the prescription container with the RFID reader. A long range RFID reader, will allow the RFID tags be read automatically once the patient is within range, requiring no manual effort (Want, 2004). After scanning, prescription's data can be retrieved from the pharmacy via a secure communication channel. After the data is received, a final check for conflicts between the new prescription and current medications, health conditions, and foods in the home will take place. This third checking is necessary to detect conflicts of prescriptions filled at different pharmacies. Also, we assume the SS maintains a food inventory. Since this information is available only at home, this checking has to take place at home. If a medication conflict or health condition conflict is found, the appropriate parties are notified. Otherwise, the medications are placed in a SMC or loaded into an automatic medication dispenser and the patient will be notified of any potential food conflicts. Figures 6-8 describe the interactions within the SS. Figure 8 also describes the conflict triggered when a food item is consumed or brought into the Smart Home.

In addition to checking for the safety of a new prescription, we want ensure that the patients comply with the doctor's instructions by taking the proper dosage of each medication at the designated time. A patient's compliance with a given prescription can be evaluated based on two factors: timeliness and completeness. Timeliness determines whether the medications are taken at the correct time, and completeness defines whether the correct dosage is taken. Formal definitions of the timeliness and completeness are presented later with the system model, which is followed with a description of how the context information

Figure 5. Pharmacy subsystem



(Gu, Pung, & Zhang, 2004) and the notification services (Reyes Álamo, Sarkar, & Wong, 2008) in a smart home can be used to assist with prescription compliance.

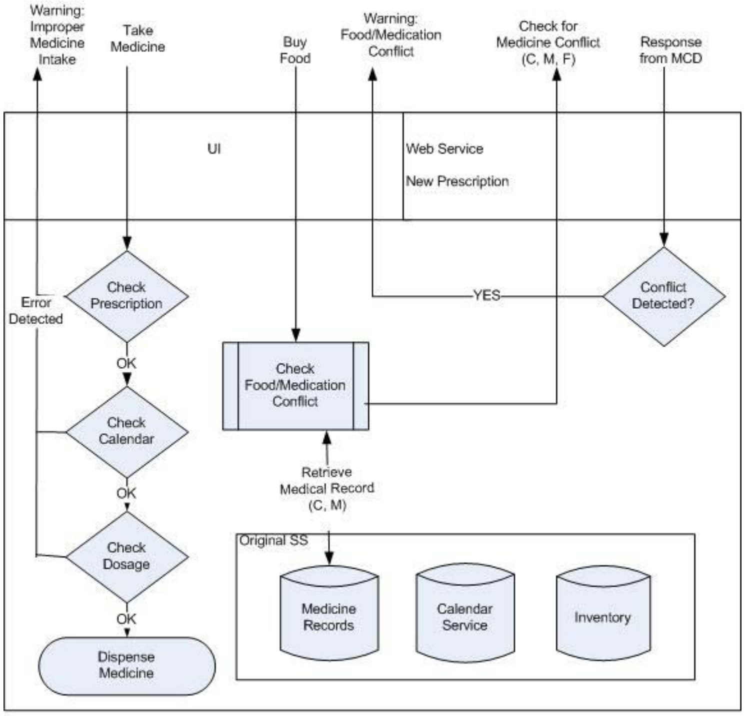
Interoperability by Using Web Services

MISS is intended to be an extension of the existing DS and PS, not a replacement, and one of our primary goals is to maximize the interoperability between existing systems. Since most doctors' offices and pharmacies already have some kind of computer systems to perform their daily functions and their respective employees are comfortable and accustomed to using these systems, it is essential that MISS works with different existing systems. Also the prescription information is sensitive data which should be shared only among doctors or pharmacies with proper authorization from the patient (OCR, 2009). It is necessary to use secure communication mechanism among subsystems for data transfer. WS can provide this secure communication as well as interoperability, since they are platform and language independent and network friendly and secure (Papazoglou & Dubray, 2004). Each subsystem will provide secure WS to allow communication with other subsystems in an efficient and secure way. Our system architecture achieves interoperability by encompassing existing systems with wrappers, and uses WS as the universal interface for secure communication between subsystems.

Designing for Privacy

Because MISS stores, uses, and discloses personal health information, it is mandatory that patients' concerns about the privacy of their data as well as related privacy legislation such as the Health Information Portability and Accountability Act (HIPAA) (Hodge, Gostin, & Jacobson, 1999; OCR, 2009) should govern its design and operation. To demonstrate how this is the case, we identify the potentially problematic aspects of MISS from a privacy perspective and show case by case that our design is in line with the

Figure 6 Smart home subsystem



corresponding HIPAA requirements. There are essentially four high-level problem areas (PA) that HIPAA addresses:

- **PA1:** The access and use of Protected Health Information (PHI) by employees within a health system or health information database
- **PA2:** The disclosure of PHI to other systems and health service providers
- **PA3:** The ability of the individual to access and amend PHI
- **PA4:** The ability of the individual (or a governing body) to audit the uses and disclosure of PHI including the management of individual consent

Since MISS essentially wraps WS around existing doctor, pharmacy, and smart home systems and uses a MCD, it is the disclosure of PHI among these systems (PA2) that is of primary concern. Implementing appropriate access control policies and other data security safeguards (PA1) are the responsibilities of each individual doctor and pharmacy systems and not of the MISS framework proper. If these systems correctly provide these mechanisms, then we can assume that only authenticated and authorized doctors and pharmacists can access PHI in their respective systems. Similarly, it is the responsibility of the original systems to provide access, amendment, and audit mechanisms that individuals can use to check, correct, and challenge the uses and disclosures of their PHI (PA3 and PA4). If these mechanisms are in place, then MISS can also wrap them with WS in a way that preserves the functionality of the original mechanisms but provides the interoperability and universal access of WS. The cases in which health information is sent between subsystems are 1) the transfer of information from doctor to pharmacy, 2) from pharmacy to doctor, 3) from doctor to home, and 4) from three systems to the conflict detection service.

Figure 7. Smart home subsystem 2

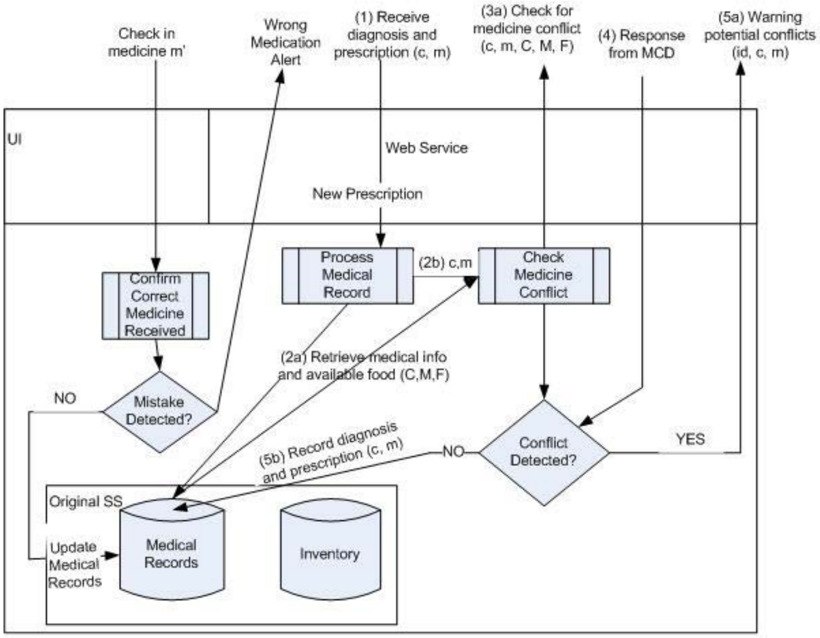
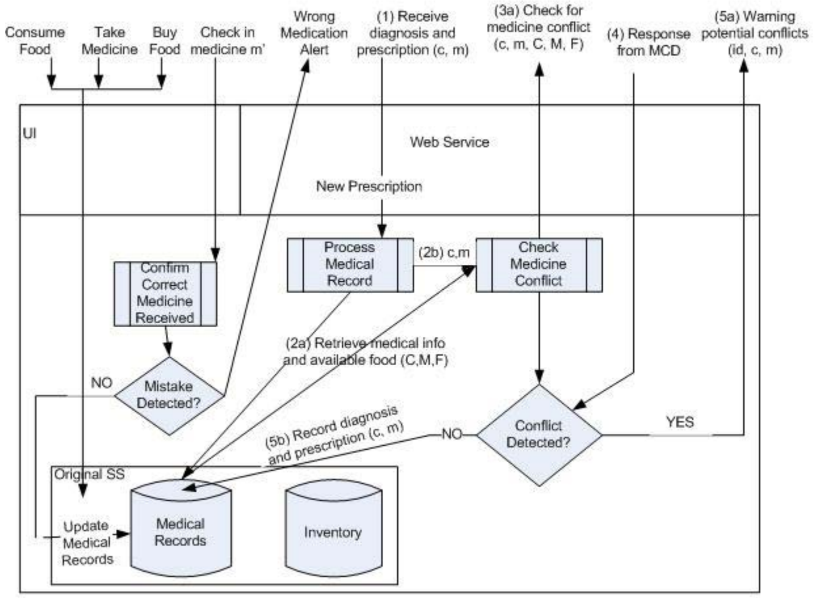


Figure 8. Smart home subsystem 3



Case 1: DS Disclosure to PS

HIPAA permits the disclosure of PHI to other health care services providers if they have a previously established relationship with the individual and the disclosed information is necessary to that relationship. This rule applies to the transfer of prescription information from a doctor system to a pharmacy system as an identifier is transferred along with the prescription information. However, since the individual has chosen the pharmacy to which the identifier and prescription are routed, it follows that the necessary relationship between pharmacy and individual must exist. Also, the use of secure WS as a communication channel will protect this information in transit.

Case 2: PS Disclosure to DS

The reply from the PS to the DS when a conflict is found also leaks some information back to the DS because the presence of a conflict allows doctors at the DS to infer what the medication causing the conflict may be. Of course, the strength of this inference depends on the number medicines the patient has been prescribed by that doctor and the number of potentially conflicting medicines. However, this information flows between healthcare providers that have an existing relationship with the patient, and secure WS protects this information in transit.

Case 3: DS/PS Disclosure to the SS

The third case in which PHI is disclosed is from either the doctor or pharmacy subsystem to the home subsystem following the diagnosis of a new condition. However, because the home subsystem is viewed as a trusted representative for the individual, it follows that the doctor subsystem should be permitted to disclose this information to the home. Moreover, this information does not contain personal identifiers. On the other hand, since the doctor subsystem is communicating with an individual home subsystem (i.e. the home of a particular patient), the communication could be reasonably used to identify the individual if the destination of the messages were known. Therefore, secure WS is also required here to prevent information from leaking to eavesdroppers.

Case 4: DS/PS/SS to MCD

The fact that the doctor, pharmacy, and home subsystems submit medical information to the global conflict detection service also pertains to privacy. However, because both the doctor and pharmacy submit completely de-identified health information (only medication and health conditions) for conflict detection and de-identified information is returned by this service, there is no privacy risk inherent to these communications. On the other hand, the invocation of the conflict detection service by the home system does pose a privacy threat according to HIPAA. The fact that the request is coming from a system operating on behalf of an individual could allow the owners of the conflict checking service to identify on whose behalf the service request was made, thus linking the medication or condition to the individual. The MISS framework mitigates this situation with two security mechanisms. First, encrypted communication is done between the home system and conflict detection service, preventing eavesdropping. Secondly, a trusted anonymizing proxy is used by the home system to aggregate web traffic from multiple sources, sufficiently decreasing the likelihood that such information can be attributed to the originating individual.

SYSTEM MODELING

This section contains a model of the medication management system to further define and examine conflict detection and prescription compliance with different types of prescriptions.

Model the MCD

A medication management system must be accurate, reliable and provide safety by detecting conflicts that a new prescription may cause because of the interaction with other medications, health conditions, or foods. The trusted MCD defines the conflicts over the set of medications M, a set of food F, and the set of health conditions C using several functions over the set of medications. We define the Medication System Model as follows:

Definition

We define the Medication System Model as follows:

- M, the set of medications
- C, the set of medical conditions
- F, the set of foods
- D, the set of doctors, hospitals or clinics the patient may visit
- P, the set of pharmacies where the patient may get prescriptions filled
- H, the patient's Smart Home

Denoting the power set of X as P(X), we define the following functions maintained at the MCD:

- conflicting_medications: $M \rightarrow P(M)$
- conflicting_conditions: $M \rightarrow P(C)$
- conflicting_food: $M \rightarrow P(F)$

Where the function conflicting_medications: $M \rightarrow P(M)$ returns the set of medications that conflict with a given medication, the function conflicting_conditions: $M \rightarrow P(C)$ returns the set of health conditions that conflict with a given medication, and the function conflicting_food: $M \rightarrow P(F)$ returns the set of foods that conflict with a given medication.

A patient p is represented by a tuple p = (id, Mp, Cp, Fp, CMp, CFp, CCp). The id field uniquely identifies the patient, and $Mp \subseteq M$, $Cp \subseteq C$, $Fp \subseteq F$ be the subset of medications currently prescribed to patient p, the health conditions diagnosed to patient p, and the foods patient p has available in the smart house, respectively. The sets of medicines, conditions, and foods that are unsafe for patient p can be defined as follows:

$CMp = \bigcup_{m \in Mp}$ conflicting_medications(m)

represents the set of medications that conflicts with the medications prescribed to patient p,

- $CCp = \bigcup_{m \in Mp}$ conflicting_conditions(m) be the set of medical conditions that conflicts with the patient's medications.
- $CFp = \bigcup_{m \in Mp}$ conflicting_food(m) be the set of food that conflicts with the patient's medications.

These sets provide information to doctors when prescribing medications for a new or existing health condition. Given a newly prescribed medication m to patient p, the MCD is queried to determine what conflicts with m, and returns the results of applying the three conflict functions to m. If we let the sets of potential conflicts of the new medication m be

CM = conflicting_medications(m),
CC = conflicting_conditions(m),
and CF = conflicting_food(m),
respectively, m can be determined to be a safe medication if

1. $CM \cap Mp = \emptyset$ and $m \cap CMp = \emptyset$
    - None of p's current medications conflict with the new medication and the new medication does not conflict with any of p's current medications and

2. $CC \cap Cp = ø$
   - The new medication does not conflict with any of the conditions that patient p has) and
3. $CF \cap Fp = ø$
   - The new medication does not conflict with any of patient p's food

Conflict Checking

Each MISS subsystem (DS, PS, or SS) checks for conflicts with almost the same algorithm, but each subsystem is expected to capture a different set of conflicts because of differences in the data stored in the local databases. For example, the doctor and pharmacy subsystems focus on detecting conflicts among medicines and health conditions while the Smart Home focuses on conflicts among medications and foods. The generalized conflict checking algorithm and supporting functions are defined as follows:

Definition: Get_Data (GD)

```
Input: Prescription $r = (p, m)$

//Get patient's p data from the local database
Query Mp, Cp, Fp, CMp, CCp, CFp

//Get medication m conflicting data from the global database
Compute CM, CF, CC
```

Definition: Conflict_Checking (CC)

```
Input: Prescription $r = (p, m)$

Call Get_Data (r)
If ($CM \cap Mp = ø$ and $m \cap CMp = ø$)
    If ($CC \cap Cp = ø$)
        If ($CF \cap Fp = ø$)
            //No conflict found
            $CMp = CMp \cup CM$
            $CCp = CCp \cup CC$
            $CFp = CFp \cup CF$
        Else
            Medication m creates food conflict
    Else
        Medication m creates a health condition conflict
Else
    Medication m creates a medications conflict
```

Conflict Checking at Doctor, Pharmacy and Smart Home Subsystem

In this model the DS provides a new prescription r = (p, m) that r contains the id of the patient p and the id of medication m. The DS has a local database with patient's p record. The DS does not to store information related to food, therefore the checking at DS focuses on identifying conflicts between medications and health conditions. To perform this checking, we invoke the function CC with input r. If no conflict is found then the prescription r is forwarded to the PS.

At the PS, it is assumed that the prescription r has already been checked and cleared at the DS. The PS matches the new prescription r with the patient's local record of previous prescriptions and over-the-counter medications to check for possible conflicts. This second check is necessary as the patient might have prescriptions filled from multiple doctors. Over-the-counter medications may also be obtained at pharmacies and may also cause conflicts. The checking at the PS is performed by calling function CC with input r using the pharmacy's dataset. If no conflict is detected, the prescription r is cleared and forwarded to the SS.

Once the SS receives the prescription r, SS performs a final check for conflicts using its local inventory of medications, food and records of medical conditions. This check is necessary as the patient might be having prescriptions from different doctors filled at different pharmacies. Ultimately, SS will be responsible for detecting all the conflicts not identified during previous safety checks. Figure 9 shows an example of these multiple paths of conflicts. It illustrates how a patient might be visiting different doctors and pharmacies in which case some conflicts might go undetected, but the SH can detect them. It also illustrates how conflicts can be detected early in the process as each subsystem performs a safety check.

If all three stages of safety checks are passed, then all local databases involved are updated as necessary with p's new medication and new potential conflicts.

Compliance Monitoring

There are two aspects in determining if a patient is complying with a given prescription: if the right medication is being taken in the right dose and if it is being taken at the right time (Sarriff et al., 1992). We call the former requirement completeness and the latter as timeliness. For completeness monitoring, we currently make the assumption that the smart home has the capability to determine if a correct dose of medication was taken. This is not an unreasonable assumption if automatic dispensers are used to distribute the correct dose of medication and patients can be trusted to take all of the medication given to them. On the other hand, timeliness proves to be a much more complicated issue.

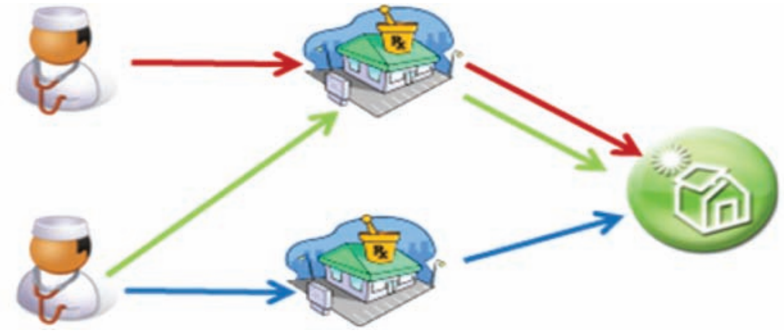
Different medications often come with different types of intake instructions requiring a medication management system to keep track of which medicines should be taken and when. For this paper, we study the three common categories of prescription instructions (Mazzullo, Lasagna, & Griner, 1974) listed below:

1. Do not take more than dosage d within time interval t
2. Take dosage d every time interval t
3. Take dosage d before (or after) activity a

In the following discussions on timeliness, it is assumed that the system has the capability to detect when medications are taken and deduce related context information about the patient such as if the patient has recently had a meal or is in the process of going to bed. It is also assumed that the system is able to dispense medications and is able to notify patients and doctors based on prescription instructions and a patient's intake actions.

For the first category of prescription instructions ("do not take more than dosage d within time interval t"), we need to keep track of the amount and time of medication intake. To monitor this condition, we use the common concept of a sliding window to create a Prescription Sliding Window (PSW) that continuously tracks the amount of the given medication taken in a given time period as follows. When a patient intakes a medication, the system generates an intake event e that consists of

Figure 9. Multiple paths of conflicts



the medication taken m, the dosage de of m, and a timestamp te. Each time an intake event occurs, MISS looks into the PSW, which covers the events from te-t to te. If the accumulated dosage ∑de'| ∀e' such that te-t ≤ te' < te exceeds permitted dosage d, an overdose exception xod is generated and the appropriate healthcare professional notified. In the actual implementation, the SS subsystem keeps a separate PSW queue for each medication, and when an intake event occurs, the dose amount is inserted to the corresponding queue and the accumulated dosage updated. The queues are maintained in a lazy fashion, meaning that MISS does not proactively remove intake events prior to te' - t but only purges events when a new intake event occurs and the recorded events fall outside of the PSW (i.e. they are outdated).

For the second category of prescription instructions ("take dosage d every time interval t"), the patient is required to space out the medication intake by a certain interval of time. These intervals are setup when the patient intakes the medication for the first time, which we label t0. Using t0 as the starting point, the subsequent intake events tn should occur at tn = t0 + nt for n=1 to the size of the prescription. However, instead of requiring the patient to take the dose at exactly some time tn, we allow a patient to take a dose at approximately time tn, providing a little bit of flexibility for the patient. To accommodate this flexibility, we introduce the concept of timing tolerance. We define tolerance tol as, given a scheduled time te for administering a dosage, the patient should take the medication at within some time interval which deviates from te by at most tol. In other words, only medications taken within the time interval [te –tol, te + tol] would satisfy this timeliness requirement. Any medication intake outside of [tn –tol, tn + tol] would be considered a violation to the prescription instruction. For most medications, this tolerance is in the order of minutes. However, should the patient miss a medication intake in a given tolerance time interval, both the patient and the doctor are notified. When the patient then intakes the medicine the system will adjust the schedule of medication, that is, establish a new set of time intervals, based on a new time t0' when the patient takes the first dosage after missing the previous dose. When the patient takes the medication, the system monitors if the dosage dtn at time tn corresponds to the prescribed dosage d. Figure 10 shows a visual representation of these intervals.

For the third category of prescriptions ("take dosage d before (or after) activity a"), the scheduled time for a patient to take the medication

Figure 10. Timeliness intervals: Take dosage d every time interval t

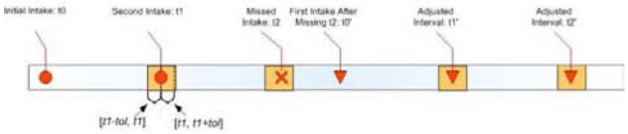
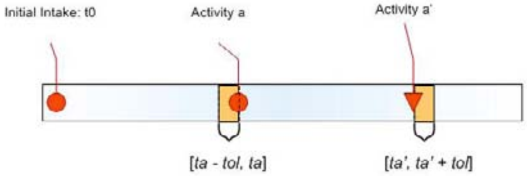


Figure 11. Timeliness intervals: Take m before activity a, take m' after activity a'



is relative to a certain activity that the patient performs, such as eating a meal or preparing for bed. We will use the same notation as in the previous discussion, assuming the patient takes the medication at time te, and the timing tolerance is tol. If the prescription instruction dictates "taking medication with dosage d before activity a," the system checks back at te + tol to see if activity a has occurred since te. On the other hand, if the medication is supposed to be taken after an activity a, the system first check if the time of occurrence ta of activity a falls into the time interval te - tol. In the former case, the system notifies the patient to take medicine if the activity of interest is detected as starting, and in the latter case, the system dispenses the medication and reminds the patient to take medication at the completion of the activity a. If the medication intake event e does not occur within the tolerance period, the patient would have violated the prescription instruction which would trigger notifications to the patient as well as the doctor. Figure 11 shows a visual representation of these intervals. In all three cases if the patient attempts to take more medicine than prescribed, takes a dosage out of schedule or miss it, the appropriate parties will be notified. The system can further impose compliance and safety by taking actions such as locking the pill dispenser to prevent an overdose.

PROTOTYPE IMPLEMENTATION

A prototype implementation of DS, PS and SS has been implemented in our SH Lab to demonstrate the feasibility of MISS. Our prototype of DS is an application that supports entering the prescription details, checks for conflicts and stores patients' record. This node forwards the data to another node that implements the basic pharmacy functionalities. The pharmacy receives the data, prepares the prescription and assigns an RFID tag to the prescription. Another node acting as the SH, queries the pharmacy using the RFID tag as the key and downloads the specific information about the prescription. A Phidget RFID reader is used to read RFID tags and identify the medications ("Phidgets Inc. - Unique and Easy to Use USB Interfaces," 2009). Different RFIDs assigned to several containers were tested to simulate a patient taking different medications. SH stores this data in its database to enable other services such as the reminder, notification and medication inventory. When a conflict is detected, the corresponding warning message is displayed and notifications are given (Reyes Álamo et al., 2008). The SS was developed as a bundle that runs in OSGi, a framework particularly suitable for SH applications (Gu et al., 2004). Our prototype implementation successfully transfers the relevant data from the DS all the way to the SS and captures all the conflicts presented in the experimentation scenarios.

To provide interoperability, WS are used to communicate among subsystems. The DS uses WS to access the third-party MCD. It also uses WS to communicate and send the data to the pharmacy. A WS is also provided so that a patient can have access to his or her record at any time with the appropriate authentication mechanism. Likewise the pharmacy makes a similar use of the WS technology. It accesses the third-party conflicts definition database via WS. It also provides a WS for the doctors to establish a connection and forward prescription data.

The SS makes use of the WS provided by the DS and the PS in order to keep a more complete record of the resident's medications and health conditions so that a final and more thorough check for conflicts can be performed at the house. The SH also has a mechanism to check for compliance with the prescription instructions. Timeliness and compliance requirements are enforced by using the prescription's data to define what to monitor, and the context information provided by the SH. When the patient is at home it is notified by giving voice reminder and pop-up windows. Text messages and emails are used to communicate with family and health care provider. Because public acceptance of RFID remains to be seen, we have also developed another version using barcodes and barcode readers.

CONCLUSION AND FUTURE WORK

Smart Homes are equipped with technology to help the elderly and persons with special needs to perform their activities of daily living, live more independently, and stay home longer. One vitally important activity of daily living is the management of medications. Several solutions have been proposed to help with medication management, but they tend to be non-networked and neglect the safety problems that arise from taking multiple medications, such as having medications interact with each other and knowing when to take each medication. This paper presents MISS, a comprehensive solution for successful medicine management that uses web services to provide interoperability among independent and existing medical systems and can detect conflicts among a patient's medications, health conditions and food intake. Because patient's preferred doctors and preferred pharmacies may vary, safety checking is enforced at multiple levels to catch more types of conflicts. We also investigate compliance with several types of prescription dosing instructions by monitoring intake actions with respect to the timeliness and completeness of each dose. Lastly, we use modeling techniques for the analysis of both the safety checking and the compliance monitoring.

This system can definitely help the patients with the management of their medication but certain limitations remain, including the need to follow the recommended steps for getting the prescriptions, the need for a universal standard medicine and food database and a more active role in error prevention. Our future work attempts to address some of these issues. A more complete integration between OSGi and WS as well as the implementation of the compliance checking routine is also in the work. We are currently applying formal techniques to further model and verify the compliance and safety of the entire system and are looking to perform a case study with medical experts to validate the usefulness of our design.

REFERENCES

Brusey, J., Harrison, M., Floerkemeier, C., & Fletcher, M. (2003, August). Reasoning about uncertainty in location identification with RFID. Paper presented at International Joint Conferences on Artificial Intelligence (IJCAI), Acapulco, Mexico.

e-pill (2009). e-pill Medication Reminders: Pill Dispenser, Vibrating Watch, Pill Box Timer & Alarms. Retrieved March 2, 2009, from http://www.epill.com/.

FDA. (2009). U.S. Food and Drug Administration Homepage. Retrieved February 17, 2009, from http://www.fda.gov/.

Floerkemeier, C., Lampe, M., & Schoch, T. (2003, September). The Smart Box Concept for Ubiquitous Computing Environments. Paper presented at International Conference On Smart homes and health Telematic (ICOST), Paris, France.

Fook, V., Tee, J., Yap, K., Phyo Wai, A., Maniyeri, J., Jit, B., et al. (2007, June). Smart Mote-Based Medical System for Monitoring and Handling Medication Among Persons with Dementia. Paper presented at International Conference On Smart homes and health Telematic (ICOST), Nara, Japan

Gu, T., Pung, H., & Zhang, D. (2004). Toward an OSGi-based infrastructure for context-aware applications. IEEE Pervasive Computing / IEEE Computer Society [and] IEEE Communications Society, 3(4), 66–74. doi:10.1109/MPRV.2004.19

Health, G. (2009). Google Health Homepage. Retrieved April 15, 2009, from https://www.google.com/health.

HealthVault. (2009). HealthVault Homepage. Retrieved March 30, 2008, from http://www.healthvault.com/.

Helal, S. (2005). Programming Pervasive Spaces. IEEE Pervasive Computing / IEEE Computer Society [and] IEEE Communications Society, 4(1), 84–87. doi:10.1109/MPRV.2005.22

Hodge, J. G., Gostin, L. O., & Jacobson, P. D. (1999). Legal Issues Concerning Electronic Health Information: Privacy, Quality, and Liability. [JAMA]. Journal of the American Medical Association, 282(15), 1466–1471. doi:10.1001/jama.282.15.1466

Koppel, R., Metlay, J. P., Cohen, A., Abaluck, B., Localio, A. R., & Kimmel, S. E. (2005). Role of Computerized Physician Order Entry Systems in Facilitating Medication Errors. [JAMA]. Journal of the American Medical Association, 293(10), 1197–1203. doi:10.1001/jama.293.10.1197

Lampe, M., & Flörkemeier, C. (2004). The Smart Box application model. Paper presented at the International Conference on Pervasive Computing, Vienna, Austria

Mazzullo, J. M., Lasagna, L., & Griner, P. F. (1974). Variations in interpretation of prescription instructions. The need for improved prescribing habits. [JAMA]. Journal of the American Medical Association, 227(8), 929–931. doi:10.1001/jama.227.8.929

Ni, L. M., Liu, Y., Lau, Y. C., & Patil, A. P. (2004). LANDMARC: Indoor Location Sensing Using Active RFID. Wireless Networks, 10(6), 701–710. doi:10.1023/B:WINE.0000044029.06344.dd

Noury, N., Virone, G., Barralon, P., Ye, J., Rialle, V., & Demongeot, J. (2003, June). New trends in health smart homes. Paper presented at the International Workshop on Enterprise Networking and Computing in Healthcare Industry, Healthcom, Santa Monica, CA, USA

Nugent, C. D., Finlay, D., Davies, R., Paggetti, C., Tamburini, E., & Black, N. (2005, July). Can Technology Improve Compliance to Medication? Paper presented at International Conference On Smart homes and health Telematic (ICOST), Sherbrooke, Quebec, Canada

OCR. (2009). Summary of the HIPAA Privacy Rule. Retrieved February 26, 2009, from http://www.hhs.gov/ocr/privacy/hipaa/understanding/summary/index.html.

Papazoglou, M. P., & Dubray, J. (2004). A Survey of Web service technologies. (Technical Report DIT-04-058). Trento, Italy: University of Trento, Informatica e Telecomunicazioni.

PDR. (2009). The Physicians' Desk Reference Homepage. Retrieved February 17, 2009, from http://www.pdr.net/login/Login.aspx.

Phidgets Inc. (2009). Phidgets Inc. - Unique and Easy to Use USB Interfaces. Retrieved April 15, 2009, from http://www.phidgets.com/.

Reyes Álamo, J. M., Sarkar, T., & Wong, J. (2008, December). Composition of Services for Notification in Smart Homes. Paper presented in 2nd. International Symposium on Universal Communication (ISUC), Osaka, Japan.

Reyes Álamo, J. M., Wong, J., Babbitt, R., & Chang, C. (2008, July). MISS: Medicine Information Support System in the Smart Home Environment. Paper presented at International Conference On Smart homes and health Telematic (ICOST), Ames, IA USA.

Sarriff, A., Aziz, N. A., Hassan, Y., Ibrahim, P., & Darwis, Y. (1992). A study of patients' self-interpretation of prescription instructions. Journal of Clinical Pharmacy and Therapeutics, 17(2), 125–128.

Siegemund, F., & Floerkemeier, C. (2003, March). Interaction in Pervasive Computing Settings using Bluetooth-enabled Active Tags and Passive RFID Technology together with Mobile Phones. Paper presented at Pervasive Computing and Communications, Fort Worth, TX, USA

Strategic Projects, I. T. (2009). MediConnect Homepage. Retrieved April 16, 2009, from http://www.medicareaustralia.gov.au/provider/patients/mediconnect.jsp

Szeto, A., & Giles, J. (1997). Improving oral medication compliance with an electronic aid. IEEE Engineering in Medicine and Biology Magazine, 16(3), 48–54. doi:10.1109/51.585517

Testa, M., & Pollard, J. (2007, June). Safe pill-dispensing. Paper presented in Leading Internation Event of the International Council on Medical & Care Compunetics, Amsterdam, Netherlands

Vergnes, D., Giroux, S., & Chamberland-Tremblay, D. (2005, July). Interactive Assistant for Activities of Daily Living. Paper presented at International Conference On Smart homes and health Telematic (ICOST), Sherbrooke, Quebec, Canada ePharmacy. (2009). ePharmacy Homepage. Retrieved April 16, 2009, from http://www.hisac.govt.nz/moh.nsf/pagescm/7390

Wan, D. (1999, September). Magic Medicine Cabinet: A Situated Portal for Consumer Healthcare. Paper presented in First International Symposium on Handheld and Ubiquitous Computing, Karlsruhe, Germany

Want, R. (2004). Enabling ubiquitous sensing with RFID. Computer, 37(4), 84–86. doi:10.1109/MC.2004.1297315

Web, M. D. (2009). WebMD Mobile for Apple iPhone. Retrieved February 20, 2009, from http://www.webmd.com/mobile.aciduis ciduisi bla facillum nulla feuguer adignit amet

This work was previously published in International Journal of Advanced Pervasive and Ubiquitous Computing, Vol. 1, Issue 3, edited by J. Symonds, pp. 42-60, copyright 2009 by IGI Publishing (an imprint of IGI Global).

Chapter 8.7

Personal Health Records:

Patients in Control

Ebrahim Randeree
Florida State University, USA

Melinda Whetstone
Florida State University, USA

ABSTRACT

An increasing focus on e-health and a governmental push to improve healthcare quality while giving patients more control of their health data have combined to promote the emergence of the personal health record (PHR). The PHR addresses timeliness, patient safety, and equity, goals that the Institute of Medicine has identified as integral to improving healthcare. The PHR is vital to the National Health Information Network (NHIN) that is being developed to give all Americans access to electronic health records by 2014. Despite increasing public access to PHRs via employers, insurance companies, healthcare providers, and independent entities, it is unclear whether the PHR will be successfully implemented and adopted by the public. This chapter looks at how PHRs address the needs, desires, and expectations of patients, explores the data quality concerns regarding patient-generated information (data capture, sharing and integration with other systems), discusses social implications of adoption, and concludes with a discussion of the evolving role that PHRs play in the growth of patient-centered e-health.

DOI: 10.4018/978-1-60566-016-5.ch004

INTRODUCTION

The ongoing transition toward the electronic medical record (EMR), initially referred to as computerized patient record or electronic patient chart (Tang & McDonald, 2001), was spurred by concerns over medical errors and rising costs in healthcare. As EMR systems became more robust, they proved themselves to be beneficial to healthcare providers in many ways. The EMR reduced information duplication (Ewing & Cusick, 2004), improved utilization of lab and radiology results (Ewing & Cusick, 2004; Wang, Middleton, Prosser, Bardon, Spurr, Carchidi, et al., 2003), increased the efficiency of coding and billing (Menachemi & Brooks, 2006; Schmitt & Wofford, 2002), and provided healthcare personnel with quicker access to patient records (Sandrick, 1998; Wang et al., 2003).

Yet, patients and their caregivers share EMR benefits only indirectly. Patients continue to be viewed by EMR developers as passive participants who should not have direct access to or control of health data that are contained within the EMR. At the same time, patients want to be more engaged in their own healthcare and are seeking information online (Ball, Smith, & Bakalar, 2007). Use of the Internet to gather information about healthcare has increased substantially in recent years (Clark, Williams, Clark, & Clark, 2002; Gerber & Eiser, 2001; Lenhart, Horrigan, & Fallows, 2004), and the Pew Internet & American Life Project estimates the number of Americans searching for online health information at 113 million (Fox, 2006). As a result, patients have been undergoing a role change that is facilitated by Internet technology. The traditional paradigm of the patient as a passive recipient of physician diagnosis and instruction is evolving toward the patient becoming the driver of healthcare relationships. Patients have more options for receiving care, such as newly-created "store front" clinics being offered by major retailers to provide basic care (Wal-Mart, 2007). In addition, the Internet has greatly improved access to health information (Greenberg, D'Andrea, & Lorence, 2004), allowing patients to explore new treatments, to access current research journals, and to utilize increasingly sophisticated interactive and individually tailored programs through the Internet and Internet-enabled devices for health behavior change and chronic disease management (Ahern, 2007).

The personal health record (PHR) has emerged as a mechanism for patients to participate directly in the benefits of electronic records and integrated e-health delivery. Proposed benefits of the PHR include secure online access, comprehensive personal health history, means to become one's own health advocate, benchmarks and prompts for health maintenance, fluid communication between patient and provider, and automatic data entry (Morrissey, 2005). As patients manage their own personal health records using a PHR, it is hoped that this will help them make more informed choices about available options and give them the ability to exercise greater control over their own healthcare (Tsiknakis, Katehakis, & Orphanoudakis, 2002), in effect converting patients from passive information recipients to proactive consumers and generators of health information.

Leading health informatics groups in the U.S.—the American Health Information Management Association (AHIMA) and the American Medical Informatics Association (AMIA)—note that PHRs empower patients by providing a means for collecting, tracking, and sharing important, up-to-date health information for them or those in their care (AHIMA, 2006). Additionally, PHRs can promote patients' health management by providing cues for health issues (e.g., weight control or diabetes management), delivering reminders for medical test scheduling, and supporting entry of information—such as blood pressure or blood glucose levels—that may increase compliance to treatment protocols.

Patients have increasing opportunities to use a PHR, but many current initiatives offer only a partial PHR solution, are difficult to use, or raise privacy concerns. Typical offerings by employers and national insurers implement partially complete PHR designs that are limited in the scope of information that is readily included. For example, the PHR offered by Aetna, Inc. primarily provides information that is found in insurance records, such as billing and coding (Havenstein, 2007), and Kaiser's PHR contains only limited types of medical information (Hines, 2007). Although third-party PHRs have the potential to contain more complete healthcare documentation, the amount of manual data entry that users are required to perform and concerns over unauthorized secondary usage and privacy have dampened interest.

Despite positive news coverage of PHRs and their proposed benefits, nearly half of all Americans are still unaware of PHRs (Sprague, 2006). Adoption has been encouraged via legislation, with the premise that empowered consumers will help to decrease healthcare costs. However, the implications of further adoption—financial, social, and health-wise—are unknown. This chapter looks at how PHRs address the needs, desires, and expectations of patients, explores the data quality concerns regarding patient-generated information (data capture, sharing and integration with other systems), discusses social implications of adoption, and concludes with a discussion of the evolving role that PHRs play in the growth of patient-centered e-health.

BACKGROUND

PHRs have emerged as a new option for patients to become active participants in the federal push towards widespread digitized healthcare in the U.S. National Committee on Vital and Health Statistics (NCVHS, 2001) has identified the individual (personal health) as a key stakeholder in a technological National Health Information infrastructure, along with communities (population health) and healthcare providers. PHRs are seen as a critical component of an effective healthcare system, as they promote the patient-centeredness aspect of the six aims for improving healthcare called for by the Institute of Medicine, including safety, effectiveness, patient-centeredness, timeliness, efficiency, and equity (IOM, 1999, 2001).

The drive toward PHRs gained momentum in 2004 when the U.S. President signed Executive Order 13335, calling for "the development and nationwide implementation of an interoperable health information technology infrastructure to improve efficiency, reduce medical errors, raise the quality of care, and provide better information for patients, physicians, and other healthcare providers" (Brailer, 2005). This momentum is continuing in the U.S. with a steady flow of bills promoting a National Health Information Network (NHIN), overall health information technology adoption (S.1408, 2007; S.1455, 2007; S.1693, 2007), physician grants for EMR purchases (HR 2377, 2007), and physician reimbursement for each PHR that is provided to a patient.

Privacy and Security

As the push for PHRs increases and more companies provide access to them, the federal government will need to consider implications for health information privacy and security. Currently, personal health information is protected under the Health Insurance Portability and Accountability Act (HIPAA) of 1996, Public Law 104-191 (HIPAA, 1996). In addition to protecting personal health information, HIPAA ensures portability of medical records while governing the ability to disclose information contained within the records. HIPAA provides for sharing personal health information when "covered entities" have "reasonable safeguards and minimum necessary policies and procedures" in place (HHS OCR, 2003). A covered entity as defined by HIPAA is a health plan, healthcare clearinghouse, or healthcare provider who transmits protected health information in electronic form in connection with a transaction covered by the HIPAA transactions regulation (HIPAA PL 104-191, Sec 1172(a)). Under HIPAA, covered entities are expected to "maintain reasonable and appropriate administrative, technical, and physical safeguards" in order to "ensure the integrity and confidentiality of the information; to protect against" data or disclosure breaches and "ensure compliance with this part by the officers and employees of such person." Many security issues relating to the transmission and storage of PHR data have yet to be worked out, especially in the context of online PHRs, and this could slow the progress of PHR initiatives.

The concept of the PHR continues to evolve; its purpose and definition is still changing in step with technology advances and consumer demands (NCVHS, 2006). However, it is envisioned as an integral health resource that will promote informed health decisions as a consequence of increased health literacy, improved knowledge of healthcare practices, and expanded healthcare choices (AHIC, 2007). Optimally, the PHR will interrelate with other types of medical records, primarily the electronic medical record (EMR) and the electronic health record (EHR).

Electronic Medical Records and Electronic Health Records

The EMR is considered to be the legal record created in hospitals and ambulatory environments (Garets & Davis, 2006), and is the encompassing concept for health information (Stead, Kelly, & Kolodner, 2005). The EHR is a subset of the EMR that spans episodes of care across multiple healthcare providers and is designed specifically to be a resource for patients (Garets & Davis, 2006). Both records are generated as by-products of the healthcare provider's EMR system (Stead et al., 2005), the computerized system used by a healthcare provider to collect and manage detailed medical information (Connecting for Health, 2003; Garets & Davis, 2006). In effect, the EMR encompasses the various pieces of information collected and managed by the EMR system, and the EHR represents portions of the EMR that are most relevant to patients, potentially integrating documentation of care that is received from multiple providers. Although much of this information is only useful for administrative, financial, and billing parts of a healthcare practice, the EMR and EHR also contain patient encounter information which is highly relevant to the PHR.

Personal Health Information Management

Patients are not new to searching, retrieving, and storing health information. They have historically gathered personal medical information, including stacks of receipts, journal clippings, and lab results which are then organized to support ongoing management of health conditions or according to personal conceptions of future need. Moen and Brennan (2005) report that individuals use a wide range of media to manage health information for themselves and their families, including calendars, phonebooks, medical histories, and independent paper documents containing information about procedures, medication side effects, and medical instructions. These nondigital "personal health records" often are stored under refrigerator magnets, in shoeboxes, or simply piled in a drawer (Moen & Brennan, 2005). Only infrequently is a personal computer or personal digital assistant (PDA) used to manage personal health information at the present time.

Approaches to the PHR

Vendors of new PHR products strive to provide an efficient cataloging and health information management system that can replace *ad hoc* methods which patients have come to use. These new PHRs are intended to provide affordable, easy to use, life-long health and medical histories that are complete and accurate and can be generated and maintained effectively by patients or their caregivers (AHIC, 2007; AHIMA, 2005). Specific contents of PHRs vary, but these typically include the information that is normally filled out on a standard new patient questionnaire, such as personal identification, emergency contacts, prior healthcare providers, and insurance documentation. PHRs also frequently include documentation relating to immunizations, allergies and adverse drug reactions, prescribed medications (including dose and how often taken), over-the-counter medications and herbal remedies, incidents of illness and hospitalization, surgeries and other medical procedures, laboratory test results, and family histories. Additional information that may be encompassed by the PHR includes living wills and advance directives, organ donor authorization, physical examination results, physician opinions, eye and dental records, permission forms, and lifestyle information (AHIMA, 2005; Connecting for Health, 2004). As a complete and life-long record, the PHR should be designed to contain health information from all organizations and providers that serve patients (Connecting for Health, 2003). Additionally, the PHR should be maintained within a private, secure, and confidential environment (Connecting for Health, 2003).

Standards for data transfer and interoperability are supported by America's Health Insurance Plans (AHIP), a national association representing 1300 health insurers, and the Blue Cross and Blue Shield Association (BCBSA), a national federation of health coverage providers (MNT, 2006). Current standards primarily support data-driven PHRs, as described below. However, new standards have been proposed that will apply to all PHRs (Health Level Seven, 2007).

The three primary approaches to creating a PHR are as independent and personal applications, as transaction data-driven applications, and as EHR-integrated applications. Creation methods and security characteristics vary substantially among these approaches:

- **Independent and personal:** These PHRs are created manually by the individual user using commercially available applications and are unbound from any specific healthcare provider. They are categorized as standalone (independent) or Web-based types. When these PHRs are used as standalone systems, they offer high levels of security and privacy. However, they also require the most time to create and maintain, and standalone PHRs may not offer the level of "anyplace-anytime" access that is available with Web-based PHRs.
- **Transaction data-driven:** These PHRs are automatically created and typically maintained using transaction data from sources such as a healthcare provider, a health plan, or a pharmacy. As a result, they will typically be limited to automatically providing only information that is specific to the source, for example, an insurance company may only provide information pertaining to office visit dates, diagnoses, and costs related to covered providers. This type of PHR is sometimes referred to as "tethered" due to linkage with and control by a specific source entity. At least 70 million Americans have some form of access to a transaction data-driven PHR (Sprague, 2006), yet actual usage is estimated to be low, based on overall PHR use patterns (Denton, 2001).
- **EHR-integrated:** These are considered to be the "holy grail" among PHRs, as they are automatically populated with data from a healthcare provider's EHR, potentially providing the most complete collection of relevant patient information that can be made available (Tang & Lansky, 2005, pp. 1292). EHR-integrated PHRs often include additional functionality, such as secure email messaging, prescription renewal, appointment scheduling, and the ability for the user to add supplemental information (Sprague, 2006; Tang, Ash, Bates, Overhage, & Sands, 2006). Limited versions of the EHR-integrated PHR simply provide a view of the provider's EHR data. Several large organizations, such as the Pal Alto Medical Foundation (PAMF) (Tang, Black, Buchanan, Young, Hooper, & Lane, et al., 2003), Kaiser Permanente and the Veterans Health Administration

(Sprague, 2006) currently provide this type of limited access. Until a greater proportion of healthcare providers adopt EHRs, however, availability of EHR-integrated PHRs will be constrained.

Each approach described above presents tradeoffs. For example, the standalone PHR ensures high levels of privacy, but requires a high personal labor cost for creation and maintenance. While PHRs that are automatically populated with data from healthcare provider systems may appear to be optimal in that they require the patient to invest less startup effort, there are higher costs associated with this PHR approach as it requires the healthcare provider to use an EHR and to pay for the PHR to be integrated with it.

DATA QUALITY CONCERNS

We have discussed the importance of ease of use and interoperability in gaining patients' acceptance of PHRs. Ensuring data quality and relieving patients' concerns in this area are also important. High quality health information can reduce medical errors, avoid duplicating services, and give patients and their providers reliable information on which to base decisions. Quality issues are inherently multifaceted, and attention must be given to a number of dimensions in order to comprehensively address data quality issues and mitigate patients' concerns for data quality in PHRs:

- **Relevant content:** The most important criteria of a PHR is content (i.e., its informational and transactional capabilities) (Agarwal & Venkatesh, 2002). Relevant content promotes usage, especially where the content fosters self-education (Walter & Tung, 2002). This makes it important for PHR designers to learn which types of content are essential to patients and develop interfaces that allow quick access to this content while minimizing distractions. This is not a trivial exercise, as the relevance of content can be affected by numerous variables, including motivation, reading level, culture, primary language, technical knowledge, and background experiences of software users (Calongne, 2001).
- **Accuracy:** Accuracy (including completeness) of health information is very important for PHR users and their healthcare providers, as inaccurate information can lead to medical errors and practitioner liability. As the volume of electronic data increases, there is always the potential to overlook or aggregate relevant information. Of the various types of data entry methods employed by PHRs, approaches that rely on guided or automated entry of data elements abstracted from primary source documents may promote more accurate entry (Kim & Johnson, 2004). An additional concern for information that is provided to patients is the need to avoid descriptions that patients are likely to misinterpret. It is not in the best interests of patients or their physicians to provide health information with insufficient structure, patient education, or guidance to make it understandable to them (Walter & Tung, 2002).
- **Privacy/Security:** Security and privacy issues are of concern to both PHR users and developers. Patients using Web-based PHRs must be aware of the potential for misuse, unauthorized secondary usage, and other dangers that come with online transmission and remote data storage. Striking a balance between privacy concerns and the need for access can be difficult (Kelly & Unsal, 2002). Web-based data must be secured by the PHR provider, and patients should be confident that their data is secured and encrypted during online transmission. PHR providers should

attempt to meet all HIPAA standards for protection of patient health information, even where these are not directed explicitly toward online operations. Currently, many providers of Web-based PHRs operate outside of HIPAA rules, as they are not covered entities as defined by HIPAA and are not regulated by HIPAA privacy rules (Conn, 2006). Nevertheless, health records contain information that is highly sensitive, and patients have a strong expectation that such information will be used only in the context of providing effective care (Rindfleisch, 1997). Privacy and confidentiality issues are primary concerns underscoring the reluctance of administrators, physicians, and patients to completely embrace Internet technologies (Kerwin & Madison, 2002).

- **Authority:** Qualification of the author is crucial in determining the credibility of health information in PHRs. Physicians receive and process large amounts of data. If they allow patients to bring in PHR data, there must be checks and balances to support its interpretation. Similarly, patients who import EHR data into a PHR database must be able to verify who has provided the information. Authority has been recognized as the underlying theme in source credibility (Rieh & Belkin, 1998), and trust is established when the information is presented by a recognized author (Lin & Umoh, 2002). Authority criteria should include author identification (physician identification if the information is collected from an EHR). Identification of the author promotes perceptions of legitimacy and accountability of the information.
- **Timeliness:** Availability of timely health information is essential to improving the quality of healthcare. In addition, it is important that medical decisions be based upon correctly sequenced health information. For this reason, PHR entries should be accompanied by the dates and times the information was created, modified, and added to the PHR in order to inform judgments as to the value and relevance of the information. In addition, the PHR should be updated following medical encounters or to reflect changes in the patient's health status.
- **Usability:** Ease of use has been extensively researched across the IT domain (Agarwal & Venkatesh, 2002), and the general IT findings suggest usability is a key driver of PHR usage. Presence of design elements that support usability is an important determinant of whether visitors are likely to return to Web sites (Klein, 1998). A recent study of health records reports that attention to navigation, context, and information design is critical to the usability of a system (Rose, Schnipper, Park, Poon, Li, & Middleton, 2005). PHR developers should conduct usability testing to support patients in obtaining quality access to health data.
- **Information audits:** Given the critical nature of health information contained in the PHR, patients must have the ability to audit the information in order to identify and correct any discrepancies or to update information. Where the PHR is integrated with a provider's EHR, giving patients a moderated ability to review and update data could make both health records more robust. Auditing capabilities give patients control over the information dissemination and, by providing access histories, may help allay patients' concerns for privacy and security.

SOCIAL CONCERNS

Historically, one unfortunate side effect of the diffusion of new technology has been increased disparity for the socioeconomically disadvantaged (Rogers, 2003). The PHR is multifaceted in that it can operate as a data repository, a health information management tool, or an educational dissemination portal. The PHR is also a developing technology, and vendors generally have objectives toward using PHRs to support equitable and patient-centered healthcare. However, if efforts are not made ensure equitable access and to develop the appropriate levels of health literacy and technology competence for all potential users, the PHR may further alienate populations that have the most to gain from using it, such as chronically ill patients who have difficulty affording healthcare. Despite developers' intentions, PHRs may act to highlight and even exacerbate social inequities in healthcare. These social concerns can be broadly represented by the digital divide phenomenon with a secondary focus on literacy:

- **Digital divide:** Focusing on those with access to technology and those without will be a challenge for any PHR developer to overcome. The traditional racial and socioeconomic disparities of access to financial means, to computers, and to the healthcare system in general become more apparent in a PHR designed for Web access. While some may see public Internet access, at the library, for example, as a means to overcome barriers, a challenge still remains in how to provide PHR access to those who do not have medical insurance. Although "free" PHR access is available, these products typically offer limited functionality and still require extensive access to a computer.
- **Literacy:** Concerns of literacy relating to PHRs can be subdivided into three distinct areas: technology literacy (ability to understand and use the technology such as Web portals, Web forms, and so on), information literacy (ability to understand the information presented and the instructions provided), and health literacy (ability to understand the medical content provided sufficient o make basic health decisions). Use of PHRs is hindered by a range of barriers including lacking access to computers or devices, cognitive disabilities, physical disabilities, low computer skills or reading literacy, and low health literacy (Lober, Zierler, Herbaugh, Shinstrom, Stolyar, Kim, & Kim, 2006).

CONCLUSION

The national focus on applying health information technologies to improve healthcare delivery quality and lower costs has created momentum for patient-centered solutions. Increasing patient demand and a changing healthcare market now make it likely that Internet-based communication between providers and patients could soon be an everyday part of healthcare throughout the Internet-connected world (Wilson, 2003). The true benefits of PHRs become apparent when they are fully integrated with the healthcare provider's EHR or EMR. Using integrated PHRs, patients will not only gain access to their medical records but also will have the ability to update, correct, or add to the records. This will allow patients to become more engaged with their medical histories, plans of care, and options for treatment. While issues of data quality exist, inclusion of the patients will allow for these primary stakeholders in the healthcare process to be active participants in their own care. Potential benefits include better compliance with care protocols (translating to lower costs for insurers and patients), increased patient literacy, increased convenience for patients and their providers (translating to service improvements and better coordination of care), and better quality outcomes.

The monitoring of chronic conditions is an ideal fit for PHRs. The movement to involve patients stems to a large degree from the desire to engage patients in managing chronic diseases, along with selecting care based on quality characteristics, improving the quality of the care delivery system, and making healthcare more market-driven by increasing patients' share of costs (Fowles, Kind, Craft, Kind, Mandel, & Adlis, 2004). Chronic conditions require long term treatment plans and provide an opportunity for cost reduction if the care is coordinated effectively between the physician and the patient. Incorporating home monitoring and self-reporting features offers some of the most interesting opportunities for PHRs (Heubusch, 2007).

PHRs have potential to transform the healthcare setting: they can replace or augment existing care processes, provide interactive communication, support information exchange, initiate consumer activity, and increase convenience and efficiency of healthcare services (Hartman, 2006). In order for PHR benefits to be realized, however, several criteria must be addressed in the areas of PHR standards, interoperability, and system functionality:

- **Standards:** Current PHR systems are either linked to an EMR/EHR or are standalone systems that lack national standards. These heterogeneous systems will need to coalesce towards a shared standard that allows for simplified data transfer among systems. Records must be of sufficient size and scope to include both clinical and nonclinical data. Data standards should also determine the sources of information that is allowed to flow into and out of the PHR.
- **Interoperability with Privacy/Security:** The current focus in health information exchange initiatives is to connect electronic medical records among healthcare providers to allow sharing of data among physicians and healthcare facilities. The proprietary nature of health information systems presents a barrier to health information exchange in its current form. As patients interact with multiple providers and multiple systems, the creation of a national standard for electronic records will facilitate the exchange. The Certification Commission for Healthcare Information Technology (CCHIT) is a recognized certification body for electronic health records and their networks, and an independent, voluntary, private-sector initiative (www.cchit.org). CCHIT is working to accelerate the adoption of health information technology by creating an efficient, credible and sustainable certification program. The certification allows for development of interoperability standards among vendors that market electronic medical records.
- **Functionality:** Use of PHRs will be directly related to the benefits that patients perceive from usage. In this case, the functionality of the PHR and its ability to reduce costs increase the likelihood of quality outcomes. The ability to easily view and enter health information will help to increase use, as will automated integration of information between the PHR and the healthcare provider's EHR or EMR. Additional benefits of reduced insurance premiums for chronic condition management as well as participation in the management of care decisions could incentivize PHR usage.

As PHR vendors compete for market share, new models will need to be developed. PHR vendors must move toward providing more complete integration and access to medical records for patients to become fully empowered. PHR vendors must also integrate their services with traditional EMR and EHR vendors. For physicians to support these efforts, the PHR must not interfere with the workflow of the office and must be interoperable with existing systems so data can move seamlessly among systems, assuming adequate privacy and security protections are in place.

The growth of patient empowerment initiatives will continue to drive the direction of healthcare. Studies on how the Internet affects patients' experience of empowerment within the clinical encounter have shown mixed outcomes. While patients' desire to use the Internet for health information is increasing generally, many patients are reluctant to discuss information from the Internet in the clinical encounter for fear of challenging the physician's authority, and some physicians express frustration in dealing with patients who arrive with health information they obtain online (Jacobson, 2007). In contrast, PHRs tend to empower patients in their personal healthcare and in interactions with healthcare providers. In a comparison of effects of computer-generated medical record summaries and written PHRs on patients' attitudes, knowledge and behavior concerning health promotion, researchers found that patients receiving summaries as part of mail recruitment were significantly more likely to attend for a health check; those receiving both PHR and summaries were more likely to keep and use the record; and those receiving PHR improved their knowledge of health promotion, became more aware of lifestyle issues, and were more likely to change their lifestyle (Liaw, Lawrence, & Rendell, 1996).

The growth of patient self-management tools for remote monitoring will fuel PHR adoption, if tools and standards are developed that make clinical information understandable to and usable by patients (Ball et al., 2007). As a caveat, it must be recognized that not all patients will be excited to adopt PHRs. The use of a PHR to empower patients with their medical records will be beneficial to early adopters and those with chronic conditions. However, some patients, such as those who experience a rare acute incident, may not be attracted to PHRs. Patients also exist at varying levels of literacy, and not all will be eager to delve into their medical records without support.

For PHRs to have a future, the healthcare industry must determine the public's needs and interests and provide flexible tools that offer a range of data and resources that can be used to satisfy these needs and interests (Heubusch, 2007). In addition, physicians must be willing to share information with their patients through PHRs. In many cases, physicians concerns for negative impacts of information sharing are overblown and based on anecdotal sources, as empirical research in this area is limited and dated (Fowles et al., 2004). Much of the value of PHRs lies in shared information and shared decision-making in support of the continuity of care (Ball et al., 2007).

REFERENCES

Agarwal, R., & Venkatesh, V. (2002). Assessing a firm's Web presence: A heuristic evaluation procedure for the measurement of usability. *Information Systems Research*, *13*(2), 168–186. doi:10.1287/isre.13.2.168.84

Ahern, D. K. (2007). Challenges and opportunities of eHealth research. *American Journal of Preventive Medicine*, *32*(5), S75–82. doi:10.1016/j.amepre.2007.01.016

AHIC. (2007). *Community meeting: Consumer empowerment workgroup.* Mountain View, CA: American Health Information Community.

AHIMA. (2005). The role of the personal health record in the EHR. *Journal of American Health Information Management Association, 76*(7), 64A-D.

AHIMA. (2006). The value of personal health records. A joint position statement for consumers of healthcare. *Journal of American Health Information Management Association*, *77*(9), 22–24.

Ball, M., Smith, C., & Bakalar, R. S. (2007). Personal health records: Empowering consumers. *Journal of Healthcare Information Management*, *21*(1), 76–86.

Brailer, D. J. (2005) *Is there a doctor in the mouse?: Using information technology to improve healthcare.* Testimony before the U.S. House of Representatives, Committee on Government Reform, Subcommittee on Federal Workforce and Agency Organization. Retrieved May 14, 2008, from http://www.hhs.gov/healthit/t050727.html

Calongne, C. M. (2001). Designing for Web site usability. *Journal of Computing in Small Colleges*, *16*(3), 39–45.

Clark, R., Williams, J., Clark, J., & Clark, C. (2002). Assessing Web site usability: Construction zone. *Journal of Healthcare Information Management*, *17*(2), 51–55.

Conn, J. (2006). Personal and (maybe) confidential. *Modern Healthcare*, *36*, 28–31.

Connecting for Health. (2003). *The personal health working group final report.* Markle Foundation. Retrieved May 14, 2008, from http://www.markle.org/downloadable_assets/final_phwg_report1.pdf

Connecting for Health. (2004). *Connecting Americans to their healthcare: Final report.* Markle Foundation. Retrieved May 14, 2008, from http://www.connectingforhealth.org/resources/wg_eis_final_report_0704.pdf

Denton, I. C. (2001). Will patients use electronic personal health records? Responses from a real-life experience. *Journal of Healthcare Information Management*, *15*(3), 251–259.

Ewing, T., & Cusick, D. (2004). Knowing what to measure. *Healthcare Financial Management*, *58*(6), 60–63.

Fowles, J. B., Kind, A. C., Craft, C., Kind, E. A., Mandel, J. L., & Adlis, S. (2004). Patients' interest in reading their medical record: Relation with clinical and sociodemographic characteristics and patients' approach to healthcare. *Archives of Internal Medicine*, *164*(7), 793–800. doi:10.1001/archinte.164.7.793

Fox, S. (2006). *Online health search 2006.* Pew Internet & American Life Project. Retrieved May 14, 2008, from http://www.pewinternet.org/PPF/r/190/report_display.asp

Garets, D., & Davis, M. (2006). Electronic medical records vs. electronic health records: Yes, there is a difference. *HIMSS Analytics.* Retrieved May 14, 2008, from http://www.himssanalytics.org/docs/WP_EMR_EHR.pdf

Gerber, B. S., & Eiser, A. R. (2001). The patient physician relationship in the Internet age: Future prospects and the research agenda. *Journal of Medical Internet Research*, *3*(2), E15. doi:10.2196/jmir.3.2.e15

Greenberg, L., D'Andrea, G., & Lorence, D. P. (2004). Setting the public agenda for online health search: A white paper and action agenda. *Journal of Medical Internet Research*, *6*(2), e18–10. doi:10.2196/jmir.6.2.e18

Hartman, M. J. (2006). Personal health records and electronic health records: Navigating the intersections. *Health Policy Newsletter*, *19*, 1.

Havenstein, H. (2007). Aetna clients to get access to online health data. *Computerworld.* Retrieved May 14, 2008, from http://www.computerworld.com/action/article.do?command=viewArticleBasicandarticleId=278859

Health Level Seven. (2007). *HL7's EHR technical committee opens public comment on personal health record system (PHR-S) functional model.* Retrieved May 14, 2008, from http://www.hl7.org/documentcenter/public/pressreleases/HL7_PRESS_20070827.pdf

Heubusch, K. (2007). Piecing together the PHR. *Journal of American Health Information Management Association*, *78*(4), 28–32.

Hines, L. (2007). Healthcare targets paper trail. *Press Enterprise.* Retrieved May 14, 2008, from http://www.pe.com/localnews/inland/stories/PE_News_Local_D_medicalrecords31.27afdf2.html

HIPAA. (1996). *Health insurance portability and accountability act of 1996 (public law 104-191).* Retrieved May 14, 2008, from http://aspe.hhs.gov/admnsimp/pl104191.htm

IOM. (1999). *To err is human: Building a safer health system.* Washington, DC: Institute of Medicine, National Academies Press.

IOM. (2001). *Crossing the quality chasm: A new health system for the 21st century.* Washington, DC: Institute of Medicine, National Academies Press.

Jacobson, P. (2007). Empowering the physician-patient relationship: The effect of the Internet. *Partnership: The Canadian Journal of Library and Information Practice and Research, 2*(1). Retrieved May 14, 2008, from http://journal.lib.uoguelph.ca/index.php/perj/issue/view/31

Kelly, E. P., & Unsal, F. (2002). Health Information privacy and e-healthcare. *International Journal of Healthcare Technology and Management*, *4*(1/2), 41–52. doi:10.1504/IJHTM.2002.001128

Kerwin, K. E., & Madison, J. (2002). The role of the Internet in improving healthcare quality. *Journal of Healthcare Management*, *47*(4), 225–236.

Kim, M. I., & Johnson, K. B. (2004). Patient entry of information: Evaluation of user interfaces. *Journal of Medical Internet Research*, *6*(2), e13. doi:10.2196/jmir.6.2.e13

Klein, L. R. (1998). Evaluating the potential of interactive media through a new lens: Search versus experience goods. *Journal of Business Research*, *41*(3), 195–203. doi:10.1016/S0148-2963(97)00062-3

Lenhart, A., Horrigan, J., & Fallows, D. (2004). Content creation online. *Pew Internet & American life project*. Retrieved May 14, 2008, from http://www.pewinternet.org/pdfs/PIP_Content_Creation_Report.pdf

Liaw, T., Lawrence, M., & Rendell, J. (1996). The effect of a computer-generated patient-held medical record summary and/or a written personal health record on patients' attitudes, knowledge and behaviour concerning health promotion. *Family Practice*, *13*(3), 289–293. doi:10.1093/fampra/13.3.289

Lin, B., & Umoh, D. (2002). E-healthcare: A vehicle of change. *American Business Review*, *20*(2), 27–32.

Lober, W., Zierler, B., Herbaugh, A., Shinstrom, S., Stolyar, A., Kim, E., & Kim, Y. (2006). Barriers to the use of a personal health record by an elderly population. In Proceedings of 2*006 AMIA Annual Symposium Proceedings* (pp. 514-518).

Menachemi, N., & Brooks, R. G. (2006). Reviewing the benefits of electronic health records and associated patient safety technologies. *Journal of Medical Systems*, *30*(3), 159–168. doi:10.1007/s10916-005-7988-x

MNT. (2006). AHIP, BCBSA issue standards for personal health records. *Medical News Today.* Retrieved May 14, 2008, from http://www.medicalnewstoday.com/articles/59052.php

Moen, A., & Brennan, P. F. (2005). Health@Home: The work of health information management in the household (HIMH): Implications for consumer health informatics (CHI) innovations. *Journal of the American Medical Informatics Association*, *12*(6), 648–656. doi:10.1197/jamia.M1758

Morrissey, J. (2005). But what does the public think? For consumers to adopt PHRs, they need reasons that hit home. *Journal of American Health Information Management Association*, *76*(10), 42–44.

NCVHS. (2001). A strategy for building the national health information infrastructure. *National Committee on Vital and Health Statistics*. Washington DC: U.S. Department of Health and Human Services.

Rieh, S. Y., & Belkin, N. J. (1998). Understanding judgment of information quality and cognitive authority in the www. *Journal of the American Society for Information Science American Society for Information Science*, *35*, 279–289.

Rindfleisch, T. C. (1997). Privacy, information technology, and healthcare. *Communications of the ACM*, *40*(8), 92–100. doi:10.1145/257874.257896

Rogers, E. M. (2003). *Diffusion of innovations (fifth edition).* New York: The Free Press.

Rose, A. F., Schnipper, J. L., Park, E. R., Poon, E. G., Li, Q., & Middleton, B. (2005). Using qualitative studies to improve the usability of an EMR. *Journal of Biomedical Informatics*, *38*, 51–60. doi:10.1016/j.jbi.2004.11.006

Sandrick, K. (1998). Calculating ROI for CPRs. *Health Management Technology*, *19*(6), 16–20.

Schmitt, K. F., & Wofford, D. A. (2002). Financial analysis projects clear returns from electronic medical records. *Healthcare Financial Management*, *56*(1), 52–57.

Sprague, L. (2006). *Personal health records: The peoples'choice?* (Publication No. 820). Washington D.C.; National Health Policy Forum. Retrieved May 14, 2008, from http://www.nhpf.org/pdfs_ib/IB820_PHRs_11-30-06.pdf

Stead, W. W., Kelly, B. J., & Kolodner, R. M. (2004). Achievable steps toward building a National Health Information infrastructure in the United States. *Journal of the American Medical Informatics Association*, *12*(2), 113–120. doi:10.1197/jamia.M1685

Tang, P. C., Ash, J. S., Bates, D. W., Overhage, J. M., & Sands, D. Z. (2005). Personal health records: Definitions, benefits, and strategies for overcoming barriers to adoption. *Journal of the American Medical Informatics Association*, *13*(2), 121–126. doi:10.1197/jamia.M2025

Tang, P. C., Black, W., Buchanan, J., Young, C. Y., Hooper, D., Lane, S. R., et al. (2003). *PAMFOnline: Integrating EHealth with an electronic medical record system.* Paper presented at the 2003 AMIA Annual Symposium Proceedings.

Tang, P. C., & Lansky, D. (2005). The missing link: Bridging the patient-provider health information gap. *Health Affairs*, *24*(5), 1290–1295. doi:10.1377/hlthaff.24.5.1290

Tang, P. C., & McDonald, C. J. (2001). Computer-based patient-record systems. In E.H. Shortliffe & L.E. Perreault (Eds.). *Medical informatics: Computer applications in healthcare and biomedicine* (Second edition, pp. 327-358). New York: Springer-Verlag.

Tsiknakis, M., Katehakis, D. G., & Orphanoudakis, S. C. (2002). An open, component-based information infrastructure for integrated health information networks. *International Journal of Medical Informatics*, *68*, 3–26. doi:10.1016/S1386-5056(02)00060-6

Wal-Mart. (2007). *400 health clinics to open in Wal-mart stores during next three years.* Retrieved May 14, 2008, from http://www.walmartfacts.com/articles/default.aspx?id=4973

Walter, Z., & Tung, Y. A. (2002). E-healthcare system design: A consumer preference approach. *International Journal of Healthcare Technology and Management*, *4*(1/2), 53–70. doi:10.1504/IJHTM.2002.001129

Wang, S. J., Middleton, B., Prosser, L. A., Bardon, C. G., Spurr, C. D., & Carchidi, P. J. (2003). A cost-benefit analysis of electronic medical records in primary care. *The American Journal of Medicine*, *114*(5), 397–403. doi:10.1016/S0002-9343(03)00057-3

Wilson, E. V. (2003). Asynchronous healthcare communication. *Communications of the ACM*, *46*(6), 79–84. doi:10.1145/777313.777316

This work was previously published in Patient-Centered E-Health, edited by E. Wilson, pp. 47-59, copyright 2009 by Medical Information Science Reference (an imprint of IGI Global).

Chapter 8.8

Transforming Continuing Healthcare Education with E-Learning 2.0

Rajani S. Sadasivam
University of Massachusetts Medical School, USA

Katie M. Crenshaw
University of Alabama at Birmingham, USA

Michael J. Schoen
University of Alabama at Birmingham, USA

Raju V. Datla
Massachusetts Medical Society, USA

ABSTRACT

The e-learning 2.0 transformation of continuing education of healthcare professionals (CE/CME) will be characterized by a fundamental shift from the delivery of static information online to a seamless, digital operation in which all users have the ability to access, create, and share knowledge in a multidimensional, instantaneous, collaborative, and interactive manner. This transformation will be disruptive, blurring existing boundaries between CE/CME professionals, content experts, and student learners, and modifying the traditional structured learning process to a more informal one. While the opportunities are unlimited, the transformation will present not only technology challenges but also social and educational challenges. Recent experiences with similar disruptive technologies show that a meaningful transformation can be achieved only if the application of technology is accompanied by strategic operational changes. This chapter offers a conceptual framework to guide CE/CME professionals interested in transforming their operations with new e-learning 2.0 technologies. Employing several usage scenarios, a new e-learning 2.0-based model of CE/CME operation is introduced. We also present several examples of approaches adopted by our academic group to address the various challenges discussed in this chapter.

DOI: 10.4018/978-1-60566-788-1.ch019

INTRODUCTION

The threats of disruptive approaches to management education, CME, and probably to higher education as a whole are real. But so are the opportunities. Disruptive innovations – such as personal computers, photocopiers, helical scan video recorders, and microwave ovens – generally have brought useful technologies to much larger groups of people than previously had enjoyed access to them. Disruptive approaches to continuing education are likely to have a similar impact. Based on new models for learning, they are likely to be increasingly effective in delivering relevant knowledge to larger audiences than are reached by current programs. The lessons learned by private sector companies that have succeeded and failed in the face of disruptive technologies can provide useful models for directors of CME as they formulate strategies for the future (Clayton M. Christensen & Armstrong, 1998).

E-learning 2.0 technologies have the potential to profoundly impact continuing education for healthcare professionals (CE/CME). The evolution of CE/CME over the years can be characterized as a move from old-fashioned didactic lectures over coffee and donuts to online instruction closely resembling the traditional counterparts to a digital enterprise of high-tech, interactive, global, instantaneous, and collaborative exchange of information. For years, the tradition and culture of continuing medical education (CME) assumed that physician learning and performance improvement would result from a simple one-way delivery of information. Over the last decade, as it did with other learning groups, the Internet has stimulated significant changes. Healthcare educators now are able to leverage the Internet to overcome healthcare professionals' lack of time for traditional learning activities and to reach a broader audience, such as those working in more remote and underserved areas.

E-learning 2.0 technologies, such as Web services, semantic Web, social networks, and rich Internet technologies, have the potential to bring continuing healthcare education into a new era as a digital enterprise. However, like so many other disruptive technologies, they also can lead to significant failures. Building on several e-learning experiences (Casebeer, Allison, & Spettell, 2002; Casebeer, Bennett, Kristofco, Carillo, & Centor, 2002; Wall et al., 2005; Casebeer et al., 2006; Houston et al., 2007; Houston & Ford, 2008; Houston et al., 2008), our goal in this chapter is to provide a conceptual guide for early adopters of e-learning 2.0 technologies in CE/CME. While we discuss many opportunities presented by e-learning 2.0, we also recognize the need to modify current operations to facilitate the new opportunities. The chapter goes on to discuss two categories of barriers to adopting e-learning 2.0, and we describe several approaches in use by our academic CME group to develop best practices approaches for e-learning 2.0 adoptions in CE/CME operations.

E-LEARNING 2.0 OPPORTUNITIES FOR CONTINUING EDUCATION OF HEALTHCARE PROFESSIONALS

Defining E-learning 2.0

Before adopting e-learning 2.0, it is important to understand that it involves much more than technology (Downes, 2005; Ebner, 2007; Toub & Kostic, 2008). E-learning 2.0 is a cultural change, and it also has been referred to as social learning (Hart, 2008). This represents a key shift over e-learning 1.0. In e-learning 1.0, information flows "unidirectionally" from content creators to content consumers with the roles of the content creator and consumer generally fixed. In contrast, in e-learning 2.0 paradigms, information is socially and dynamically generated, meaning that a content creator in one instance becomes a content consumer in another instance involving the same learning activity. Accordingly, Ferretti et al. note

Table 1. Types of E-Learning 2.0 Technologies Beneficial to Continuing Education of Healthcare Professionals

Technology	Description
Web services	Web services provide standardized technology for integration and composition of infrastructure applications such as databases, tools, software, etc. (Brown, Johnston, & Kelly, 2002; Channabasavaiah, Holley, & Tuggle Jr., 2003). Web services are a critical piece to be considered for integration of disparate sources of information in an e-learning 2.0 infrastructure. Example Web services technology include SOAP, Web Services Description Language, and Business Process Execution Language (Newcomer & Lomow, 2005; Sadasivam, Tanik, & Kristofco, 2006; Sadasivam, 2008).
Semantic Web	The semantic Web is an extension of the current web to give information well-defined meaning, better enabling computers and people to work in cooperation (Berners-Lee, Hendler, & Lassila, 2001). The semantic Web builds upon Web services with the addition of semantics and ontologies to enhance the search for and access of information. The major efforts in the semantic Web are the development of new content markup languages, which finally has led to the W3C specifications of the Web Ontology Language (OWL) and the revised Resource Description Format (RDF) (Martin et al., 2004; World Wide Web Consortium, 2004).
Course development and management systems	Course development and management systems facilitate the easy, collaborative, and asynchronous creation of courses by different users. Examples of course development systems are Blackboard WebCT, Moodle, and Sakai.
Web 2.0, Rich Internet Applications (RIA), and social networking technologies	Web 2.0 features a new approach of presenting and developing content on the web (O'Reilly, 2005). Web 2.0 is very user-centric, enabling personal publishing where users can create their own data (Lin, 2007). Web 2.0 features include RIAs and social networking technologies. RIAs such as AJAX (Asynchronous JavaScript and XML) and Flex facilitate the enhanced presentation of content on websites. Social networking technologies such as Wiki, forums, blogs, and instant messaging facilitate the synchronous and asynchronous creation of new content. A discussion of the use of these Web 2.0 technologies in healthcare education is provided in (Kamel Boulos & Wheeler, 2007).
Video and audio technologies	Video and audio technologies provide an alternative way of presenting content. Video and audio can be presented in Real streaming, QuickTime, or Windows Media format.
Gaming and simulation technology	Gaming and simulation technology are gaining popularity as a means of e-learning. Gaming can provide a fun and engaging way of learning. Simulation technology can be used to develop models representing real world entities, which then can be used as a basis for learning.
Push technologies	Push technologies are used to enhance the e-learning experience. While pull technologies such as websites or forums expect users to come and interact with the learning medium, push technologies such as RSS, text messaging, and podcast can push content to the users. RSS (Really Simple Syndication, Rich Site Summary or RDF Site Summary) facilitates the quick publishing and syndication of new content. Podcasts allow the syndication of audio and video files. Text messaging can be used to send content to users' mobile devices.

that e-learning 2.0 has cast a new light over processes and roles in acquiring knowledge (Ferretti, Mirri, Muratori, Roccetti, & Salomoni, 2008). A broad definition of e-learning 2.0 is the ability to access socially and dynamically, create, and share knowledge in a multidimensional, instantaneous, collaborative, and interactive manner.

E-Learning 2.0 Technologies

Table 1 lists several e-learning 2.0 technologies that have played significant roles in the transformation of continuing education of healthcare professionals. The features and primary characteristics of each technology are described briefly, and references are provided for those readers interested in further study.

E-learning 2.0 and Current CE/CME Practices

Most physicians spend the majority of their active professional careers engaged in informal, self-directed learning activities. The goal of CE/CME is to provide effective, evidence-based programming to help health professionals with these identified needs, ultimately leading to better health care and improved patient health. In addition, adult learning principles (Merriam & Caffarella, 1999) are commonly used in the design of continuing education programs for healthcare professionals to increase their effectiveness for these audiences. While e-learning 2.0 presents many opportunities to enhance online learning, current CE/CME practices have not successfully integrated the use of e-learning 2.0. Despite overwhelming evidence suggesting that interactive resources are more effective than static information (Zeiger, 2005), a review of online CME practices shows that the majority of these online resources closely resemble their traditional counterparts (Zimitat, 2001). This lack of interactivity has resulted in reduced effectiveness of many online programs. For example, many physicians have reported concerns including lack of specific information, too much information, and poor formatting of resources (Andrews, Pearce, Ireson, & Love, 2005). In an age of instantaneous information, the web-based CME content development process also continues to be time-consuming and laborious. It takes too long for healthcare experts to find relevant information, coordinate their activities with CME professionals, apply necessary quality criteria, format the content into appropriate web delivery, and upload the content to web servers. Contrary to new synergistic learning models that emphasize interaction, current web-based professional continuing education is still primarily a one-way transaction between content experts and participant learners. The two following case scenarios illustrate opportunities as well as several critical challenges when using e-learning 2.0 in CE/CME activities.

The course development activity described in Case #1 is not uncommon and illustrates several critical limitations that can be addressed with e-learning 2.0.

Lack of Integrated Users and Collaboration

The organization of responsibilities in the development of the activity was distributed among a relatively large number of people in sequential fashion, contributing to a lack of efficiency. By using e-learning 2.0 collaboration software, the course can be developed asynchronously in a very efficient fashion.

Case #1. Course Development Activity

Dr. Allgood, a health expert, is interested in increasing the knowledge and skills of primary care physicians, and he assumes that with the development of an appropriate education program, this can be accomplished.

Ms. Bates, a CME professional, agrees to collaborate with Dr. Allgood to develop an online CME activity to address identified learning needs. Dr. Allgood enthusiastically agrees to prepare some educational content for the proposed course and return it to her when he thinks it is ready for distribution.

Dr. Allgood decides to contact Dr. Cook, a new junior faculty member, and asks her for help in developing up-to-date instructional content. To ensure that she includes all the important and relevant information, Dr. Cook conducts a thorough literature review of high blood pressure on the Internet by searching several databases such as PubMed, Medscape, Medline, and Science Citation Index. She synthesizes her findings and prepares a detailed Microsoft Word document. Dr. Cook forwards the document to a colleague, Dr. Doyle, to review the document's accuracy and thoroughness. Dr. Doyle agrees, and inserts his comments before sending it back to Dr. Cook, who makes some final changes and forwards the document to Dr. Allgood. Dr. Allgood makes only minor modifications before sending the document on to Ms. Bates.

Ms. Bates then makes a decision about the online instructional strategy to use and then develops a set of questions to assess participants' self-report of the impact and effectiveness of the new online module. Ms. Bates calls upon an in-house IT expert, Mr. Errez, to program and disseminate the activity through their website. Mr. Errez converts the document to an online format and configures the evaluation and instructions on the course website for earning credit for participation. Finally, the activity is released to a public audience of practicing physicians.

Lack of Integrated Information

Dr. Cook spent a large amount of time conducting a thorough literature review, which involves searches in several online databases. Instead of that, an e-learning 2.0 tool that integrates information from these different sources could be of great value to Dr. Cook and could accelerate the course content development process.

Lack of Enhanced Interaction

When the course is finally uploaded to the website, the information is presented in a static fashion. Learners have limited ability to interact with the course, the course developers, or their peers. As a result, the module is very non-interactive, reduces the effectiveness of the course, and fails to integrate critical components of adult learning theory (Knowles, 1990).

The learner experience described in Case #2 is unfortunately quite common and ultimately fails to provide a meaningful educational experience that will improve this physician's clinical performance. So what are some key issues and barriers that can be addressed using e-learning 2.0?

Lack of Integrated Information

Internet search strategies can be difficult, and locating specific, information related to complex issues involving multiple conditions and different treatment options can be time-consuming. Dr. Ferrini could have used an e-learning 2.0 tool that provided access to the various sources of information and saved both time and aggravation.

Lack of Integrated Users and Collaboration

Dr. Ferrini also discovered that once information is located, it is challenging to verify the credibility of its sources. If the accuracy of the information is questionable, physicians run the risk of using it to their patients' potential detriment. Dr. Ferrini could have benefited from the ability to debate the authenticity of the information with other professionals.

Lack of Enhanced Interaction

Dr. Ferrini's interaction with the information is limited in several ways. Dr. Ferrini was restricted to searching for static information on the Internet.

Case #2. Participation in Traditional E-learning CME Activity

Dr. Ferrini works as a primary care physician in small town. While reviewing his charts, he notices a large percentage of his patients suffer from the same chronic condition. Dr. Ferrini is uncertain about the steps he should take to improve their health. Should he investigate more about his patients' medication adherence? Should he increase their medication? Should he be more aggressive in helping them pursue healthy lifestyle modifications?

Dr. Ferrini decides to conduct on online search to see if he can find some relevant information to provide him with some direction and options. First, he sifts through abstracts he finds in literature databases. Even though he finds several relevant studies, Dr. Ferrini does not find straightforward, easy answers to his specific questions. He then looks for clinical guidelines, but he discovers that they are too lengthy and difficult to translate into concrete next steps that would apply to his specific patient population.

Fortunately, Dr. Ferrini discovers several interesting CME opportunities on new medical advances, but most are live events such as conferences and seminars and would require too much time away from the office. He also worries that the print materials he finds available for order might be out of date by the time they arrive and he gets a chance to review them. The online courses he finds force him to scroll through lines and lines of text, and several are not from recognizable providers, which makes him a little nervous and creates a question of credibility in his mind.

After about an hour on the Internet, Dr. Ferrini has found a great deal of information and has acquired some knowledge he did not have before. Unfortunately, he does not have any way to earn CME credit for the time spent searching, and he still has not found exactly what he needs.

Many of the websites that contained medical information consisted of simple presentations of best practices in managing chronic conditions. As a result, Dr. Ferrini was restricted to scrolling through several pages of text on several sites, information that was for the most part already familiar, to find relevant answers. Dr. Ferrini also could not discuss the information he found with peers to clarify some of his existing doubts. Since CME professionals have no way of monitoring Dr. Ferrini's activity, he also could not receive appropriate credit for his learning efforts.

TRANSFORMING CONTINUING EDUCATION OF HEALTHCARE PROFESSIONALS WITH E-LEARNING 2.0 TECHNOLOGIES

An E-learning 2.0-based Digital Enterprise Model for CE/CME

An E-learning 2.0 approach presents a number of new opportunities for CE/CME professionals. With e-learning 2.0 technologies, CE/CME educators have the capability to streamline needs assessment and content development processes by connecting CME facilitators, content experts, and learners to promote the exchange of information and ideas. Figure 1 depicts an e-learning 2.0-based conceptual model for CE/CME. The model shows the gradual transformation of CE/CME operations from a traditional face-face operation to a new transformed model of CE/CME that can operate as a digital enterprise. Using E-learning 2.0 technologies, all CE/CME users can be interconnected, information can flow freely between participants, access to internal and external resources such as databases and Web services can be seamless, and the interaction between participants and information can be enhanced. Successful transformation will require those adopting e-learning 2.0 technologies to focus their time and attention on three important and interdependent challenges:

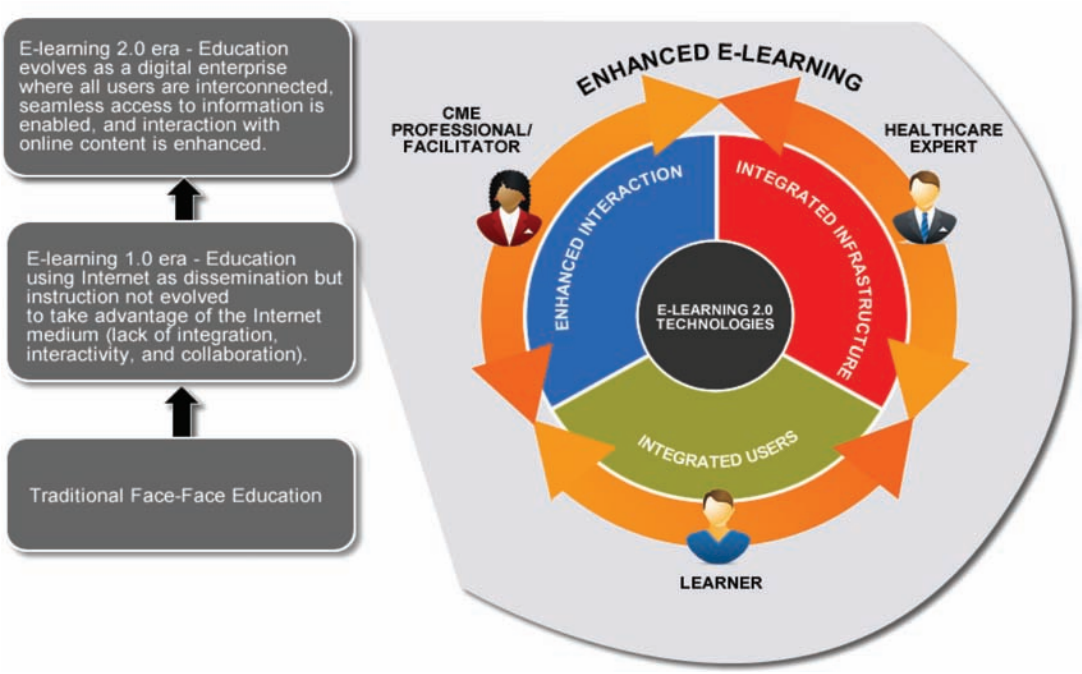
Integrating Users

Our conceptual model includes three sets of users: the CME professional/facilitator, the health care expert, and the learner. In traditional CE/CME models the roles of the three sets of users are clearly defined, but in e-learning 2.0 users are constantly moving between and among roles. A user might be a health care expert providing education to others in one instance, while in another scenario the same user could be in the role of learner. In traditional CME programs, course information typically flows in a unidirectional manner from the health care experts or facilitators to learners. In most current programs, an instructor (with help from CME professionals) designs a course with a designated amount of CME credit based on perceived level of difficulty of that course. In contrast, using e-learning 2.0 technologies, learners can initiate an educational activity by posing questions to facilitators, or healthcare experts can become learners in interactive discussion forums. Since learning happens in a very informal setting, it becomes more difficult or complicated to assign credit for a learning activity. Integrating users will allow CE/CME professionals to track user participation and assign credits in a new and improved way that reflects time and effort accurately. In addition, integration of all users contributing to a continuing educational activity creates a collaborative work process that yields the greatest efficiency in terms of time and effort. Only after all users are fully integrated can information flow in a multidirectional manner. Integrated users will be able to participate in a vast array of CE/CME activities, collaborate with each other, and actively participate in discussions while changing roles easily.

Integrating Information

In our conceptual model, information flows seamlessly between different user groups in a multidirectional manner. This is in contrast to

Figure 1. E-learning 2.0-based Digital Enterprise Model for Continuing Education for Healthcare Professionals



traditional CE/CME models, where information typically flows from health care expert or CE/CME professionals to the learners. Integration of information across diverse and disparate sources such as databases, web sites, documents, etc. is critical to the e-learning 2.0 educational process. Integrated information allows users to have an enhanced ability to search, access, and create new knowledge.

Enhancing Dynamic Interaction

Figure 1 also illustrates enhanced interaction between users involving information. Enhanced interaction means that users can access information from anywhere, using any devices. For instance, a user who is traveling will have access to information through his or her mobile device. The same user while sitting in his office will have access to information through his desktop. This transformative change implies that the information must be customized depending on the users' environment. E-learning 2.0 technologies have the capacity to build tools that allow users to interact with each other and information in a humanized, customized, and personalized way (Ramamoorthy, 2000). These technologies also can significantly enhance the way users access a particular educational activity. Activity formats can be personalized, based on educational appropriateness and learner preference, via deployment through web applications, mobile applications, audio or video activities, or even computer games and simulations. Tools that allow for this kind of personalization allow facilitators to address differences in adult learning styles.

To demonstrate application of this conceptual model, let us take another look at Cases 1 and 2 in which we now apply an e-learning 2.0-based digital operation model for each CE/CME scenario.

Case #3:*Continuing Medical Education E-learning 2.0 Activity*

During an Internet search on new medical advances, Dr. Ferrini discovers a web blog sponsored by Dr. Allgood at a university medical center. After joining the blog, he learns that Dr. Allgood and other experts at the academic medical center are conducting an interesting and lively discussion on the challenges they face in caring for patients.

The e-learning 2.0 system developed by Ms. Bates and Mr. Errez in the continuing medical education office allows the CME professional staff to monitor the content of the discussion blogs and reveals that many of the participants have very similar questions about the same set of issues. Based on this observation, Ms. Bates and Dr. Allgood decide to develop a web-based course activity anchored on the important content themes appearing in the blog, which they believe accurately reflect gaps between best practice established at the academic medical center and current practice out in the community.

Dr. Allgood then uses a literature integration software program to pull together related information from various scientific literature databases to create a strong evidence base for the CME course content. Dr. Allgood asynchronously works with several of his colleagues to revise the course information with an eye towards the potential (learner) audience. Ms. Bates (who provides instructional design expertise), manages the entire process to ensure that the revised course meets the appropriate quality guidelines. This expanded, evidence-based course content is then securely posted to the CME course website.

Dr. Ferrini is delayed at the airport late one night when he receives a text message from the CME office to his mobile phone announcing the release of a new online educational activity. Dr. Ferrini then accesses and completes the interactive, case-based module on his mobile phone. Dr. Ferrini also starts a forum thread to discuss with others application of the key elements of the case to his practice. Reflecting on this activity, Dr. Ferrini concludes that his educational experience was more meaningful than what he has experienced in the past, and he is particularly pleased that the course addressed several of his specific patient concerns. The e-learning 2.0 system developed by the CME office tracks Dr. Ferrini's course usage and awards the appropriate amount of CME credit to him.

Integrated Users

This case richly illustrates the benefits of having an integrated set of users and collaboration tools. Dr. Allgood and Ms. Bates were able to identify a key education need of the community based on the blog discussion. Dr. Allgood and his colleagues also were able to develop the course efficiently by working asynchronously with each other, and the system is aware of Dr. Ferrini's time and effort and is able to track and reward his learning activity.

Integrated Information

Using literature integration software, Dr. Allgood is able to pull together relevant information quickly from a large number of scientific literature databases to create a strong evidence base for the course content.

Enhanced Interaction

In this example, interaction is enhanced in multiple ways. First, Dr. Allgood is able to pull together quickly information from different databases. Then he is able to develop his course rapidly by working with others asynchronously. Ms. Bates is able to identify a key education need by monitoring the blog and can manage the course development activity asynchronously to ensure quality. Dr. Ferrini is able to participate in a discussion that enhances his educational experience, interact with the course from his mobile phone, and obtain the benefit of a course developed based on his specific clinical questions in the online discussion. The CME professionals are able to track Dr. Ferrini's leaning activity and assign appropriate CME credits to Dr. Ferrini.

Socio-Technological Barriers to Adoption of E-Learning 2.0 in CE/CME

Despite the exciting potential e-learning 2.0 technologies have for continuing educational of healthcare professionals, significant barriers exist that could interfere with their successful adoption. For purposes of discussion, these barriers will be categorized as either socio-technological or educational. In practice, however, the barriers are intertwined and sometimes difficult to untangle. If left unchecked, these barriers can create inefficiency and reduce adoption of e-learning 2.0 technologies. A useful framework for identifying these barriers is the interaction model (IM) of digital enterprises, which describes three types of interactions in a digital enterprise (Ramamoorthy, 2000). The first category of interactions is described as mechanistic or computer-to-computer interactions. An example of this type of interaction is website software interacting with a database for data access. The second category is mechanistic-individual or interactions between computer processes and individuals. An example would be a learner interacting with a website to complete an online course. The third category is mechanistic-team interactions, or those between computer processes and teams. An example of this interaction type would be a healthcare expert team working with facilitators or CME professionals to develop an online course. Using the IM model as a framework, we propose that the full scope of CE/CME transformation to a digital operation involves integration of a range of human interaction processes (Harrison-Broninski, 2005). Inability of organizations to address social, technological, and behavioral factors of the human interaction processes will lead to problems such as integration confusion. Integration confusion (Yeh, Pearlson, & Kozmetsky, 2000) occurs when incompatible e-learning 2.0 technologies are adopted (no sharing of information or users) and no organizational changes are made to accommodate these technologies. Consequently, organizations will find that the users and information linked with each e-learning 2.0 technology exist in functional silos, implying a lack of integration.

To avoid such problems as integration confusion, organizations should carefully and systematically modify existing policies and procedures to accommodate new e-learning 2.0 technologies. Enhanced interactions between CME professional staff, content experts and learners may require new skills for all participants who may be more used to traditional roles and educational models. Accurately identifying the new skills and behaviors needed to implement e-learning 2.0 technologies will require an additional level of analysis. For that purpose, we have classified socio-technological factors into three categories: (1) settings, which includes geographic and economic considerations; (2) people, which includes familiarity with and acceptance of such technologies in health care; and (3) technology, which includes challenges such as lack of a variety of infrastructure resources, data standards, proprietary issues, security, integrity, and privacy.

Settings

The specific work settings where users are found play an important role in the adoption and success of e-learning 2.0 applications. For example, e-learning 2.0 applications that are successful in an urban location may not work effectively in a rural location due to technology limitations and economic constraints. Questions about whether the available technological resources are able to support an application deployment platform will need to be answered before selecting the deployment approach.

People

Users' comfort level with technology and computer knowledge also plays a decisive role in the selection of an appropriate application. Studies have shown that lack of computer or information-seeking skills and lack of time often prevent physicians from engaging in Internet-based educational activities (Bennett, Casebeer, Zheng, & Kristofco, 2006). Sophisticated applications with complex interfaces are more likely to be accepted by technologically savvy users, while less sophisticated users are more likely to adopt simpler applications with easy-to-use interfaces. For some educators, the lack of technical know-how makes it difficult to design and deploy educational programs on the Internet. In other cases where collaboration technologies such as discussion forums have been tested, participation rates of healthcare professionals sometimes have been negligible, which may reduce the motivation level of educators who may otherwise employ them. People also must be open to the idea of granting access to information and sharing in ways that they may not be used to doing.

Technology

Technology factors, including lack of infrastructure resources, data availability, data standards, proprietary issues, security, integrity, and privacy play a key role in determining the complexity level of educational applications. For some educators, the lack of technical infrastructure is simply too overwhelming or burdensome to develop interactive applications. Integration of data and services must overcome issues such as legacy applications, incompatible interfaces, and proprietary limitations in order to provide effective continuing education. Integration of users overcoming issues such as diversity of locations, time factors, and technology access level also is a key factor in providing effective continuing medical education. The security, integrity, and privacy of data must be considered in determining the type of applications that can be deployed so that users can trust that their contributions, and in some cases their educational records, are safe and valued.

Educational Challenges to Adoption of E-Learning 2.0 Technologies to Continuing Education of Healthcare Professionals

While e-learning 2.0 presents many opportunities to enhance CE/CME education, it also introduces a number of educational challenges. Consider a web-based blog learning activity as an example. A user blogs on a health topic of interest. Another user finds the blog and comments on it. The first user synthesizes the comments, conducts some research on the topic, and responds to the comment on the blog. The discussion goes back and forth, with many other users joining in. Questions that could be asked on the activity include: 1) Does learning happen on the blog? 2) Is the learning happening in a structured format as in e-learning 1.0? While the answer to the first question is yes, learning happens, the answer to the second question is that it is not a structured activity. This dynamic and unstructured format of learning presents a number of challenges to CE/CME educators. We list a number of key questions below:

How Do We Measure Learning Needs and Outcomes?

Continuing education programs for healthcare professionals should be learner-centered, responsive to learner needs, and have meaningful and measurable outcomes (Davis et al., 1999). Use of e-learning 2.0 technologies provides educators with more sophisticated options in the design of educational content, based on the results of needs assessment. Traditional barriers to identifying learner needs through needs assessment have involved lack of time and difficult access to learners prior to program planning and design (Mazmanian, 1980; Moore & Cordes, 1992). However, most of these are based on the e-learning 1.0 paradigm (Grant, 2002; Norman, Shannon, & Marrin, 2004). The dynamic nature of learning with e-learning 2.0 presents new challenges in measuring learning needs and outcomes.

How Do We Maintain Quality Standards for Course Content?

A digital learning environment can lead to the rapid development of course content in response to identified learners needs. Maintaining rigorous quality standards for course content provides both a challenge and an opportunity for the continuing education professional. As the number of e-learning opportunities has increased dramatically in the last 5 years, the need for standards has become more clear (Ruiz, Mintzer, & Leipzig, 2006). A number of organizations have published standards for the development of e-learning, including the United Stated Department of Defense SCORM specifications (Fallon & Brown, 2003). Since e-learning 2.0 also occurs in places such as blogs and discussion forums, how do we ensure the quality of the course content?

How Do We Award CME Credit?

Continuing medical education credit is currently (and traditionally) awarded based on number of participant hours, with different states mandating various amounts of hours per year for re-licensure (Zeiger, 2005). When physicians participate in online learning for CME credit, most CME providers translate the number of hours the participant reports having spent on the activity into CME credit earned. This approach to translating learner activity into CME credits becomes problematic when e-learning 2.0 continuing education activities expand the range of learner behaviors to include time spent on internet searches and other self-directed learning activities. One example of an approach to address this challenge is the American Medical Association's Self-Directed/Self-Initiated (SDSI) Internet CME Pilot Project (American Medical Association, 2004). While professional associations recognize that this takes place, they have not yet been able to create a credit system that rewards the activity or behavior of facilitating the learning of others. In other words, continuing education accreditation standards have not yet caught up to technology as it relates to new models of learning.

How Do We Integrate E-Learning 2.0 with Other Traditional CME Offerings?

A question for researchers and program developers involves whether programs designed using e-learning 2.0 technologies can replace completely the need for more traditional CME activities. Are all learning needs effectively addressed with e-learning? Are all areas of the CME curriculum effectively taught by e-learning approaches? Can "e-conferences", for example, replace the need for live conferences, grand rounds lectures, journal clubs and other live events? Clearly, one advantage of e-learning approaches is their ability to create options for learners who may prefer live events but have real barriers involving time and place (Zeiger, 2005).

These educational challenges, like the socio-technological barriers described earlier, need to be addressed appropriately in order for e-learning to complete the transformation of continuing education of healthcare professionals to a digital enterprise.

Technology Framework: Service-Oriented Approach for Deployment of E-Learning 2.0 Technologies

Service-oriented-architecture (SOA)-based deployment may provide an effective technical framework for addressing barriers and adopting e-learning 2.0 technologies (Sadasivam, 2008; Sadasivam & Tanik, 2008). SOA provides a flexible, scalable, common, and convenient platform for integrating and consuming disparate data sources (users and infrastructure) (Newcomer & Lomow, 2005; Sadasivam, Tanik, & Kristofco, 2006). SOA also provides a pluggable framework for incorporation of organizational policies and procedures. Many commercial entities lead in the adoption of SOA-style deployment for transforming infrastructure into digital enterprises. Transformation with SOA is typically performed in phases, in which organizations first develop a consistent global strategy of deployment and then proceed with implementation in small, digestible chunks (Channabasavaiah, Holley, & Tuggle Jr., 2003). This development paradigm parallels our model of transforming continuing education, which involves building a seamless digital enterprise that advances in a gradual fashion.

SOA addresses socio-technological challenges of applying e-learning 2.0 technologies at three levels (Willig, Sadasivam, & Tanik, 2008). First, SOA provides a standard approach to the integration of heterogeneous data sources (sources with users and learning activity data). It also provides a flexible solution to configure and integrate the policies and procedures that are necessary to address the different socio-technological challenges. Finally, SOA provides a business-process-oriented approach to deploying targeted applications that address user needs. As business processes form a key lifeline for all organizations, deploying applications with a business-process-oriented approach allows the needs of an organization to be addressed in a systematic manner.

Two parts of SOA application development are the creation of services and the consumption of services.

Creation of Services

A service is defined technically as a location on the network that has a machine readable description of the messages it receives and returns (Newcomer & Lomow, 2005). A service provides uniform access to data sources. In this initial phase, services are developed for accessing the infrastructure resources by wrapping each heterogeneous resource with a service interface. The service interfaces describe the method of invocation, operations to be performed, the input format of the request, and the output format of the response. Other implementation details of the sources, including the type of data source and programming language of the data source, are hidden behind the service interface. Once the service is created, the data sources can be accessed and consumed through the service interface. Application developers are not concerned with the heterogeneity of the infrastructure resources. Instead, they deal with a homogenous service interface with well-defined rules for consumption.

Consumption of Services (Process-Oriented-Composition)

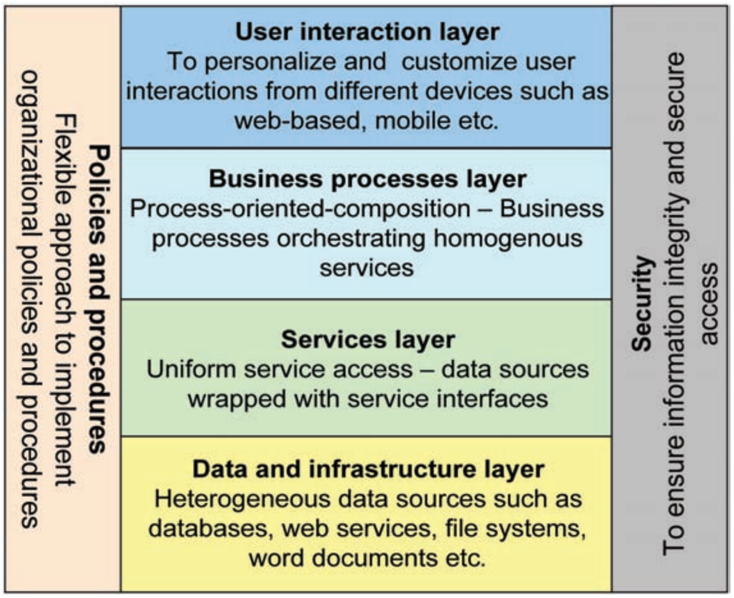
Once the services are created, application developers then build applications to request and consume the services. To avoid problems such as integration confusion, SOA recommends a business-process-oriented style of application development, with an emphasis on the consumption of services using business processes. Business processes can be implemented programmatically, as we are doing in our CME infrastructure, or using specialized business process languages, such as Business Process Execution Language or Business Process Modeling (Juric, Mathew, & Sarang, 2004; Pasley, 2005).

Figure 2 illustrates the layers of enterprise development with SOA. The base layer represents the heterogeneous infrastructure of an enterprise, such as databases, software, tools, and technology that a user would need to complete the task. The services layer represents a uniform layer of service interfaces that can be used to consume the infrastructure resources. The third layer is the business process layer or application layer. It represents the various applications of the enterprise that correspond to different needs. Finally, the top layer is the interaction support layer, which represents web-based or interaction tools that allow users to interact with the enterprise applications. On the left side is the policy and procedures layer, which represents a flexible layer to configure organizational policies across the layers. On the right side is the security layer to ensure secure access and storage of the organizations' information.

Towards E-Learning 2.0 Adoption: Example Implementation Approach

Our academic medical center has been developing and deploying e-learning applications for more than a decade. However, as with many other e-learning organizations, our infrastructure has often grown in response to the disparate needs

Figure 2. Layers of Enterprise Development with Service-Oriented Approach



of each new project. Over time, this sequence of non-strategic changes has made us inadvertently less efficient in achieving our long-term academic goals. Consequently, we recently have begun strategic development of several e-learning 2.0 initiatives that we predict will transform our unit into a more efficient, seamless digital enterprise. Two projects that illustrate our new approach to content development and delivery (or service creation and consumption) will be reviewed in this section. We begin by outlining and evaluating our efforts to address the infrastructure needs for deploying e-learning programs. The point-of-care CME program described next illustrates our efforts to identify specific challenges in the application of e-learning 2.0 technologies with an innovative point-of-care pilot study.

Example service-oriented approach for e-leaning 2.0 adoption: Reconstruction of CME infrastructure:
The CME infrastructure project addresses integration of our resources (users and information). The steps in the project follow the SOA approach closely.

Creation of CME Services

The first step in creation of CME services was to develop a data model to capture our users and course information. This step required that we analyze our existing projects, including the e-learning materials offered, the users list, the users' responses, and assessment protocol. Based on these results, we designed and implemented a data model that captures all the necessary information. A SQL database was used to implement the data model. We also created a service layer using Microsoft .Net technology to perform operations on the SQL database in a systematic manner. The creation of CME services enables us to deploy e-learning 2.0 activities integrating the existing users in our database. For users, this means the ability to traverse from one e-learning 2.0 application to another seamlessly without having to re-register or re-login. For CME professionals, this means being able to monitor the users' learning activities and award them appropriate credit.

Consumption of CME Services

In order to facilitate consumption of these services, we then created an online LMS system using Microsoft .Net technology. This gave us the capacity to develop new courses quickly and easily and deploy them through our three primary websites – the online continuing medical education site, the Alabama practice-based network, and the Mississippi practice-based network. The LMS has two parts. The first is an administrative interface that provides features to create courses collaboratively and asynchronously, and the second is a business process layer that makes it easy to consume the course. We are currently working on the development of a user-interaction layer to present the course on all the sites using the data from the business process layer. The user-interaction layer also will customize the course to other mediums, such as mobile phones or other portable devices. We also are working on adding discussion forums to the CME website to allow users to participate and discuss their questions with their peers and health experts.

While we have only started the work on reconstruction of the CME infrastructure, we will have an integrated and interconnected infrastructure on which to deploy new e-learning 2.0 programs once it is finished. We anticipate that it will be relatively easy to deploy new programs, leveraging the integrated infrastructure and not having to redevelop specific structures such as the database model and data access programs from scratch. The integrated infrastructure also will make it easier to personalize the learners' interaction with the education program. For instance, learners can interact using web-based or mobile devices depending on their preferences. In addition, we will be able to access a learner's data from one source instead of from several sources. A learner's data will provide a rich source to estimate the effectiveness of the CME programs and for data that is usable for program improvement.

Example modifications to educational policies: Point-of-care CME program

In point-of-care (POC) activities, physicians engage in an active search for specific information at the point of the patient encounter when a new condition or a clinical question arises(American Academy of Family Physicians). The significance of POC as a CME activity is the direct impact it can have on the quality of patient care (Ebell, 2003; Berkenstadt et al., 2006; Doran et al., 2007; King et al., 2007). Similar to other e-learning 2.0 scenarios, point-of-care learning represents a striking change in the way continuing education for health professionals is traditionally conducted and raises a number of challenging questions from an educational viewpoint. Some of these include questions about factors that motivate learners to access resources at the point-of-care, as well as questions concerning the quality of point-of-care learning encounters.

The learning activity website was designed for use during a five week period from July 16, 2007, until Aug 21, 2007, and contained resources for delivering effective clinical care for participating physicians (or the physicians' staff). Participants for this pilot study were primary care physicians from two practice-based networks that serve Alabama and Mississippi. The primary goal of the study was to identify a means of providing CME credit that would encourage physicians to participate in e-learning 2.0 activities and overcome barriers to such participation.

The pilot study was conducted in two phases of two weeks duration each, with physicians needing to complete a short questionnaire at the end of each phase in order to receive CME credit. Phase 1 awarded 4 CME credits for a minimum of 8 logins to the site and completion of the questionnaire by the user. During phase 2, users were awarded 0.5 CME credit every time they logged on, up to a maximum of 6 CME credits. A final questionnaire was required at the end of phase 2 to print the CME certificate carrying the CME credits that were awarded for usage of the website. All participants were eligible for the same incentives, which were advertised during the initial recruitment invitation. Benefits of participation included 24-hour access to the website and links to a collection of publicly available resources; a potential total of 10 CME credits for complete participation; a search feature for available topics within the site; and online access to an electronic therapeutics update subscription service. E-mail reminders were sent out weekly to registered participants, encouraging them to participate in the study and use the website in their practice.

The primary content area on the website was a list of 63 keywords and 188 links to the most common topics (Cancer, AIDS, women's health, etc), alphabetically ordered and linked to external websites that were either "framed" within the website or were placed as external links (in compliance with their web policies). The website was developed using the Content Management System DotNetNuke ("DotNetNuke Web Portal System") and included an SQL server database in the backend for capturing user data related to website usage.

A total of 24 CME credits was awarded in phase 1 of the study, and 24.5 credits were awarded for phase 2. The number of CME credit hours that could be claimed in phase 2 was higher by 2 credit hours, for a greater number of logons per learner, assuming that total time spent would be higher. While no conclusive data were found to suggest the relative effectiveness of one type of CME credit (partial or complete) over the other, the availability of credit appeared to be a highly effective incentive for participants.

Learners were asked about the factors influencing their decision to participate in the project. Results revealed an overwhelming majority of participants reported "free CME credits" and "convenience of on-line CME" as the major factors for participation in the study. The participant base was not completely new to on-line CME courses, with at least 7 of 9 users having had prior experience of 5 or more on-line CME courses. This might indicate that the participant base understands the advantages and convenience of on-line CME. Most of the learners suggested that they found the quality of the resources provided was 'excellent' or 'good.'

This pilot study clearly demonstrated that awarding CME credit was a motivating factor for health care providers to engage in point of patient care learning activities, although the amount of CME credit offered did not appear to be influential. Physicians were generally satisfied with the quality of the resources provided and reported that participation had an impact on their professional effectiveness. Lack of time surfaced as the largest barrier to participation, suggesting that e-learning 2.0 designers need to focus attention on displaying important information efficiently to make it salient to busy health care professionals.

CONCLUSION AND FUTURE TRENDS

This chapter has advanced the argument that e-learning 2.0 technologies have tremendous potential to dramatically change the landscape of continuing education programs for healthcare professionals. E-learning 2.0 technologies can be viewed as a type of disruptive innovation that will change fundamentally the way professional health education programs function, by adopting a user-centered approach that emphasizes interactivity among all participants. As the examples in this chapter illustrated, e-learning 2.0 cannot be applied successfully without carefully modifying existing continuing healthcare education learning and business models to accommodate the transformative changes. We have described a futuristic model of continuing education for health professionals following a transformation into a digital enterprise. While it is clear that e-learning 2.0 technologies have the power to simplify the process of interactive knowledge creation, management, and dissemination, they need to be deployed based on sound strategies to enhance the educational experience of the participants. A service-oriented approach of technology adoption has been presented, along with a discussion of the need for educational changes to address the manner in which e-learning 2.0 programs can be assessed and credited.

ACKNOWLEDMENT

We would like to thank Gayathri Sundar (Software Engineer, Infinity Insurance) for her assistance with creating Figure 1. We thank Dr. Murat Tanik (Professor, Electrical and Computer Engineering, UAB) for his thoughtful review of the chapter. We also thank Dr. Chittoor V. Ramamoothy (Professor Emeritus, University of California at Berkeley) for his overall guidance with digital enterprises. Finally, we are appreciative of the support and encouragement we received from Jeroan Allison (Assistant Dean and Director, CME, UAB) throughout the duration of this project. We would like to thank Susan Chandler Walker and Laura Gallitz (Administrative Assistants, Division of Preventive Medicine) for proofreading our chapter.

REFERENCES

American Academy of Family Physicians. (n.d). *Point of Care CME*. Retrieved Jan., 2009, from http://www.aafp.org/online/en/home/cme/cmea/cmeapplying/pointofcare.html

American Medical Association. (2004). *CPPD report: Newsletter for the continuing medical education community*. Chicago: The Division of Continuing Physician Professional Development.

Andrews, J. E., Pearce, K. A., Ireson, C., & Love, M. M. (2005). Information-seeking behaviors of practitioners in a primary care practice-based research network (PBRN). *Journal of the Medical Library Association*, *93*(2), 206–212.

Bennett, N. L., Casebeer, L. L., Zheng, S., & Kristofco, R. (2006). Information-seeking behaviors and reflective practice. *The Journal of Continuing Education in the Health Professions*, *26*(2), 120–127. doi:10.1002/chp.60

Berkenstadt, H., Yusim, Y., Katznelson, R., Ziv, A., Livingstone, D., & Perel, A. (2006). A novel point-of-care information system reduces anaesthesiologists' errors while managing case scenarios. *European Journal of Anaesthesiology*, *23*(3), 239–250. doi:10.1017/S0265021505002255

Berners-Lee, T., Hendler, J., & Lassila, O. (2001). The semantic Web [Electronic Version]. *Scientific Amer.* Retrieved May from http://www.sciam.com/article.cfm?articleID=00048144-10D2-1C70-84A9809EC588EF21

Brown, A., Johnston, S., & Kelly, K. (2002). A Rational software white paper: Using service-oriented architecture and component-based development to build service application [Electronic Version]. *developerWorks*, 15. Retrieved Nov. from http://www-106.ibm.com/developerworks/rational/library/content/03July/2000/2169/2169.pdf

Casebeer, L., Allison, J., & Spettell, C. M. (2002). Designing tailored Web-based instruction to improve practicing physicians' chlamydial screening rates. *Academic Medicine*, *77*(9), 929. doi:10.1097/00001888-200209000-00032

Casebeer, L., Andolsek, K., Abdolrasulnia, M., Green, J., Weissman, N., & Pryor, E. (2006). Evaluation of an online bioterrorism continuing medical education course. *The Journal of Continuing Education in the Health Professions*, *26*(2), 137–144. doi:10.1002/chp.62

Casebeer, L., Bennett, N., Kristofco, R., Carillo, A., & Centor, R. (2002). Physician Internet medical information seeking and on-line continuing education use patterns. *The Journal of Continuing Education in the Health Professions*, *22*(1), 33–42. doi:10.1002/chp.1340220105

Channabasavaiah, K., Holley, K., & Tuggle, E. M., Jr. (2003). Migrating to a service-oriented architecture, part 1 [Electronic Version]. *developerWorks*. Retrieved Dec. from ftp://www6.software.ibm.com/software/developer/library/ws-migratesoa.pdf

Clayton, M. Christensen, & Armstrong, E. G. (1998). Disruptive technologies: A credible threat to leading programs in continuing medical education? *The Journal of Continuing Education in the Health Professions*, *18*(2), 69–80. doi:10.1002/chp.1340180202

Davis, D., O'Brien, M. A., Freemantle, N., Wolf, F. M., Mazmanian, P., & Taylor-Vaisey, A. (1999). Impact of formal continuing medical education: Do conferences, workshops, rounds, and other traditional continuing education activities change physician behavior or health care outcomes? *Journal of the American Medical Association*, *282*(9), 867–874. doi:10.1001/jama.282.9.867

Doran, D. M., Mylopoulos, J., Kushniruk, A., Nagle, L., Laurie-Shaw, B., & Sidani, S. (2007). Evidence in the palm of your hand: Development of an outcomes-focused knowledge translation intervention. *Worldviews on Evidence-Based Nursing*, *4*(2), 69–77. doi:10.1111/j.1741-6787.2007.00084.x

DotNetNuke Web Portal System, (n.d.). Retrieved Sept. 25, 2008, from http://www.dotnetnuke.com/

Downes, S. (2005). E-learning 2.0. *eLearn, 2005*(10), 1.

Ebell, M. H. (2003). Point-of-care information that changes practice: It's closer than we think. *Family Medicine*, *35*(4), 261–263.

Ebner, M. (2007). *E-Learning 2.0 = e-Learning 1.0 + Web 2.0?* Paper presented at the The Second International Conference on Availability, Reliability and Security (ARES).

Fallon, C., & Brown, S. (2003). *E-learning standards: A guide to purchasing, developing, and deploying standards-conformant e-learning*. Boca Raton, FL: St. Lucie Press.

Ferretti, S., Mirri, S., Muratori, L. A., Roccetti, M., & Salomoni, P. (2008). *E-learning 2.0: you are We-LCoME!* Paper presented at the International cross-disciplinary conference on Web accessibility (W4A), Beijing, China.

Grant, J. (2002). Learning needs assessment: Assessing the need. *BMJ (Clinical Research Ed.)*, *324*(7330), 156–159. doi:10.1136/bmj.324.7330.156

Harrison-Broninski, K. (2005). *Human Interactions: The Heart and Soul of Business Process Management*. Tampa, FL: Meghan-Kiffer Press.

Hart, J. (2008). *An introduction to social learning: What is social learning?* Retrieved December 2008, from http://www.c4lpt.co.uk/handbook/sociallearning.html

Houston, T. K., & Ford, D. E. (2008). A tailored Internet-delivered intervention for smoking cessation designed to encourage social support and treatment seeking: Usability testing and user tracing. *Informatics for Health & Social Care*, *33*(1), 5–19.

Houston, T. K., Funkhouser, E., Allison, J. J., Levine, D. A., Williams, O. D., & Kiefe, C. I. (2007). Multiple measures of provider participation in Internet delivered interventions. *Studies in Health Technology and Informatics*, *129*(Pt 2), 1401–1405.

Houston, T. K., Richman, J. S., Coley, H. L., Ray, M. N., Allison, J. J., & Gilbert, G. H. (2008). Does delayed measurement affect patient reports of provider performance? Implications for performance measurement of medical assistance with tobacco cessation: A Dental PBRN study. *BMC Health Services Research*, *8*, 100. doi:10.1186/1472-6963-8-100

Juric, M. B., Mathew, B., & Sarang, P. (2004). *Business Process Execution Language for Web services: BPEL and BPEL4WS*. Birmingham, UK: Packt Publishing.

Kamel Boulos, M. N., & Wheeler, S. (2007). The emerging Web 2.0 social software: An enabling suite of sociable technologies in health and health care education. *Health Information and Libraries Journal*, *24*(1), 2–23. doi:10.1111/j.1471-1842.2007.00701.x

King, W. J., Le Saux, N., Sampson, M., Gaboury, I., Norris, M., & Moher, D. (2007). Effect of point-of-care information on inpatient management of bronchiolitis. *BMC Pediatrics*, *7*, 4. doi:10.1186/1471-2431-7-4

Knowles, M. S. (1990). *The adult learner: A neglected species* (4th ed.). Houston, TX: Gulf Pub. Co.

Lin, K. J. (2007). Building Web 2.0. *IEEE Computer*, *40*(5), 101–102.

Martin, D., Burstein, M., & Denker, G. Hobbs, Kagal, L., Lassila, O., et al. (2004). OWL-S 1.0 release. *Semantic Web services*, from http://www.daml.org/services/owl-s/1.0/

Mazmanian, P. E. (1980). A decision-making approach to needs assessment and objective setting in continuing medical education. *Adult Education Quarterly*, *31*(1), 3–17. doi:10.1177/074171368003100101

Merriam, S. B., & Caffarella, R. S. (1999). *Learning in adulthood: A comprehensive guide* (2nd ed.). San Francisco: Jossey-Bass Publishers.

Moore, D. E., & Cordes, D. L. (1992). Needs assessment. In A. B. Rosof & W. C. Felch (Eds.), *Continuing Medical Education: A Primer* (Second ed., pp. 42-51). New York: Praeger Publishers.

Newcomer, E., & Lomow, G. (2005). *Understanding SOA with Web services*. Upper Saddle River, NJ: Addison-Wesley.

Norman, G. R., Shannon, S. I., & Marrin, M. L. (2004). The need for needs assessment in continuing medical education. *BMJ (Clinical Research Ed.)*, *328*(7446), 999–1001. doi:10.1136/bmj.328.7446.999

O'Reilly, T. (2005). *What is Web 2.0: Design patterns and business models for the next generation of software*. Retrieved Sept. 30, 2008, from http://www.oreillynet.com/pub/a/oreilly/tim/news/2005/09/30/what-is-web-20.html

Pasley, J. (2005). How BPEL and SOA are changing Web services development. *IEEE Internet Computing*, *9*(3), 60–67. doi:10.1109/MIC.2005.56

Ramamoorthy, C. V. (2000). A study of the service industry - functions, features, and control. *ICICE Transactions Communications . E (Norwalk, Conn.)*, *83-B*(5), 885–903.

Ruiz, J. G., Mintzer, M. J., & Leipzig, R. M. (2006). The impact of e-learning in medical education. *Academic Medicine*, *81*(3), 207–212. doi:10.1097/00001888-200603000-00002

Sadasivam, R. S. (2008). *Architecture framework for process-personalized composite services: Service-oriented architecture, Web services, business-process engineering, and human interaction management* (Paperback ed.). Saarbrücken, Germany: VDM Verlag Dr. Mueller e.K.

Sadasivam, R. S., & Tanik, M. M. (2008). Composite process-personalization with service-oriented architecture In B. Unhelkar (Ed.), *Handbook of Research In Mobile Business: Technical, Methodological And Social Perspectives*. Hershey, PA: IGI Global.

Sadasivam, R. S., Tanik, M. M., & Kristofco, R. (2006, June 25-30). *A service-oriented approach for intelligent information integration and retrieval.* Paper presented at the Int. Design and Process Technology, San Diego, CA.

Toub, D., & Kostic, M. (2008). Collaborative CME using Web 2.0 technologies. *Alliance for CME Almanac*, *30*(8), 1–3.

Wall, T. C., Mian, M. A., Ray, M. N., Casebeer, L., Collins, B. C., & Kiefe, C. I. (2005). Improving physician performance through Internet-based interventions: Who will participate? *Journal of Medical Internet Research*, *7*(4), e48. doi:10.2196/jmir.7.4.e48

Willig, J. H., Sadasivam, R. S., & Tanik, M. M. (2008). *A conceptual framework for personalized mobile health care.* Paper presented at the Int. Design and Process Technology, Taiwan.

World Wide Web Consortium. (2004). *Web services consortium*. Retrieved from http://www.w3c.org

Yeh, R. T.-Y., Pearlson, K., & Kozmetsky, G. (2000). *Zero time: Providing instant customer value – Every time, all the time*. New York: Wiley.

Zeiger, R. F. (2005). Toward continuous medical education. *Journal of General Internal Medicine*, *20*(1), 91–94. doi:10.1111/j.1525-1497.2004.30049.x

Zimitat, C. (2001). Designing effective on-line continuing medical education. *Medical Teacher*, *23*(2), 117–122. doi:10.1080/01421590120036538

ADDITIONAL READING SECTION

American Academy of Family Physicians. Point of Care CME. Retrieved Jan., 2009, from http://www.aafp.org/online/en/home/cme/cmea/cmeapplying/pointofcare.html

Bower, J. L., & Christensen, C. M. (1995). Disruptive Technologies: Catching the Wave . *Harvard Business Review*, 13.

Harrison-Broninski, K. (2005). *Human Interactions: The Heart and Soul of Business Process Management*. Tampa, FL: Meghan-Kiffer Press.

Knowles, M. S. (1990). *The adult learner: A neglected species* (4th ed.). Houston: Gulf Pub. Co.

Merriam, S. B., & Caffarella, R. S. (1999). *Learning in adulthood: A comprehensive guide* (2nd ed.). San Francisco: Jossey-Bass Publishers.

Newcomer, E., & Lomow, G. (2005). *Understanding SOA with Web Services*. Upper Saddle River, NJ: Addison-Wesley.

Ramamoorthy, C. V. (2000). A study of the service industry - functions, features, and control. *ICICE Transactions Communications (Norwalk, Conn.)*, *83-B*(5), 885–903.

Rosof, A. B., & Felch, W. C. (1992). *Continuing medical education: a primer* (2nd ed.). New York: Praeger.

Tanik, M. M. NG, P., & Yeh, R. T. (1997). Electronic enterprise engineering – a 21st century discipline for a new generation of engineers. *NJIT Research*, 6-11.

Wikipedia.org. Disruptive technology. Retrieved Feb., 2009, from http://en.wikipedia.org/wiki/Disruptive_technology

KEY TERMS AND DEFINITIONS

Adult learning: A relatively new area of study, the term "Andragogy" initially popularized by the original work of Malcolm S. Knowles. Knowles postulated that adults are autonomous and self-directed learners, practical, goal-oriented, and are guided in their learning by previous life experiences and prior knowledge

CME or Continuing Medical Education: Continuing professional development of physicians that is required by each state for keeping up with advances in medicine and with changes in the delivery of care. A variety of CME providers exist, including the American Medical Association, state medical associations, medical specialty societies, most academic medical centers, etc. CME formats vary depending on provider, audience and special needs of the physicians

Disruptive technology or disruptive innovation: A technological innovation that improves a product or service in ways that the market does not expect, typically by being lower priced or designed for a different set of consumers. The term was first coined by Clayton M. Christensen in his 1995 article Disruptive Technologies: Catching the Wave

Digital enterprises: Enterprises whose operations are predominantly electronic. Can also be referred to as Service enterprises or electronic enterprises.

E-learning 2.0: The ability to access socially and dynamically, create, and share knowledge in a multidimensional, instantaneous, collaborative, and interactive manner

SOA or Service-Oriented-Architecture: A style of design that guides all aspects of creating and using business services throughout the development life cycle. The SOA lifecycle runs from the conception of the business service to its retirement. A service is defined technically as a location on the network that has a machine readable description of the messages it receives and returns.

Human interaction processes: Are business processes that are human driven rather than machine driven. Humans participate in and influence the execution of the processes. Keith Harrison-Broiniski describes the unique characteristics of human interaction processes in detail in his book "human interactions: The heart and soul of business process management."

Point-of-care access: Situations in which physicians engage in an active search for specific information at the point of the patient encounter when a new condition or a clinical question arises.

This work was previously published in Handbook of Research on Practices and Outcomes in E-Learning: Issues and Trends, edited by H. Yang and S. Yuen, pp. 308-328, copyright 2010 by Information Science Reference (an imprint of IGI Global).

Chapter 8.9

Health Information Standards:
Towards Integrated Health Information Networks

Stergiani Spyrou
The Medical School, AUTH, Greece

Panagiotis Bamidis
The Medical School, AUTH, Greece

Nicos Maglaveras
The Medical School, AUTH, Greece

ABSTRACT

This chapter presents an abstract view of the regional health information networks (RHN). A presentation of the architecture and structures of the RHN is included. It also reveals the need for integration of information in the framework of a RHN and key issues for the applicability of health information standards to achieve interoperable health care organizations which are the stakeholders of the RHN are presented. Furthermore, a list of case studies for the implementation of RHN in health systems in European, as well as non-European countries, such as the U.S., Canada, New Zealand, and Australia are demonstrated. Finally, important areas to focus when evaluating RHN are described. The authors hope that the abstract view of RHN would assist in the understanding of the key areas when building regional health networks.

DOI: 10.4018/978-1-60566-356-2.ch008

DEFINITION OF RHN

Since 1990s, the regional innovation systems gain the focus of researchers and policy makers as the framework for financial development in regional level and generally for innovation policy making. The territorial dimension of regional systems remains ambiguous, along with the role of actors in those systems. The regional health network offers health care services in a region through efficient administrative organization of health care providers in region and by means of regional innovation systems like the information systems, eHealth tools and services.

The definition of regional systems should start with the definition of the region. The literature is ambiguous on the nature and characteristics of the regional innovation systems (Doloreux & Parto, 2005). The term region has sometime the same meaning with the administrative regions or divisions of country. However a regional health network does not always correspond to administrative regions. The regional structure is also ambiguous, where the providers can be public or private companies and their collaboration is diverse depending mainly on the scope of the collaboration.

According to Oates & Jensen in (Oates & Jensen, 2000) "A health region is the geographical area where most health services are provided to the inhabitants in the area, and in which area the patient typically receives almost all of the health services they need." Following this definition in many healthcare regions the population may reach the 0,5 million or more.

Additionally, according to Grinten & Jarvis in (Grinten & Jarvis, 2007) "a Regional Health Information Organization is a multi-stakeholder organisation that enables the secure exchange and use of patient health information among clinicians and caregivers to improve the delivery, efficiency, quality, and safety of patient care."

Generally the new area for development of regional health networks follows the need for active involvement of patients in the decision making process regarding the health services or knowledge about health and quality of life. The eHealth tools and services, the World Wide Web and other information system and communication tools facilitate these needs.

The healthcare providers in region are mostly the following (Oates & Jensen, 2000): (1) Primary care providers, (2) Secondary, Tertiary and specialised hospitals, (3) Pharmacies, (4) Laboratories and diagnostic centers, (5) Specialists, (6) Other healthcare providers, and (7) Home care providers and midwife services

The aim of the regional health networks is the sharing of health care information among the healthcare providers in regional, national or cross-border level. The factors that define the degree of development of those networks are the organizational structure of health system, the need for information flows according to the organizational structure and the penetration of ICT in health.

HEALTH INFORMATION NETWORKS: ARCHITECTURE AND ORGANIZATIONAL STRUCTURE

There is a wide variation on how the ICT facilitate the organizational structure of RHN and the sharing of information either patient information or administrative and financial information. The organizational structure of a RHN provided by the health policy makers, determines the possible data owners and the ability to achieve interoperability among the stakeholders of a RHN determines the architecture of the information system that supports the RHN. The models for the architecture of RHN can be an abstraction of the architecture models of the Health Units. The systems that support the health units can be categorized in three models: transactional, federated, centralized depending to their ability for health information exchange with other health care providers, individuals, patients etc.

The participation of stakeholders in a regional system depends on the implementation of an interoperable health information infrastructure. The main barriers to achieve the interoperable infrastructure and facilitate the information sharing are the patient matching and legal data sharing agreements.

According to Wilcox et. Al. in (Wilcox et al., 2006) and the experience from the case studies of Health Information Networks, the architecture approaches for an interoperable health information infrastructure in an organization are (Thielst & Jones, 2007):

Transactional Model

The transactional model is characterized by the fact that the architectures supporting the stakeholders are separated systems. The communication among those systems is achieved through telephone, fax and other means especially facilitating the personal communication. This type of health information exchange is the most common even nowadays and especially for clinicians. However this approach requires little changes in the healthcare provider to participate in the healthcare exchange environment. The patient is often the "carrier" of this information.

Centralized Model

In this case, the systems supporting the healthcare enterprises are centralized. The model implied systems supporting the RHN to be centralized or even monolithic. Their implementation is based on a central data repository for the health information that is exchanged. This approach requires having shared data among disparate systems using tools and methodologies for interoperability among those systems. Interoperability issues that are key factor in achieving data sharing through this model include the common data vocabulary, standards for technical, semantic and functional/business integration, legal issues regarding the ownership of data, cost investment on integration solution's provider and coding and classification.

Federated Model

The model includes systems that are integrated through several mechanisms like notification of information exchange, context synchronization on multiple data sources according to the user selections etc. The model is characterized by data sharing environments that healthcare providers can exchange information without having a central data repository. According to this model the users, like clinicians, of the health information systems, like clinical information systems, may view several systems and access several data sources in a RHN when technology enables interoperability among several data sources. This model is convenient in use for the providers that are already familiar with systems that are already functioning. Additional the cost of change to build an integrated RHN environment may be less than that of a centralized one as it is not required to build central data warehouses or replace applications from the health care providers, which the users are already familiar with. Moreover legal issues regarding keeping a central data warehouse with sensitive patient data are not raised as each participating organization can keep his own datasources.

Many case studies implement the federated model, while other the centralized one. In both cases a key issue is the patient identification and matching algorithm, as the patient data are the information that most RHN aim to share among its stakeholders.

Organization and Industrial Impact

The organizational models of RHN are several depending mainly on the stakeholders for their financial investment. The most common models are the following:

- *Non-profit public model:* the public organizations are characterized by the RHN authority which is under its director. The director can be either elected by the RHN authority members or is assigned by the government or the Ministry of Health. The income for the RHN can be benefit from taxes, or grants from hospitals or Ministry of Health or grants from other stakeholders of the RHN.
- *For-profit corporations' model:* For-profit organizations may serve the region with medical services, IT services, or other. The for-profit-organizations may receive a return of their investment through payment for the health care services in region. Examples could be insurance companies or other companies that outsource services for the region for example the e-procurement for the hospitals, educational services

Table 1. The 18 services in a RHN as mentioned in Oates J. & Jensen H. (Oates & Jensen, 2000)

Clinical Services	**Health Services**	**Administrative Service**
Clinical Messages	Surveillance information	Reimbursement
Clinical E-mail	Yellow Pages	*Electronic commerce*
Clinical booking	Professional guidelines	Patient id
Shared Records	Disease quality management	Resource management
Care protocols	Public health management	
Mobile and emergency	Continuing professional development	
Home-care monitorin		
Telemedicine		

in ehealth portal, home services etc. The stakeholders that participate to the non-profit corporation elect their directors.

- *Governmental district or authorities:* local governmental agencies that are settled with the government district authorities and are mostly governed by public officers or local board of advisors. The organizations' rules and services are described by state laws. The financial investments come from taxes or state's general fund.

The IT companies support with eHealth application and tools the model described above. The challenge is to provide reliable solutions for the eHealth services of any kind of RHN organizational model.

THE NEED FOR INTEGRATION

Information flows and Services in RHN

The information flows in a RHN can be divided into:

a. Clinical/patient information
b. Health information
c. Administrative information

Sharing information is the key concept for every RHN. The information flow in a RHN depends on health policy of a country, which also determines the structure of the RHN. In most of the cases the basic information flow is the patient and the clinical/patient information. In such cases the participants of the RHN need to share the patient information in the region. Examples of such cases can be the Integrated Electronic Health Patient Record (implementations are described in the paragraph "Case Studies"). In other cases the scope is to share the administrative information. In many of such cases the participants need to share the financial data to succeed reduction of costs of health services in region. Examples of such cases can be the e-Procurement projects in Germany etc (implementations are described in the paragraph "Case Studies").

The services provided in a RHN, according to Oates J. & Jensen H. in (Oates & Jensen, 2000), are those described in Table 1. This clarification of services is hardly the first attempt to record the services that could be provided by a RHN in 1990-2000. Based on those services, important project for regional networks has been developed like the PICNIC project (Saranummi, Piggot, Katehakis, Tsiknakis, & Bernstein, 2005) and other.

Based on the services described in Table 1 are built most of the Regional Health Networks. The only important advancement concerns the services in italic which are the clinical messages/

clinical email and the electronic commerce. The services for providing the clinical messages/clinical email among the healthcare providers has evolved in many cases to services provided clinical information through shared data sources and are facilitating by tools offered by the world wide web for the healthcare providers and the patient as well.

The services for electronic commerce has enriched with the services of e-procurement to facilitate the material management in the healthcare organizations.

Patient Identification & Matching

The implementation of clinical/patient information flow to provided services in a RHN is a key issue to succeed the scope of sharing information and ultimately improve the provided services. To succeed clinical/patient information flow, accurate patient identification and matching in the data sources of the RHN is required. In Hospitals or health units, patient identification is accomplished with the Master Person Index (MPI). In RHN, where several data sources often from many enterprises with patient information have to be integrated, the patient identification is accomplished with the Enterprise Master Patient Index (EMPI). There is great difficulty to achieve patient identification and matching with the MPI in unit level as well as to achieve patient identification and matching with the EMPI in regional level. There are several techniques that implement algorithms to patient identification and matching, the most common used are the deterministic matching, ad hoc scoring/ matching, probabilistic algorithm. According to the model of the structure RHN and subsequently to the data model used in the RHN the appropriate algorithm is used.

The model of data storage can be centralized, federated or hybrid:

- **Centralized data model:** Patient information is kept in a clinical data repository/data warehouse centrally. The data warehouse may contain clinical as well as other information like administrative. Legal issues may rise when the patient data are kept elsewhere from the data sources that are created from.
- **Decentralized/federated data model:** The data is physically stored in the participating organization in a RHN and the health information exchange among them ensures the sharing of information. The data may adhere to a standard of data representation to enable sharing information. The original data sources are kept intact in the hospitals.
- **Hybrid data model:** It is an aggregation between a centralized and decentralised architecture. The data may be physically stored and managed in a central location but the data is logically separated into data sources for each organization that contributes data. On the opposite the data may be physically stored in the organization, and managed centrally as a virtual data warehouse.

The ultimate scope is the accurate patient matching.

Health Information Standards: Key Issues in RHN

The implementation plan for an RHN has to accommodate also integration techniques with the usage of interoperability methodologies and standards.

According to the European Interoperability Framework for Pan-European eGovernment Services the definition for interoperability is as follows (IDABC_EIF, 2004), "Interoperability means the ability of information and communication technology (ICT) systems and of business processes they support to exchange data and to enable the sharing of information and knowledge."

The levels of interoperability for building integrated systems are:

- **Organizational interoperability:** This level aims in the determination of business objectives and the conformity of business processes so that the collaboration of services and administrations is achieved even when they have different internal structures and processes. It concerns the interoperability of business processes inside an organization or among organizations that collaborate.
- **Semantic interoperability:** Interoperability at this level aims that the information that is exchanged and has the same meaning from every recipient. In order to achieve interoperability in this level it is important to implement: (1) data integration, (2) functional integration and (3) presentation integration.
- **Integration at technical level:** This level includes all the technical matters for the exchange of information and the interoperability of information systems and services.

In order to achieve integration in RHN, integration techniques should apply to all levels to have interoperable stakeholders within the RHN. The integration in regional systems for all levels can be further analyzed as follows:

- **Organizational level:** Synchronization of business processes for the communication of organizations/stakeholders at regional level.
- **Semantic level:** Common Information model for the region that contains the meta-data needed for communication.
- **Technical level:** Customizations of systems and adherence to standards for the communication and the common services at organizational level.

On the other hand, the standards for interoperability are several. There are no rules or methodologies regarding the appliance of standards along with the needs for integrating systems.

The standards can be distinguished in the following categories:

- Standards for the communication (e.g. EDI, HL7, IEEE MEDIX, DICOM)
- Standards for the representation of clinical and other data (e.g. *open*EHR technology, CEN ENV 13606-2, HL7 version 2.x messaging standard, HL7 v3 Reference Information Model, HL7 Clinical Document Architecture (CDA), Good European Health Record (GEHR), coding standards: ICD, ICPC-2, Read Codes, SNOMED, DRG, ATC, LOINC)
- Standards for the identification
- Standards for data safety and safety for medical data

The structures of Regional Health Networks are building following one of the model centralized, federated, and transactional as mentioned in previous paragraphs. The centralized, federated and hybrid data model and the EMPI for accurate patient matching along with the models for RHN structure can be aggregated in Table 2. In the cells of this table there are the most important standards that have to be adapted in order to achieve interoperability among organizations e.g. for a RHN with centralized structure and centralized data repository the most important standards are those for communication and data safety.

Studying the experiences of RHN (National_EHealth_Transition_Authority, 2006), (S. Spyrou et al., 2005), (S. Spyrou, Bamidis, Maglaveras, & Vartzopoulos, 2006; S. Spyrou, Bamidis, Maglavera, Pangalos, & Pappas, 2008) some key requirements were identified for the applicability of standards for integration especially the standards for data representation. The requirements are listed in Table 3.

Table 2. RHN structure, data model and standards for interoperability development

Data Model				
		Centralized	***Federated***	***Hybrid***
RHN Structure	***Transactional***	NA	NA	NA
	Federated	Standards for Communication Standards for data safety	Standards for Communication Standards for data safety Standards for data representation Standard for the identification	Standards for Communication Standards for data safety Standards for data representation Standard for the identification
	Centralized			

Table 3. Key requirements for applicability of standards for data representation

1.	**Comprehensive support for representing full range of data content, especially for medical documents**
2.	Vendor and Technology infrastructure independence
3.	Compatibility with well known other standards for communication, safety and security etc
4.	Supports of the incorporation of existing coding sets and standard terminologies
5.	Supports of structured and non-structured data content
6.	Supports versioning of data content
7.	Communication based on established service/message formats
8.	Ability for content management and content enrichment
9.	Translated content to several languages
10.	Supports for the evaluation of data quality metrics especially for processes including data flow
11.	Acceptability by communities / alignment to national standards
12.	Cost of implementation based on existing infrastructure
13.	Cost of implementation when existing systems are legacy systems
14.	Supports safety and privacy rules especially in data flow processes
15.	Supports access control management
16.	Supports requirements risen from other legal issues

On the other hand, the risks encountered developing interoperability projects to build RHN structure are listed in Table 4 (as described in (S. S. Spyrou, Berler, & Bamidis, 2003))

CASE STUDIES OF HEALTH INFORMATION NETWORKS

The examples that are reported in the next paragraphs are mainly good practices of work of last five-year period as well as work that is reported in various studies of eHealth projects. The trend nowadays is about the provision of integrated health care services to the citizens. The ehealth applications that are implemented for this purpose are the use of Electronic Health Record (EHR), the clinical databases, electronic referrals, electronic orders, eBooking, ePrescribing, the home care systems and other networks for the provision of health services or telemedicine.

Table 4. Risks in RHN's interoperability projects (as described in (S. S. Spyrou, Berler, & Bamidis, 2003))

Risk	Description
Annotated database schema missing	Lack of a comprehensive database schema significantly reduces the successfully reverse engineering of the database schema
Database schema contents not interpretable	The names and consequently the relations used in the schema are unclear or ambiguous
Database tables not used as described in the database schema	Database table usage has drifted away from the logical or semantic design.
Free text fields used for structured data in an ad hoc fashion	Free text fields are using to store structured data.
Inconsistent use of enumerable data types	Strict adherence to the reference tables
Required data not present	Data required according to the database schema but are found to be null in the tables. The database schema does not reflect the current structure of the database
Semantic analysis of data	Data fields does not contain semantically valid data
Character set encoding problems	There are problems with the character set encoding in the database.
Technical risks	
General Interface to access database system	Open interfaces to access the Information Systems' databases are not available.
Proprietary operating system	The database system runs on operating systems that are not open or widely known (e.g. Not Windows, Linux, Unix, or VMS)
Database not accessible	It is impossible to logon to the database.
Exotic communication protocol	The platform on which the database runs requires can only be connected through a non-TCP/IP communication protocol.
LAN not reachable	The LAN on which the pilot system is connected to cannot be reached from outside the LAN due to security matters and other reason.
Instable or failing computing environment	The computing environment is instable or failing causing the pilot system to malfunction
Organisational risks	
Not enough competent staff	IT staff is not qualified or inadequate in quantity.
Lack of individual co-operation	Individuals in the organisation are reluctant to co-operate.
Rules and procedures	Rules and procedures are becoming an obstacle or slow down progress especially in public services
Lack of decision making	There are no decision makers that can put the project in progress.
Lack of software vender support	Software vendors that need to assist do not do this.
Software vendor sabotage	Software vendors are actually sabotaging the project out of commercial interests.

In the **United States America**, the National and Regional Structures of Information of Health (National and Regional Health Infrastructure: NHII) (Dykes & Bakken, 2004), (Poon et al., 2006) has the objective to facilitate the exchange of information and improve the provided health care services and public health through the use of technologies, tools, models and applications. Programs for the exchange of health information and the implementation of Health Networks in the USA, can be mentioned such as: the network of information of health of Delaware (Delaware Health Information Network - DHIN), the Network Veterans Health Information Systems and Technology Architecture, the incident reporting system NYPORTS and other.

In **Canada**, the Canada Health Infoway is a federally-funded, independent, not-for-profit organization which invests with other collaborators of public sector to accelerate the use of Electronic Health Records across the country. From 2001, Infoway has run over 100 programs, delivering solutions of electronic health records (EHR) in the Canadians. The main objective of work is the encouragement and acceleration of growth and adoption of electronic health information systems with the compatible models and the technologies of in pan-Canadian base. The initiative for the growth of interoperable, safe pan-Canadian Electronic Health Record (Giokas, 2005), constitutes a septennial program aiming by the end of 2009 to provide to the 50% of Canada with the basic elements of the EHR.

In Australia the National Health Information Agreement (NHIA)[1] is an agreement between the Australian Government and state/territory government health authorities, the Australian Bureau of Statistics, the Australian Institute of Health and Welfare (AIHW), the Health Insurance Commission, and the Department of Veterans' Affairs. The NHIA constitutes the framework for the coordination, collection and distribution of health information technology in Australia as well as the maintance of national health data standards. The National E-Health Transition Authority[2] (NEHTA) a not-for-profit governmental company to develop better ways of electronically collecting and securely exchanging health information. NEHTA proposed a framework for the identification of health care providers (HPI) and patients (IHI). Since 1987 the AIMS and AIMS-2 systems (Stroetmann, Thierry, Stroetmann, & Dobrev, 2007) have been developed and are incident reporting systems. Up to 2002, 2000 accidents have been examined. The penetration of health information systems in the society of Australia incorporated very early. About the 90% of general doctors of Australia use software for the medical information of patients, while most Australians have access via internet in various health services.

In the New Zealand the establishment of national strategies Hospital Act 1957 and Cancer Registry Act 1993 aimed at the collection of health information in national level. The team that constitute the New Zealand Health Information Service (NZHIS)[3], that functions under the Ministry of Health, is responsible for the collection and distribution of health information at national level. Some of the databases that are maintained at national level are: (1) National Booking Reporting System that contains information for the the waiting of patients for care and treatment (2) Primary Health Organization Enrolment Collection which is the national collection with the data of Primary Health Care Units and (3) National Health Index that is a database of unique Patient Identifiers that is the National Health Index Number.

In the United Kingdom, from 1998 the NHS recognized the important role of Information and Communication Technologies in the health and "Information for Health" (IFH) (The_Department_of_Health, 11 June 2002) determined the strategic planning for the use. In the frame of National Health System the NHS Direct has been built. The NHS Direct has two departments the NHS Direct Call Centers and the NHS Direct Online (NHSDO).

The NHSDO was developed in 1998 in order to provide the citizens information on the health via internet. It is a web portal that provides information of health like diets, way of life and health, health services etc. For further information the portal[4] is connected to a telephone citizen contact center the NHS Direct Call. The two systems, the NHSDO and the telephone centre NHS Direct Call, function on a twenty-four hour base. The visitors of the web portal have been about 1.5 millions in 2000 and, according to forecasts, will be about 24 millions by 2008.

An important application in the Hospital Wirral of NHS Trust (Stroetmann, Thierry, Stroetmann, & Dobrev, 2007) includes the application of CPOE in the medicine prescribing process. Another important projects are the IHE - Integrated Healthcare

Enterprise initiative, the Chelsea and Westminster Hospital NHS Trust - ePharmacy, the National Reporting and Learning System and other.

An important project that was developed in Scotland was the CHIN - Community Healthcare Information Network. In this project a regional health network for the geographic regions of the Scotland. In this network several organizations participate and provide their services under a common frame for communication and common data structures. Each organization maintains is independent, is responsible for the maintenance of information but the data structures are indicated by the organization SHOW - the Information and Statistics Division of the National Health Service.

In Denmark, the health care system is decentralised. The central vision is the development of a common model for shared clinical data. The Danish Health Network Medcom[5] aims at the electronic communication among the health care providers ensuring the collaboration of organizations of the private and public sector. The Medcom network began in 1995 aiming at the electronic collaboration among the health care providers in national and regional level. The network that was developed allows the exchange of information via the reliable exchange of data with EDIFACT or other XML-based messages. The electronic exchange of messages is implemented in the following cases: patient referrals from general doctors to Hospitals, prescriptions for diagnostic examinations, reports of examinations, discharge letters, and refundings. More than 3.500 hospitals, pharmacies, providers of home health services, general and special doctors are connected in the network, while in 2001 more than 2.5 millions electronic documents are exchanged per month, which is more than half of the prescriptions in Denmark (Lippert & Kverneland, 2003).

Denmark has also participated in projects that are best practices for Regional and National Networks like the Baltic eHealth network, the networks Health Optimum and Sundhed.dk - The Danish eHealth Portal and other (Stroetmann, Thierry, Stroetmann, & Dobrev, 2007).

In Holland the BAZIS project (Kuhn & Giuse, 2001), (Bakker, 1990) began as an experimental governmental program and has developed in a not-profit organization for Hospital Information Systems (HIS) in the Netherlands. The development began, experimentally, in Leiden University Hospital from the Dutch government in 1972. Till now, it is a well developed HIS that is used by more than 45 Hospitals in the country which cover the 35% of beds of intensive treatment. It is remarkable that so that in order to give priority in the service of patients, the system initially did not support the processes of the economic and administrative department that was, however, added later. The system supports completely the processes in clinical department.

In France the project that was selected between the 10 best practices in the study of eHealth impact (Stroetmann, Thierry, Stroetmann, & Dobrev, 2007) is the "ELIOS-a comprehensive EPR system, and Prométhée, a sophisticated search meta-engine", which was developed in the hospital centre Institute Curie. ELIOS is an electronic patient record system (EPR), in which all that provide health services to the patient can gain access. Moreover, with the ELIOS functions and the system Prométhée that is a meta-search engine for the ELIOS and a meta-search engine in the databases of Hospitals that belong in the Institute Curie or in other clinical databases.

Also the project Bioserveur, is a centralized platform for the management and exchange of laboratory examinations and reports that concern the general doctors. Till today 45 general doctors participate and roughly 250.000 files are exchanged monthly, while this solution is used widely in the region Rhône Alpes of France. France has developed many projects including the use of e-health tools in regional health networks such as the COHERENCE, Teleif, Oncolor, RIPAM, the network REIN and other.

In Finland, the project Healthnet (Stroetmann, Thierry, Stroetmann, & Dobrev, 2007) was developed for the implementation of regional health network in the region of North Karelia in Finland. The network includes e-health solutions for integration of health units of the Primary and Secondary Health System. 15 Health Centres are connected to the network and 1340 stations in the region. It allows the storage and exchange of patient information safely and facilitates the communication of the personnel and the patient. It also includes the electronic referral of patients and the teleconference among health care providers regarding patient information and specifically the radiographs. The project contributes to the reduction of costs be means of electronic storage and electronic signature of medical documents.

Many other important ehealth projects implemented in Finland like the UUMA (Stroetmann, Thierry, Stroetmann, & Dobrev, 2007) project, which implements the electronic patient referrals and interactive teleconference in region, and constitutes one of the biggest regional networks of images and examinations of PACS in the world as well as a system for the follow-up of patients with chronic diseases via the internet or other mobile units.

Finland has participated in the implementation of other successful projects for the regional health information networks such as Baltic eHealth, the PICNIC (Saranummi, Piggot, Katehakis, Tsiknakis, & Bernstein, 2005) and other.

In Germany the project which is included in the best practices according to the study in (Stroetmann, Thierry, Stroetmann, & Dobrev, 2007) is the "MedicalOrder®Center Ahlen (MOC) – supply chain optimisation". The MedicalOrder®Center provides to the Hospitals and to other health units logistics services in a region in a range of 300 km. The center provides administrative and financial services in order to support the procurement supply chain. It includes a prototype information system for the storage of hospital materials and the supply chain in Hospital in order to reduce costs. The MOC center supports the intensive units of St. Franziskus Hospital Munich and actually is the e-procurement system.

The work, also, "GesundheitsCard Europa (GCE), access to healthcare abroad D/NL/B", concerns the national card of insurance of health that circulated from the AOK Reinland in 2003. The card of social insurance concerns the electronic form of paper form E111 that the citizens use when they travel outside from their country. The application that supports the GCE service is the multilanguage web site: http://europa.aok-tk.de. Through the access to this site the personnel of 14 hospital in the Netherlands can simultaneously confirm the actuarial situation of patients as long as they have the GCE card. Also the compensations can be completed at about 3 months in collaboration with the insurance companies in the Netherlands.

The project MuM - Δrztenetz Medizin und Mehr is a network of about 60 general and specialized doctors in the Bónde Hospital, North Rhine Westphalia.

The network supports a surgery for treatments that are not covered by the established policies of insurance companies, a central surgery and a telephone centre of service. It has also been imported the card of health of patient for the storage of elements of electronic file of patient and the direct access of doctors in the elements of patient.

In Greece many eHealth projects have been implemented. It is important to mention the implementation of European work PICNIC (Professionals and Citizens Network for Integrated Care)(Saranummi, Piggot, Katehakis, Tsiknakis, & Bernstein, 2005) . The project began in 2001 with participating countries Denmark, Finland, France, Greece, Germany, Iceland, Ireland, Holland, Spain, Sweden and United Kingdom. The objective was the preparation of the regional health services' providers to a new, friendly and secure regional network for the patient care and the continuity of care in all European territory.

The information flow within the network can be distinguished in three categories: (1) information for the administrative services and electronic trade, (2) for the public health services and (3) for the clinical services and the services of telemedicine. The architecture of project was supported by the use of systems of open architectures.

Greece has also participated in the implementation of other important eHealth projects as the CHS (Maglaveras et al., 2005) - for the health home care services -, the PANACEIA iTV (Maglaveras et al., 2003) - with application of interactive TV for the home care services and other.

EVALUATION OF RHN

Evaluation of RHN has the purpose to define and measure quality dimensions of the provided health services. There are not many implementations of projects evaluating quality of regional health care systems. Additionally, it is a complex task, as the goal of the RHN and consequently its structure and its characteristics are not standardized and different among the various implementations.

Along with the scope of building a "virtual" environment for sharing data and knowledge through the use of IT tools and techniques, evaluation on the quality of data and information that is exchanged should be planned.

Additionally a list of other issues besides the IT technologies should be examined in an evaluation plan of a RHN (S. Spyrou, Bamidis, Maglavera, Pangalos, & Pappas, 2008). The main areas for evaluation could be:

- **Financial management:** The measurements aim at the financial benefits in a regional structure of the health system such as reduction of costs (administrative and operational), reduction of hospitalization times, and management of waiting list in tertiary hospitals and exploitation of resources in primary health care system.
- **Human resource management:** Evaluation on the number of staff needs to support the health units and organization in a regional environment which may lead to reassignment and reorganization of personnel or even business processes and organizations workflow.
- **Workflow management:** Evaluation of the structures and business processes of a RHN may lead to decisions for changes in business process and consequently to workflow changes in the region e.g. reorganization of processes in laboratories for resource and cost management, paperless communication and elimination of bureaucracy etc
- **Clinical care measures:** Quality measurements for clinical care can include reducing admissions/transfer of patients, reducing adverse drug events (ADEs), disease surveillance and other.
- **Utilization/facilities management:** Evaluation of the utilization of services and structures is also of great importance such as average inpatient length-of-stay, laboratory, radiology costs and structures and other.
- **User satisfaction:** This area for evaluation is very important for the development or regional networks and especially for the acceptance of health care IT systems. The user satisfaction evaluation dimension can lead to results for usability and usefulness of IT systems supporting the RHN.
- **IT management:** Quality evaluation for the IT tools and services that supports the new age of regional healthcare systems should be developed. Metrics like safety, reliability and other are important for the IT structures and the user acceptance of the new systems.

CONCLUSION AND FURTHER RESEARCH

In the previous paragraphs, the key areas when building regional health networks were presented. The Regional Health Networks constitute the new area of organizational structure in health care domain with the main aim to lead the collaboration among several stakeholders in the healthcare regional networks and make the patient health information electronically available. These organizational and structural developments of the health care domain can help to the following:

- Improvement of quality of patient care with the involvement of patient as a user to the health services and with ensuring the patient care continuity. Examples of the improvement of quality include the assessment of medical errors, shorter clinical workflow processes and patient pathways and other.
- Control and reduction of operational and administrative costs in the health services in the region with for example fewer duplicate and unnecessary tests.
- Interoperability among the stakeholders to facilitate operability and develop the framework for real-time access to health information and medical record.

The weakness of the development of RHN so far can be distinguished to the following:

- There is no standardized patient identification and matching algorithm across multiple systems.
- The effort to achieve interoperability has as a prerequisite the continuing funding of the IT services. Additionally the implementation of interoperability framework may cause changes for the users of the Health Information Systems, which may cause frustration.
- Privacy and security mechanisms for the shared health/patient information are still developing in the several RHNs (L. O. Gostin, 1993).
- Funding of the newly introduced RHN's services should be consistent.

Further research in the area could include the expansion of the Patient Health Record following the implementation of Enterprise Master Patient Index (EMPI) in the region (Mandl, Kohane, & Brandt, 1998). The refinement of clinical workflows along with the administrative workflows in the several stakeholders can lead to the continuity of patient care and the refinement of the consultation system for the professionals in the area. The collaboration of physicians with the use of eHealth services can improve the services. The home care health services seem to expand rapidly especially in the health regions. At last the implementation of a National Patient Information Network can be built over the Regional Health Networks.

The Regional Health Networks are the new area of organizational structure in health care domain. The eHealth tools and services are actually the implementation mechanisms of the structures of RHN. The eHealth is actually connected with the notion of integration. The ultimate scope of RHN, through the sharing of information among several organizations, is the improvement of quality provided health services and the control of expenditures for the health system.

REFERENCES

Bakker, A. R. (1990). An integrated hospital information system in The Netherlands. *M.D. Computing*, *7*(2), 91–97.

Doloreux, D., & Parto, S. (2005). Regional innovation systems: Current discourse and unresolved issues. *Technology in Society*, *27*(2), 133–153. doi:10.1016/j.techsoc.2005.01.002

Dykes, P., & Bakken, S. (2004). *National and Regional Health Information Infrastructures: Making Use of Information Technology to Promote Access to Evidence*.

Giokas, D. (2005). Canada health infoway: Towards a national interoperable electronic health record (EHR) solution. In N. Saranummi, D. Piggot, D. G. Katehakis, M. Tsiknakis & K. Bernstein (Eds.), *Regional health economies and ICT services* (Vol. 115, pp. 108-140). Amsterdam: IOS Press.

Gostin, L. O., Powers, J. T. M., Kozloff, R., Faden, R., & Steinauer, D. D. (1993). Privacy and security of personal information in a new healthcare system. *Jama-Journal of the American Medical Association*, *270*(20), 2487–2493. doi:10.1001/jama.270.20.2487

Grinten, T. P., & Jarvis, W. C. (2007). Guide to establishing a regional health information organization. In C. B. Thielst & L. E. Jones (Eds.), *Guide to establishing a regional health information organization* (pp. 75-90). Chicago: HIMSS.
IDABC_EIF. (2004). *European interoperability framework for pan-European e-government services* (electronic version). Retrieved from http://ec.europa.eu/idabc/servlets/Doc?id=19529

Kuhn, K. A., & Giuse, D. A. (2001). From hospital information systems to health information systems. Problems, challenges, perspectives. *Methods of Information in Medicine*, *40*(4), 275–287.

Lippert, S., & Kverneland, A. (2003). The Danish national health informatics strategy. *Studies in Health Technology and Informatics*, *95*, 845–850.

Maglaveras, N., Chouvarda, I., Koutkias, V., Lekka, I., Tsakali, M., & Tsetoglou, S. (2003). Citizen centered health and lifestyle management via interactive TV: The PANACEIA-ITV health system. *AMIA... Annual Symposium Proceedings / AMIA Symposium. AMIA Symposium*, 415–419.

Maglaveras, N., Chouvarda, I., Koutkias, V. G., Gogou, G., Lekka, I., & Goulis, D. (2005). The citizen health system (CHS): A modular medical contact center providing quality telemedicine services. *Information Technology in Biomedicine . IEEE Transactions on*, *9*(3), 353–362.

Mandl, K. D., Kohane, I. S., & Brandt, A. M. (1998). Electronic patient-physician communication: Problems and promise. *Annals of Internal Medicine*, *129*(6), 495–500.

National_EHealth_Transition_Authority. (2006). *Review of Shared Electronic Health Record Standards*: nehta.

Oates, J., & Jensen, B. H. (2000). *Building regional healthcare networks in Europe*. Amsterdam: IOS Press.

Poon, E. G., Jha, A. K., Christino, M., Honour, M. M., Fernandopulle, R., & Middleton, B. (2006). Assessing the level of healthcare information technology adoption in the United States: A snapshot. *BMC Medical Informatics and Decision Making*, *6*, 1. doi:10.1186/1472-6947-6-1

Saranummi, N., Piggot, D., Katehakis, D. G., Tsiknakis, M., & Bernstein, K. (Eds.). (2005). *Regional health economies and ICT services*. Amsterdam: IOS Press.

Spyrou, S., Bamidis, P., Dranidis, D., Vartzopoulos, D., Maglaveras, N., & Pappas, C. (2005). *A data quality assessment framework for workflow and message oriented architectures in regional health information systems.* Paper presented at the 10th International Symposium on Health Information Management Research (ISHIMR'05), Thessaloniki, Greece.

Spyrou, S., Bamidis, P., Maglaveras, N., & Vartzopoulos, D. (2006, July 14-16). *From hospital information systems to regional health networks: The user satisfaction dimension.* Paper presented at the iSHIMR 2006, Canada.

Spyrou, S., Bamidis, P. D., Maglavera, N., Pangalos, G., & Pappas, C. (2008). A methodology for reliability analysis in health networks. *Information Technology in Biomedicine, IEEE Transactions on: Accepted for future publication*.

Spyrou, S. S., Berler, A. A., & Bamidis, P. D. (2003). Information system interoperability in a regional health care system infrastructure: A pilot study using health care information standards. *Studies in Health Technology and Informatics*, *95*, 364–369.

Stroetmann, V., Thierry, J. P., Stroetmann, K., & Dobrev, A. (2007). *E-Health for safety, impact of ICT on patient safety, and risk management*. European Commission eHealth Report.

The_Department_of_Health. (2002, June 11). *Delivering 21st century IT support for the NHS, national strategic programme*.

Thielst, C. B., & Jones, L. E. (Eds.). (2007). *Guide to establishing a regional health information organization*. Chicago: HIMSS.

Wilcox, A., Kuperman, G., Dorr, D. A., Hripcsak, G., Narus, S. P., & Thornton, S. N. (2006). Architectural strategies and issues with health information exchange. *AMIA... Annual Symposium Proceedings / AMIA Symposium. AMIA Symposium*, 814–818.

ENDNOTES

[1] http://www.health.gov.au/internet/wcms/publishing.nsf/Content/casemix-ED-NHIA+Extract

[2] http://www.nehta.gov.au/

[3] http://nzhis.govt.nz/

[4] www.nhsdirect.hns.uk

[5] http://www.medcom.dk

This work was previously published in Handbook of Research on Information Technology Management and Clinical Data Administration in Healthcare, edited by A. Dwivedi, pp. 113-127, copyright 2009 by Medical Information Science Reference (an imprint of IGI Global).

Chapter 8.10

Introducing E-Procurement in a Local Healthcare Agency

Tommaso Federici
University of Tuscia, Italy

ABSTRACT

This chapter deals with the introduction of electronic procurement in the public healthcare domain. After a brief discussion on the healthcare spending characteristics and on the suitability of e-procurement tools in the public sector, the long-lasting experience of e-procurement implementation promoted by an Italian Local Healthcare Public Agency is described. This initiative included some pilot projects and applied many different solutions, always involving both a new ICT tool and a thorough process redesign. The development of the innovation introductions is discussed, together with their organizational and managerial background, the description of the new processes, and the analysis of the most relevant results. The chapter provides a fairly comprehensive illustration of available solutions, opportunities, and challenges in this still neglected topic.

DOI: 10.4018/978-1-60566-064-6.ch015

BACKGROUND

The spending for goods and services on public healthcare, significant for many years, is still growing at a fast rate, both in absolute terms and in percent of total spending, worrying many European governments that are engaged in identifying rationalization initiatives. In parallel, e-procurement solutions widened their range of application from business-to-business (B2B) transactions among companies to business-to-government (B2G) ones, introducing innovative processes in public administrations (PAs), based on information and communication technologies (ICTs). According to the i2010 eGovernment Action Plan, two recent European directives (2004/18/EC and 2004/17/EC) committed member states to give the *capability* of carrying out 100% of procurement electronically to all their PAs with the *obligation* of managing electronically at least 50% of spending.

E-procurement should enable significant efficiency improvements in the public healthcare sector, with the reduction of purchasing and administrative costs. Until now, however, most e-procurement initiatives at the country, regional, and local levels met difficulties and did not fully deliver the expected benefits. This is mainly due to the healthcare procurement complexity in terms of variety of goods and number of suppliers and to the resistances of public institutions to technology-based process innovation. Moreover, a different approach to the e-procurement opportunities is required in healthcare to take into account the specific characteristics and peculiar needs of particular supplies.

Following the initial statements, and according to many scholars (Berardi, Calvanese, De Giacomo, Lenzerini, & Mecella, 2003; De Meo, Quattrone, Terracina, & Ursino, 2006) and definitions (e.g., listen to the voice on A.dict.it, 2007) e-procurement should be included in the e-services domain, since:

- it is entirely based on the use of computers and electronic information exchanges (Internet/extranet);
- it involves the cooperation of various organizations, which integrate their services (functionalities) through these means.

It must be noticed, however, that the semantics of many "e" terms is still not universally shared and their meaning is continuously shifting and often incoherent; for instance, the term "e-service" is also applied to the public sector in the narrower sense of a service provided on the Web by an administration to their citizens.

E-procurement-related innovations in technology and organization have been considered mostly for private operators (Kim & Shunk, 2004), particularly marketplaces (Rossignoli, 2004). Fewer works deal with the public sector (Anderson, Juul, & Pedersen, 2003; Devadoss, Pan, & Huang, 2002; Zulfiqar, Pan, Lee, & Huang, 2001); they mainly discuss policies and behaviour of central PAs and central procurement authorities (Hardy & Williams, 2005; Panayioutou, Gayialis, & Tatsiopoulos, 2004; Somasundaram & Damsgaard, 2005). Even fewer are the studies on the public healthcare sector, particularly at the local operating level, where e-procurement solutions must be actually implemented, giving rise to changes on structures and knowledge already acting within each organization, thereby requesting different approaches.

Here, a case is presented that deals with an experience of e-procurement implementation promoted by the Italian Local Healthcare Public Agency (LHA) of Viterbo. This case is particularly interesting for the comprehensive design of the e-procurement system, the differentiation of the adopted tools, the long-lasting experimentations (since 2000), and the multiple solutions implemented or in progress. The decision to examine this case is also due to the following facts: the use of e-procurement tools is seen just as one aspect of a deep reorganization of the entire supply process; most performed initiatives were followed by a detailed assessment of their outcomes.

The history and key features of this experience will be examined in detail up to the ongoing project aimed at a wide e-procurement implementation. A framework of healthcare spending characteristics is also introduced in the beginning, together with a taxonomy of e-procurement tools in public healthcare sector.

HEALTH CARE SPENDING AND E-PROCUREMENT

Health Care Spending

About 27% of the public healthcare spending in Italy is for the "purchasing of goods and services," frequently named "intermediate healthcare consumptions" (Regional Healthcare Services Agency, 2005). When referring to the whole Italian *National Healthcare System,* this component reaches a huge absolute dimension—23.8 €b in the year 2005—with an increasing trend both in absolute terms (it more than doubled from 1997 to 2005) and in percent on the total spending (in 1997 spending for goods and services was lower than 10 €b and it weighted a little more than 20% of the total).

This part of spending varies largely among the Italian regions and the market is further influenced by some complexity factors: the presence of about 350 diverse healthcare structures and about 500,000 highly differentiated suppliers (multinationals, mid-size national companies, and local SMEs).

The main issue, however, is the composite structure of the spending in healthcare, which includes standard supplies for the whole PA, together with highly specific purchases. The spending for goods and services in such sector is highly differentiated and, according to the former aggregations used by the Italian Economic Ministry (very useful to single out the most suitable e-procurement tools), can be classified into three sections:

- *common spending* for the whole PA (about 25% of total healthcare spending for goods and services); the nature of this spending (e.g., phone services, office materials) is the same for all the buying administrations;
- *common-but-differentiated spending* (25% of total); it exists for all the administrations, but it is highly differentiated through the buying sector (e.g., in healthcare: maintenance and cleaning of hospital buildings);
- *healthcare-specific spending* (more than 50% of total), composed by medical devices, drugs, and materials used in case of injury, disease, handicap, physiological application, or surgical operation.

A fundamental concern is that, while healthcare *specific* goods require high quality level of each item, together with rapid and controlled logistics, the same aspects—although important—are clearly less critical for *common* goods. Furthermore, healthcare *specific* goods and healthcare *common-but-differentiated* spending often have peculiar characteristics, with limited offering standardization. This diversity must be taken into account when devising innovative ways to manage procurement before choosing the most appropriate solutions, in order to improve quality and efficiency of supplies, while rationalizing and reducing spending.

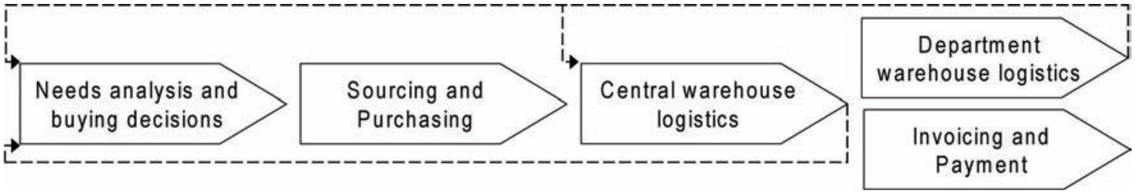
E-Procurement and E-Procurement Tools

The term "procurement" is often used in a narrow sense, associated with the sole purchasing phase, as can be seen in Panayioutou et al. (2004) or in Kim and Shunk (2004). Consequently, the term "e-procurement" is used to indicate just a class of electronic tools to link buyers and suppliers on the same network to make a deal.

Differently and according to other studies (MacManus, 2002; Somasundaram, 2004), in this work, the term "procurement" will indicate a broader process within the operations of a healthcare agency that starts with a need for a good or service and ends with its use and the payment for its supply. The procurement process then includes (see Figure 1): analysis of the needs coming from central warehouse or departments, purchase programming, sourcing choice (where and how to buy), purchasing act (through a tender or a direct order), handling of incoming material and central warehouse logistics, department warehouse replenishment, inventory control, and invoice processing and payment.

An e-procurement system then involves the whole procurement process and not just its purchasing phase. Consistently, the term "e-

Figure 1. Procurement taxonomy in the health care sector



procurement" indicates here the organizational solutions supported by ICT-based tools that allow electronic forms of procurement, potentially more effective and efficient than traditional ones, where a more or less wide-reaching and thorough process redesign is required, taking into account the whole life-time of a product or service.

The tools included in e-procurement solutions can be grouped in two main areas, which should be considered in a complementary way to streamline the whole procurement process:

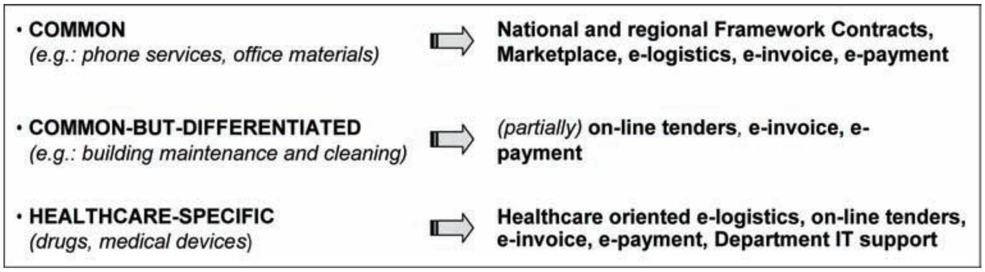
- *e-purchasing*, that includes very different tools which allows the purchasing phase to be entirely managed, from finding a product to invoicing and payment, through online tenders (*e-tendering*), or *marketplaces* and *electronic catalogues* (*e-requisitioning*), electronic invoice exchange and processing (*e-invoice*), and liquidation activity (*e-payment*);
- *e-logistics*, which aims at optimizing the management of inventories (in healthcare structures: pharmacy and the supply office) and internal goods flows, based on intranet/extranet technologies, integrating supply chain management (SCM) solutions, linking both internal and external players.

Correlation Between Spending Items and Tools

It must be taken into consideration that healthcare structures produce highly critical and specialized services vs. the rest of PAs. More than in other sectors, quality standards for many purchased goods and services (for their impact on the service quality) quality standards for many purchased goods and services (for their impact on the service quality), together with economy and timeliness of purchases, transparency of activities, and conformance to principles of competition among companies. This diversity, together with the large differences among the three spending for goods and services categories indicated above and the availability of diverse electronic tools require a careful analysis—and a segmented approach—to define (see Figure 2) which solution mostly suits each type of good/service (Federici, 2006). Then, a clear definition of the nature of the need (e.g., operating room specific devices) and a consistent purchase plan, capable of supporting both healthcare performance and economy of procurement, are necessary steps to be taken.

Goods and services within the *common* spending category, characterized by large utilization, wide offering, and repetitive purchasing quantities, can be standardized for all PAs. They are perfectly compatible with *e-requisitioning* tools, like the marketplaces and the e-catalogues based on framework contracts negotiated by a single body (at national, regional, or local level), that aggregate fractions of public demand, knock-down large standard supply contracts, perform unified tender procedures for a number of "client" entities (CONSIP, 2003) and, eventually, lower both the supply price and the administrative costs. The best opportunity for a local agency—in terms of reduction of purchase price, administrative costs, and delivery time—is therefore to turn to one of

Figure 2. Correlation between spending items and e-procurement tools



these tools; last but not least, e-logistics, e-invoice, and e-payment can improve supply management and further reduce its administrative costs.

The *common-but-differentiated* spending category consists of supplies which must absolutely guarantee the fulfillment of specific needs to the healthcare buyer. It requires the presentation and evaluation of even complex projects, for which it is difficult to define criteria for automatic score attribution. The traditional procedure can be substituted by a tender partially performed online, moving the call, presentation, intermediate, and final communications phases onto the Web (with clear benefits in terms of reduction of administrative time and costs), while keeping the offers evaluation phase off-line e-invoice and e-payment can provide further efficiency improvements.

To adequately manage the *healthcare-specific* spending, a wider e-procurement approach must be used: just looking for the lowest purchasing price might be counterproductive (Borgonovi, 2004) since the requested goods and services are highly specific and high quality levels are required. Benefits can then be obtained by redesigning the internal processes, merging several organizational changes and ICT tools on the whole procurement cycle—healthcare oriented e-logistics, online tenders, evolved forms of marketplace, e-invoice and e-payment—and providing adequate ICT supports to each healthcare cost centre (e.g., hospital wards).

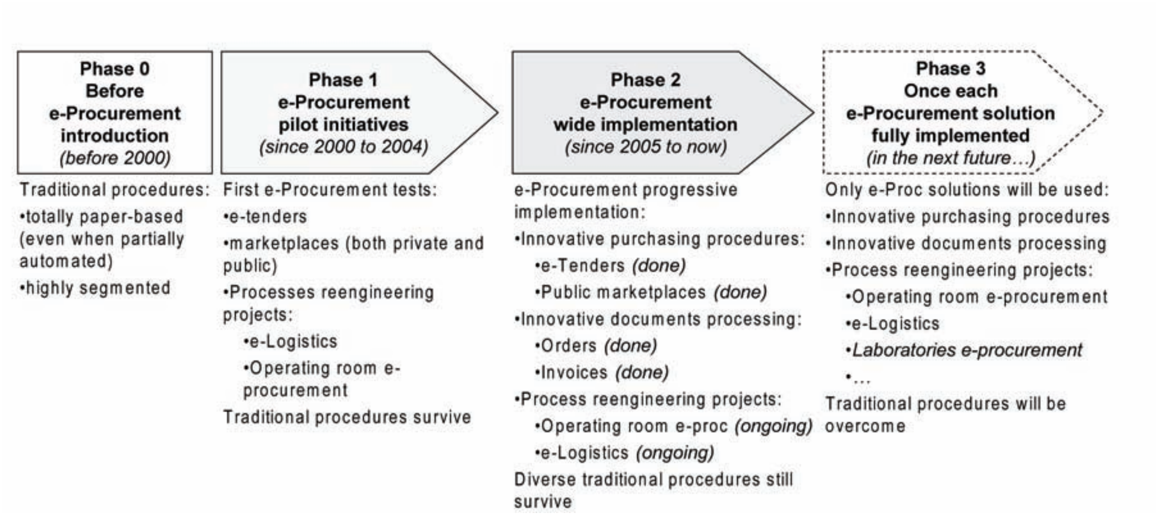
SETTING THE STAGE

E-Procurement Introduction at the LHA of Viterbo: A Long Journey

The LHA of Viterbo, aiming at gaining efficiency and reducing the expenditure for the procurement of goods and services, started in the 2000, a long journey that can be divided in four main phases (see Figure 3):

- Phase 0 (before 2000): the time before the e-procurement introduction, with traditional paper-based and highly segmented procurement procedures;
- Phase 1 (2000-2004): a period of e-procurement pilot initiatives based on different solutions, with the first e-procurement tests promoted in partnership with public and private organizations;
- Phase 2 (since 2005): a period of progressively wider implementation of diverse e-procurement solutions, that is still ongoing;
- Phase 3 (in the next future): a time of full e-procurement implementation, when the entire procurement process will be innovated and ICT-based.

Figure 3. E-procurement introduction in LHA of Viterbo



The Health Care Structure and Organization

The LHA of Viterbo, like other similar structures (Cicchetti, 2004), is organized in three areas: hospital services, territory services (first aid facilities, laboratories, etc.), and administration services. It employs about 3200 administrative and healthcare workers and provides healthcare to an Italian province (859 hospital beds) with a production value of about 350 million of euros, determined according to the individual spending allocated for each citizen of the province (a total of about 300,000 people).

As regards the procurement process, the following structures were involved, although at different levels of commitment and with diverse e-procurement solutions:

- the Procurement and Logistics (P&L) Department (in charge of tenders, purchases, and management of internal flows);
- nine different warehouses: two central (one for common goods and one for medical devices and drugs), and seven local;
- hospital wards and laboratories, which store little stocks of goods and are both applicants and recipients of new supplies.

It must be noticed that most of the structures and the procedures already operating before e-procurement introduction are still working because the innovative solutions did not substitute the former ones yet, even when fully implemented.

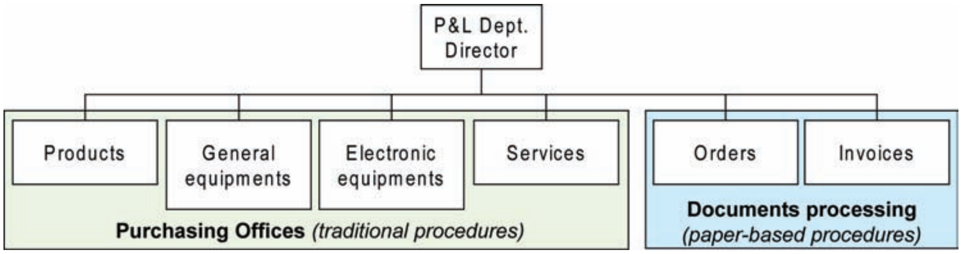
Methodological Assumptions

The above indicated assumptions about healthcare spending and its correlation with e-procurement tools—diversity in healthcare spending; broadness of the procurement process; and need to match each type of spending with the most appropriate e-procurement solution—constitute the starting concepts on which the experiences managed by the LHA of Viterbo were based.

The e-procurement project of the LHA was characterized by a diversified and systematic approach, which relied heavily on:

- the specialized competences of individual hospital wards (core structures of a healthcare agency, which actually deliver the

Figure 4. Structure of the purchasing and logistic department before the e-procurement introduction (Phase 0, before 2000)



healthcare service and are the main final users of the new tools); because of this, they were involved in the definition of the new procurement processes and took on a direct and decisive role;
- the technology and management know-how of external companies (from technology and logistics sectors); their partnership was very important in the first experimentations;
- the willingness to test diverse e-procurement solutions on pilot contexts, along the whole procurement process, before starting an extensive program for a wide diffusion; it must be considered that e-procurement was a totally new approach in those years, especially in healthcare, and there were no previous experiences to follow;
- the setting up of a review activity for each experience in order to evaluate its results in detail (which were interesting and notably different in nature and dimension from those foreseen), analyze the obstacles met (technological, organizational, and normative, as it happens for any innovation), and make the best decision about the intended wide adoption of e-procurement.

The redesign of the procurement cycle started from a detailed analysis of the need for goods and services. Specific purchase characteristics were made explicit; spending was mapped in detail, divided among *common, common-but-differentiated, healthcare-specific;* and an organic plan to link procurement needs and e-procurement solutions according to theory was prepared.

Phase 0: The Preliminary Context

Prior to starting the e-procurement introduction process, the internal situation about climate, culture, technology availability, and utilization was just similar to other analogous Italian structures and local public administrations. The purchasing activities were traditionally divided among four offices (see Figure 4), on the basis of the type of goods or services, as they are highly differentiated and specialized in healthcare, thereby implying diverse procedures and suppliers. The subject matter of the four offices was, respectively:

- products (drugs, medical devices, consumables like paper, ink, etc.);
- general equipment (furniture, cars, elevators, etc.);
- electronic equipment (medical appliances, computers, etc.); services.

This division has been maintained, as this specialization is considered useful. Therefore, the distinctive characteristics and activities of such offices, described below, are still the same existing at that period.

The activity of such offices is characterized by a knowledge oriented to correctly apply the rigid external laws (settled by the national or regional government, or by UE) and procedures (determined by the same LHA) that regulate purchases in a public administration. Another important piece of knowledge concerns information about the distinguishing characteristics of the managed type of products. To properly work in this area, the main issue is then to accumulate more and more experience in the field, while the education acquired previously to be applied in the position has little or no relevance (actually, none of the office supervisors has a degree, even less in law, as it could be expected).

The four traditional offices, which operate separately, have an average staff of four persons (generally, a supervisor and three clerks). Each of them is based on a precise division of the highly standardized tasks to be performed, that typically are sourcing of information about the product to buy (price, characteristics, suppliers), writing and revising of the tender, issuing of the same, support to the evaluation process, and award notification. Despite that knowledge is rather shared among the personnel of the same office, interchangeability is pretty difficult due to the long-lasting practice of everyone in his/her specific task. The traditional purchasing offices have then the typical form of bureaucracy. Because of their culture and organizational form, they are not flexible and not disposed to change. Moreover, even if they are effective in managing their duties, their activity is not efficient at all, as largely demonstrated by the results of the researches quoted below.

Additionally, computers are used only in the administrative offices (not in warehouses or hospital wards), and the role of IT systems is limited to automating the traditional procedures with office automation tool (word processing and occasionally spreadsheet) or legacy systems (accounting system, to check funds availability and to reserve them). Consequently, personnel are not required to have a high IT literacy.

At the beginning of the e-procurement experience, the internal climate was, and still is, highly influenced by factors like elevated level of bureaucracy, limited possibilities of career advancement, low level of responsibility, and long lasting habits to operate always in the same way (overall and particularly in areas like administration and warehouse).

These discouraging conditions to promote change were further reinforced by three other factors:

- the low cultural level outside the health departments, with only few graduated managers;
- the limited availability of different competences in staff areas: workers with a degree or a high-school qualification came all from law or accounting studies;
- the sharing of these circumstances by both employees and managers, at least middle-level ones.

Actually, the drive to introduce e-procurement in the LHA came just from two persons, both recruited after a previous career in the private sector: the former general manager and the manager of the P&L Department.

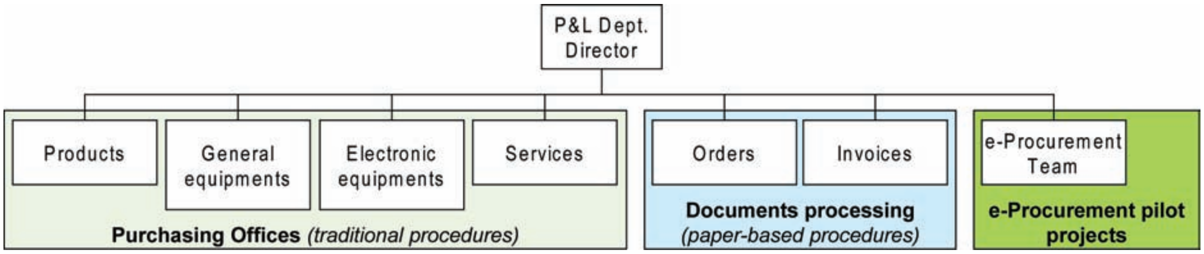
CASE DESCRIPTION

Phase 1: The Pilot Initiatives

Organizational Interventions

In order to manage the preliminary experimental phase to introduce e-procurement tools and solutions, while taking into account the obsolete culture and the poor IT education of the workers in the P&L Department, the two mentioned top managers made a strategic decision. They involved in these trials only some young people, freshly graduated in economics. At the first stage, they were two; later, two more were added. These graduates were asked to spend their postdegree training period at the LHA. As the entire staff in charge of the e-

Figure 5. Structure of the purchasing and logistic department during the e-procurement pilot initiatives (Phase 1, 2000-2004)



procurement experimentation, they were engaged full-time in it (see Figure 5).

Even though the educational level of the involved persons was quite high, this was directly used only in some part of the work (e.g., analysis of the outcomes, auditing on costs). Actually, they were selected also because of their higher IT education (although they were not IT experts) and their greater willing to innovate, compared to the workers of traditional offices. This was a successful decision, also because it isolated the persons involved in e-procurement from those still engaged in traditional procedures. Acting in this way, it was possible to adopt a trial-and-error approach in the tests, while at the same time the supplying cycle, crucial in a healthcare structure, could proceed without any inconvenience.

Many diverse ICT systems (office automation, marketplaces, platform for e-tenders, e-logistics extranet solutions, etc.) were tested by using them in real operations for a planned period, as they form the constitutive platform for e-procurement. The aim of each test was to model a new organizational solution, in order to define streamlined and more effective process and to employ human resources in more value-added tasks.

To improve the procurement and internal management of the *healthcare-specific* and *common* goods, from ward requests up to the purchasing channels (see Figure 1), the LHA designed a fully ICT-supported process, with procurement flows designed along two distinct routes, according to goods type:

- a procurement flow for nonspecific medical devices (MDs), normally used in hospital wards for routine healthcare activities (e.g., gauzes, disinfectants, etc.), and for *common* spending, involving online tenders, marketplaces, e-invoice, and e-logistics;
- another procurement flow for the specific medical devices (SMDs), used for surgical interventions in the operating rooms and for laboratory tests, with new online procurement processes aimed at optimizing the replenishment time and reducing the ward and inventory stock levels.

In the new process model, the wards, in their healthcare duty, assume a driving role, but not the responsibility to decide how to purchase specific goods.

The Trials Managed on the E-Procurement Solutions

According to the above mentioned methodological assumptions, in Phase 1 (see Figure 3) the LHA of Viterbo tested diverse e-procurement solutions before adopting them widely, in order to single out the most suitable one for each different need existing in such a complex structure. Summarizing, the experiences made in the test phase followed this path:

- in the year 2000, the first initiative was a trial of a marketplace promoted by a private merchant; despite some positive results, this experience ended quite early, when the marketplace platform failed because of the low volume of transactions;

- in 2002, even though these tools were still under construction and not yet addressed to the healthcare sector, the LHA started to use the *Public Electronic Catalogue* of the goods and services which could be purchased at predefined conditions through the *Framework Contracts* ("Convenzioni Quadro") negotiated by the Italian Central Procurement Agency (CONSIP) and the *Marketplace for the Public Administration* ("Mercato Elettronico per la Pubblica Amministrazione," MEPA), also created and managed by CONSIP (the LHA was one of the first 20 Italian PAs that took active part in the MEPA implementation);
- in 2003, a first platform for e-tenders was tested, which was later dismissed because of its lack of functionalities; it has been recently replaced by a new one, that allows to manage a tender, both partially (leaving offers evaluation off-line) or fully electronically, but does not yet support competitive online prices reductions (*e-auction*);
- the LHA also carried out two different projects on e-logistics, both promoted by private companies and based on wide outsourcing solutions supported by extranet platforms. One of them involved the central and the departments' warehouse logistics for common goods and nonspecific devices used in hospital wards for routine healthcare (e.g., gauzes, disinfectants, etc.). The other project coupled the supply of the specific medical devices used in the operating rooms with their overall logistics management, adopting an innovative "intervention-based" concept that links procurement to the surgical operations performed (according to surgical protocols defined ad hoc, which indicate the types and quantities of medical devices needed for each type of operation), instead of the traditional "stock-based" approach, which just manages the inventory levels.

The most significant experiences of those indicated above, due to their innovation rate and process broadness, were *e-logistics* (for common goods and nonspecific devices) and *operating room e-procurement*. They will be then described in more detail in the following paragraphs (see also Federici, 2005).

E-Logistics Solution

The LHA of Viterbo managed in 2002–2003 a pilot experiment about centralization and outsourcing of the warehouse function. The e-logistics program outsourced replenishment and inventory management for hospitals and offices to an external logistics service provider, with significant reduction of the operating and economic burden on the LHA. The results of such initiative reinforced the statement that savings in healthcare should be pursued by supporting the procurement processes of the structures with ICT tools and by thoroughly reviewing and integrating the logistics management (Bianchini, 2002b). With the technical support of CONSIP, a pattern was later drawn to extend this solution to other LHAs.

After making the ICT support available to all the recipient structures involved in the trial, they were provided with an easy accessible product inventory, divided by categories, and a daily loading/unloading procedure with indication of actual stock levels.

The process was activated by a need, for example (see Figure 6), born in a ward. Every day, in its healthcare duty, the hospital ward unloaded the consumed goods from its inventory and issued a replenishment request when they went beyond their minimum stock levels. The replenishment request of medical devices or supply office goods, through a software application linked to the hospital management information system, was sent to the logistics service provider periodically (once or twice a week) by the ward sister, after validation by the hospital pharmacy (in case of nonspecific medical devices). The logistics service provider, if the good was available, replenished the requesting ward inventory from its warehouse by sending the good together with electronic and paper transport documents (TD). The ward sister checked the conformity of the received good in quality and quantity with the transport document and loaded its electronic inventory. In this way, the P&L Department was informed centrally in real time about the stock levels of both the logistics service provider and of the individual wards.

The logistics service provider was the sole procurement intermediary, but it could not make any decision for new supplies, on behalf of the LHA, when a good was not available in its warehouse. The LHA outsourced the management of central inventory and delegated the unloading of ward inventories, but did not externalize the purchasing function, which remained exclusively in its hands. In case of stock-outs, the logistics service provider sent a purchase order proposal to the LHA:

- when the goods were part of a still open supply agreement, after the validation by the P&L Department, the order was mailed to the awarded supplier (see Figure 7), which sent the goods and related transport document to the logistics service provider, that then loaded its electronic inventory;
- when the supply agreement was closed, or for new goods, the P&L Department could decide to open a new tender (in a traditional way, or online), at the end of which the illustrated route between the awarded supplier and the logistics service provider was activated.

Figure 6. Replenishment request internal flow with e-logistics solution

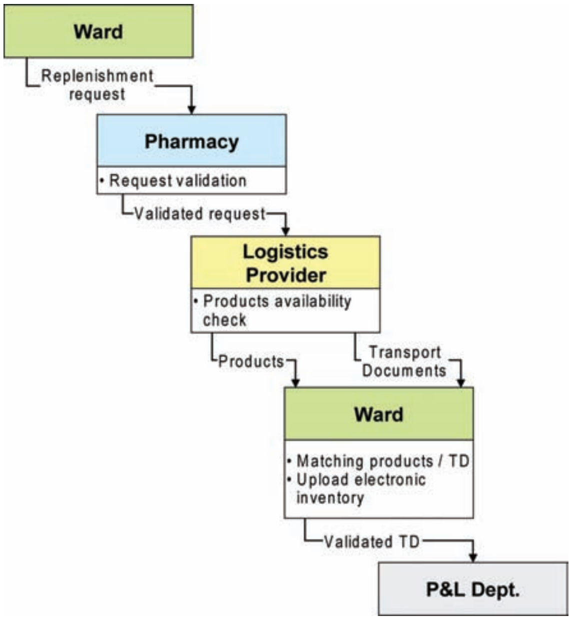
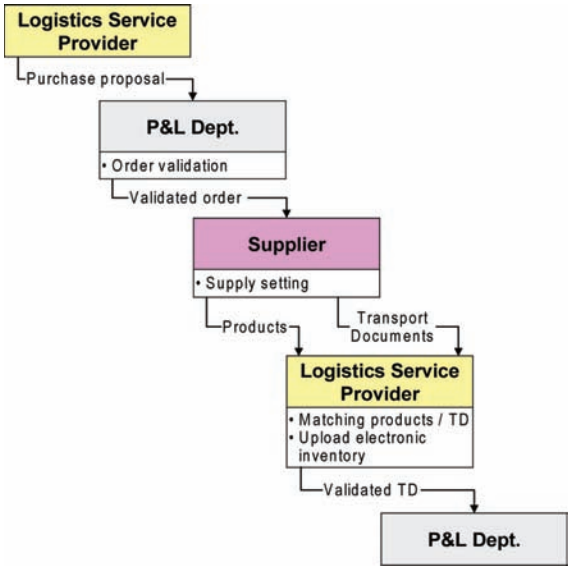


Figure 7. Supply order flow with e-logistics solution in case of an open agreement



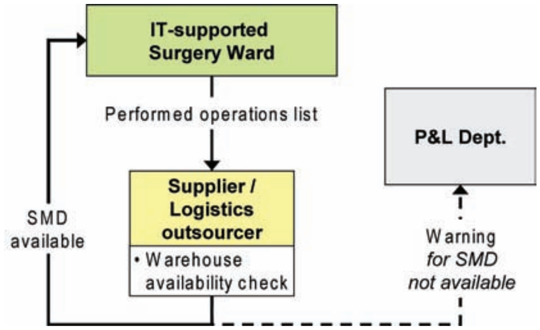
Operating Room E-Procurement

The traditional planning of operating room provisioning is performed by the hospital responsible and the pharmacist, who manage the hospital inventories by periodically sending types and quantity estimates of goods to be provided to the respective purchasing office, according to past consumption and future consumption forecast. This approach, based on estimates, generates problems in purchase planning when the hospital wards are not provided with adequate ICT supports: the pharmacist unloads the goods allocated to a ward from the inventory, as if it were consumed at once; the good might remain instead unused in the ward for an unpredictable period of time, with no indication to the pharmacist and, least of all, to the purchasing office.

The pilot experience of "operating room e-procurement" was carried out at the hospital of Civita Castellana since 2001 (it was chosen, because it is a little hospital and its ward personnel is willing to pursue innovation). The operating and technical staff of the General Surgery Department was directly involved in rethinking and redesigning the specific medical devices procurement process from scratch. The model conceived is based on:

- a novel approach to provide the specific medical devices to the operating room, based on the type of surgical operation performed (information immediately available) and no longer on the specific medical devices stock level (information that requires a large administrative work);
- the definition of surgical protocols which indicate the type and quantity of the medical devices consumed by each type of operation and allow to determine the right quantities to be reordered;
- the contractual allocation of the products supply and management to a single player, with innovative paying terms.

Figure 8. Flow diagram of operating room e-procurement process (at the end of each shift)



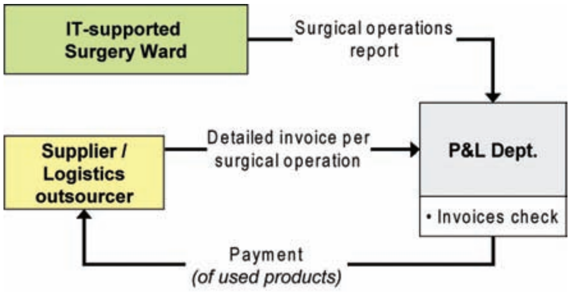
The new procurement process was supported by a shared application platform based on an extranet. At the end of each shift (see Figure 8), the ward sister sent the list of the operations performed to the supplier. The supplier, according to the product quantities indicated by the corresponding surgical protocols, knew product consumptions in real time and could thus replenish them. The goods were delivered directly to the ward which had requested them and thus covered actual needs with no intermediate steps, cost/time increase or stock-out risks.

The process ended monthly (see Figure 9) when:

- the surgery ward sent to the P&L Department the report of the surgical operations performed;
- the supplier issued a detailed invoice per surgical operation;
- the P&L Department activated the payment of the actually used products, after a brief cross-check.

At the same time, a so detailed invoice provided data to the P&L Department for an effective periodical comparative analysis of ward needs. The objective of the experimentation was to verify the operating-economic impact that a specific supply system, based on online methodologies and provisioning *per surgical operation,* would provide

Figure 9. Flow diagram of operating room e-procurement process (monthly)



vis-à-vis the traditional procedure (Bianchini, 2002a). The analysis performed at the end of the first semester of experimentation indicated that, to reduce spending, it is necessary to consider the whole supply cost and not only the purchase price, on which the procedure was focused before, in order to negotiate the lowest one.

Actually, the economic advantages were mostly concentrated in the administrative costs, which decreased from about 100 €k per semester to only 20. On the contrary, the purchase price of the operating room devices slightly increased (by 4%, due to their increase in market price); this witnesses that the project was aimed at not sacrificing the quality of supply at all. With savings on the total final cost of the specific medical devices supply of more than 73 €k per semester (30% less than the traditional approach), the experimentation of the LHA of Viterbo suggested that the e-procurement per surgical operation can provide substantial cost savings, not to be pursued by reducing the purchase costs (in order not to dangerously penalize the supply quality), but by redesigning the procurement process and thus reducing the administrative costs.

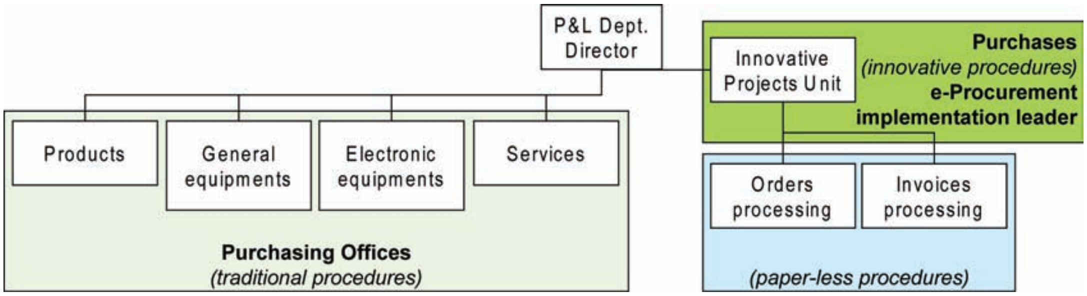
It may be interesting to examine the breakdown of savings among the various cost items:

- 42% of savings came from reducing the fixed and financial inventory costs (management cost per squared meter of inventory premises, financial costs of the capital locked into stocks, and cost of obsolete products), by outsourcing logistics and shifting the payment terms after consumption;
- 26% of savings came from reducing personnel costs (of hospital pharmacy and operating room), for the fraction linked to the inventory management activities outsourced to the logistics provider (book-keeping, product replenishment, incoming goods inspection, order/delivery expediting);
- 24% of savings came from reducing the administrative cost for purchasing and supply monitoring, by unifying sets of diverse medical devices into surgical protocol kits, instead of using a separate procedure for each type of device, and by being provided with detailed information directly from the invoices per surgical operations;
- 8% of savings came from reduced order management and invoicing costs.

Phase 2: The Progressive Implementation

Since 2005, after these pilot experiences limited in size and time although performed in real operations, the LHA of Viterbo launched an extensive program (Phase 2, see Figure 3) with the purpose of innovating the end-to-end procurement process (as seen in Figure 1), through the adoption of diverse solutions, coherently linked to the different specific requirements. The first completed steps were the implementation of multiple e-procurement solutions in two segments of the broad procurement process: purchasing and invoice processing. The changes introduced in these first steps were analyzed in detail, as summarized below. After overcoming the resistances expressed by suppliers, the full deployment of operating room e-procurement is now ending, while the implementation of e-logistics outsourcing model for common goods and nonspecific devices is still ongoing.

Figure 10. Structure of the purchasing and logistic department during the e-procurement wide implementation (Phase 2, since 2005).



New Organizational Interventions

At the end of the testing phase, when it was decided to promote the widespread adoption of e-procurement, two more graduates were selected, and the former informal project team became a unit devoted to the all e-procurement processing (named Innovative Projects, or IP).

This unit (see Figure 10) was integrated with two other offices (already moved to a totally paperless activity), in charge of orders and invoices processing, in the staff coordinated by the Director of the P&L Department. Even though innovative e-purchasing solutions are fully implemented and frequently used already, this unit is still separate from the other offices, which keep running the purchasing activity in the traditional ways.

In addition, while the traditional offices manage the sole purchasing phase, this unit not only operates as a buyer (through online tenders or direct purchases on MEPA), but also supervises the entire procurement process (including supply chain and logistics), being directly linked to external providers, warehouses (for common goods and for medical devices and drugs), and internal departments recipient of the supplied goods. Furthermore, the IP unit manages supplies regardless to the type of goods.

After being set up, the IP unit led the full implementation projects of the new purchasing solutions and of operating room e-procurement. At present, it is leading the e-logistics project introduction, managing online purchases, and supervising the go-live phase of the operating room e-procurement.

Research Findings on the Completed Implementations

After the full implementation of e-procurement solutions in purchasing and invoice processing, a detailed research was performed (Federici, 2006) in order to assess the actual organizational changes introduced and the performance benefits obtained. Five new procedures were examined: four located in the purchasing phase (two related to e-tendering, #1 and #3, and two to e-requisitioning, #2 and #4) and one in invoice processing (#5).

The analysis compared five workflow pairs representing homologous segments of the end-to-end procurement cycle (see Table 1), each related to a traditional paper-based procedure (T) and to an innovative one (I). Although very different, the compared procedure pairs receive the same input at the same stage of the procurement cycle and produce the same output in the same overall context (normative, good or service to be purchased, value of the purchase, etc.).

In order to point out the changes introduced when implementing e-procurement solutions, the following quantitative comparisons were performed between the workflows of equivalent procedures:

Table 1. Matching between the equivalent procedures considered (Legend: T: Traditional, I: Innovative)

COMPARISON	VERSION	PROCEDURE	DESCRIPTION	ICT TOOLS
1	T	Tender over threshold	Public tender for purchases of goods and services for amounts higher than the threshold set by the European Union (EU). Totally paper-based procedure	Office automation (word processing, spreadsheet, etc.)
	I	Online tender over threshold	Public tender for purchases of goods and services for amounts higher than the threshold set by the EU. Web-based procedure from initial notification, receipt of bids, intermediate communications, up to award notification. Evaluation of the bids can be performed off-line. Call must be published as for off-line tender	Platform for e-tendering Office automation
2	T	Tender over threshold	*see above*	
	I	Direct Order on e-catalogue	Purchase (also for amounts higher than the EU threshold) fully performed on the e-catalogue for PAs managed by CONSIP, which includes goods and services already negotiated through Framework Contracts. A limited choice of items is available.	Web-based catalogue
3	T	Negotiated procedure	Restricted tender procedure with few invited participants (faster then normal tender). To be adopted only in specific cases and under EU threshold. Totally paper-based procedure	Office automation (word processing, spreadsheet…)
	I	Request for Quotation (RfQ) on MEPA	Restricted tender procedure fully performed on CONSIP Marketplace for PAs with few participants selected by LHA (among the suppliers admitted by CONSIP), that can be asked for (and can submit) a technical tender To be adopted under EU threshold.	e-Marketplace (with special functions for tender asking and submitting)
4	T	Small direct purchase	Purchase directly performed with a single supplier. To be adopted for very small buying (under the threshold of € 5000) and only in specific cases. Totally paper-based procedure	Office automation (word processing, spreadsheet…)
	I	Direct Order on MEPA	Purchase directly performed on CONSIP Marketplace with a supplier already admitted by CONSIP, and only of goods or services allowed. To be adopted under EU threshold	e-Marketplace platform (with cart function)
5	T	Invoice processing	Paper-based procedure of: invoice acquisition, checks (on the accounting system and with orders and transport documents) and submitting of verified invoices to the persons in charge of payment	Office automation (word processing, spreadsheet…) Accounting system
	I	LIQUIWEB	After keying in the incoming invoice data, totally paper-less checks (on the accounting system and with orders and transport documents) and submission of verified invoices	Intranet application for invoice processing Accounting system

- three on organizational dimensions: number of the performed tasks, number of the offices, and number of the different roles involved;
- two on performance indicators: total elapsed time (in calendar days) and total effort (in minutes), calculating for each of them the standard value, and the range between maximum and minimum values.

In short, the research revealed several changes brought in by the e-procurement solutions already implemented:

- the number of tasks is almost always lower in the innovative (I), generally simpler, paperless workflows (in three cases by more than 30%);
- the number of offices involved is equal in the two versions of the workflows, except in comparisons #2 and #3 where all the evaluation or a large part of it is performed on the innovative procedures introduced by CONSIP for all PAs;
- the number of roles involved is slightly lower in the innovative (I) workflows; tenders over threshold are an exception, since the online process asks for a new activity—the technical preclassification of tenders submitted, performed by an expert in the field of the purchased goods—that is not present in the traditional (T) workflow;
- the length of the workflows (in terms of total elapsed time) is largely reduced with e-procurement in both standard value and min–max range (the reduction sometime is greater than 80%): this means that the supply contracts can be closed in a shorter and more predictable time, which is very important for critical services, like in healthcare;
- the total effort requested to achieve the same target is always lower for e-procurement workflows (I), often significantly (from 15% up to more than 90%). In three cases out of five, the reduction is greater for range than for standard value: this suggests that, besides the efficiency improvement, the use of resources could be better programmed.

The significant results measured originated anyway more from cleaning-up the workflows and using faster communication tools than from performing a deeper redesign, as suggested by the involvement of the same offices and roles, and by the similarity in the number of tasks, in each workflow pair (it must also be observed that the examined workflows refer to procedures heavily conditioned by laws and rules that limit the depth of the redesign action).

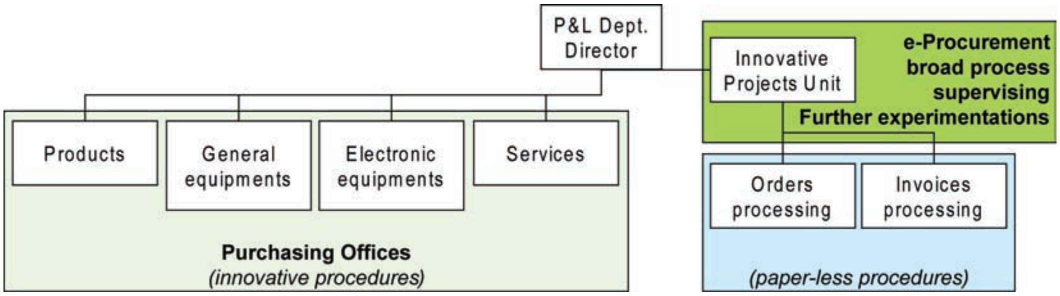
The largest differences and the best results were found in those comparisons—#2, where a tender paper-based procedure is replaced by an e-requisitioning solution, and partially #3—in which the new solutions (up to now used only for common spending) lack some activities for the buyer LHA—sourcing, evaluating, and admitting suppliers; classifying goods and services—performed in advance by an external subject (CONSIP).

Phase 3: Towards a Totally Electronic Procurement Process

The described scenario for the development of e-procurement is the outcome of a series of managerial decisions based on the assumption that the characteristics of the traditional and innovative sides are quite different in terms of: required knowledge, operating ways, and personnel profiles. The P&L Department Director's goal is now to completely substitute the traditional purchasing procedures with the innovative ones become usual for the agency, at least in the IP unit. Then he wants to reassign to the four traditional purchasing offices the use of the e-purchasing tools in all of their operations. To reach this target, the know-how related to the new solutions must be transferred to them, and he thinks to assign this task to the IP unit, to be performed with short courses and an extended period of support on the job.

At the end of this process (see Figure 11), the IP unit will lose its buyer role and will be in charge of controlling and auditing the broad e-procurement process and of carrying out tests on other possible innovative solutions along it. The LHA of Viterbo is now planning other innovative solutions in the procurement domain, first of all, the adaptation to the laboratory tests of the "intervention-based" concept, already introduced in operating room e-procurement. This innovation involves highly specialized goods and until now encountered the

Figure 11. Structure of the purchasing and logistic department with fully implemented e-procurement (Phase 3: in the next future)



resistances of the suppliers, which are very hard to be overcome because of their limited number.

CURRENT CHALLENGES

Various challenges are still open for the LHA in question, in order to achieve the full substitution of the traditional procurement procedures with brand new ICT-based solutions all along the end-to-end procurement process. These challenges are related to external factors and/or agents, or originate in the internal environment:

- some law restrictions and/or catalogue limitations (indicated in Table 1), which today prevent a wider utilization of the most favorable purchasing solutions for a Local Agency (like direct orders on e-catalogue and on MEPA); these restrictions/limitations should be removed by the Central Procurement Authority in order to increase the attainable improvements;
- limited suppliers' readiness to manage their sales with the innovative tools: most of them (even the biggest ones) often showed not to be prepared to (or not interested in) the most innovative solutions, which join supplies with other services and fully allocate their management on electronic platforms. This problem caused long delays in issuing the tenders both for operating room e-procurement and e-logistics, and still prevents other planned innovations.
- while the sanitary staff in the hospital wards showed a positive will to accept the new solutions, the personnel employed in the administrative areas, in the warehouses and in the laboratories, accustomed since long to work in traditional ways, appeared (and appear) culturally inadequate and resisted/resist to change. Therefore, it will be a hard task to spread innovation in all the environments involved in procurement activities;
- the adoption of new procurement solutions can ask to eliminate some structures (e.g., the centralization of inventory management in the e-logistics project will cause the closure of local warehouses), thereby originating strong resistances by the involved personnel, that should be transferred to other structures and/or change their duty.

Despite these significant obstacles, as stated above, the LHA of Viterbo is already planning other innovative solutions in the procurement domain, first of all the adaptation of the "intervention-based" concept in the procurement for laboratory tests.

CONCLUSION

Procurement in the healthcare sector is quite different from the rest of PA because of a much wider number of goods and sellers, technical characteristics and peculiarities of goods and services, impact on the delivery of critical and specialized services requiring high quality standards, and timeliness of purchases.

Also recalling the previously cited works (Federici, 2005; Federici, 2006), it can be suggested that:

- healthcare spending is highly varied and can be segmented in three categories: *common*, *common-but-differentiated*, and *healthcare-specific*;
- procurement is a process much broader than pure purchasing, which asks for carefully diversified ICT-based solutions as well as thorough process rethinking/redesign;
- to properly respond to the variety of needs and contexts in healthcare, it is advisable to appropriately segment the organizational solutions and adopt coherent e-procurement approaches.

The case of the LHA of Viterbo constitutes a long and articulated experience with positive results, as the adoption of e-procurement solutions led to greater effectiveness and significant efficiency improvements (although of largely different dimensions). These outcomes could be used to eventually materialize administrative cost reductions and/or service enhancements, while respecting organizational or normative restrictions and policies not dealt with in this work.

Some hints can be singled out from the experience, in order to assess its transferability:

- e-procurement can provide improvements also in those contexts, like the purchasing phase, where a deep process redesign is presently inhibited by law constraints;
- improvements are much larger when several tools are brought together to model brand-new organizational solutions, capable to link the supply of goods with their logistics and the processing of the related documents, along the entire procurement process;
- involvement of new resources, with higher education, IT literacy, and will to innovate, in the e-procurement initiatives;
- adoption of a progressive approach, with experimentations and succeeding implementations projects;
- temporary parallel presence of traditional and innovative procedures, until the latter are fixed, in order to secure the supply operations, crucial in a healthcare structure.

REFERENCES

A.dict.it. (2007). Electronic service (eService). Voice in K. Lipinski (Ed.), *A dictionary of IT*. Retrieved June 7, 2008, from http://a.dict.it/definition/lexikon//eservice_electronic%20service.html

Anderson, K. V., Juul, N. C., & Pedersen, J. K. (2003, June). *Fractional institutional endeavours and eprocurement in local government*. Paper presented at the 16th Bled Electronic Commerce Conference, Bled, Slovenia.

Berardi, D., Calvanese, D., De Giacomo, G., & Lenzerini, M. &. Mecella, M. (2003). *A foundational framework for* e-*services* (Tech. Rep. No. 10). Rome, Italy: University "La Sapienza," Dipartimento di Informatica e Sistemistica.

Bianchini, A. (2002a, May 8). *La sperimentazione dell'e-procurement negli approvvigionamenti di Sala Operatoria.* Paper presented at the Acquisti Ed E-procurement in Sanità at FORUM PA Conference, Rome. Retrieved June 7, 2008, from www.forumpa.it/forumpa2002/convegni/archivio/S.7/1363-andrea_bianchini.pdf

Bianchini, A. (2002b, November 5). I vantaggi conseguibili attraverso l'esternalizzazione della Logistica di un'azienda sanitaria, proceedings, Milano.

Borgonovi, E. (2004). E-procurement in Sanità: dalla logica di modello alla logica di processo. *Mecosan*, *41*, 2–5.

Cicchetti, A. (2004). *La progettazione organizzativa.* Milan, Italy: FrancoAngeli.

CONSIP. (2003). *Il Programma di razionalizzazione della spesa per beni e servizi della Pubblica Amministrazione*. CONSIP Annual Report (*house journal*), Rome, Italy.

De Meo, P., Quattrone, G., Terracina, G., & Ursino, D. (2005). Agent-based mining of user profiles for e-services. In J. Wang (Ed.), *Encyclopedia of data warehousing and mining* (pp. 23–27). Hershey, PA, USA: Idea Group Publishing.

Devadoss, P. R., Pan, S. L., & Huang, J. C. (2002). Structurational analysis of e-government initiatives: A case study of SCO. *Decision Support Systems*, *I*(34), 253–269.

Federici, T. (2005). An integrated approach in healthcare e-procurement: The case-study of the ASL of Viterbo. In M. Böhlen et al. (Eds.), *E-government: Towards electronic democracy, TCGOV 2005* (LNAI 3416, pp. 298–309). Berlin: Springer.

Federici, T. (2006). Public healthcare: Changes introduced when implementing e-procurement. In *Proceedings of the 2006 Mediterranean Conference on Information Systems*. Venice, Italy: University of Trento.

Hardy, C., & Williams, S. P. (2005). Public eprocurement in action: Policies, practice and technologies. In M. Böhlen et al. (Eds.), *E-government: Towards electronic democracy, TCGOV 2005* (LNAI 3416, pp. 286–297). Berlin: Springer.

Kim, J., & Shunk, D. L. (2004). Matching indirect procurement process with different B2B e-procurement systems. *Computers in Industry*, *I*(53), 153–164. doi:10.1016/j.compind.2003.07.002

MacManus, S. A. (2002). Understanding the incremental nature of e-procurement: Implementation at the state and local levels. *Journal Public Procurement*, *I*(2), 5–28.

Panayiotou, N. A., Gayialis, S. P., & Tatsiopoulos, I. P. (2004). An e-procurement system for governmental purchasing. *International Journal of Production Economics*, *I*(90), 79102.

Rossignoli, C. (2004). Nuove forme organizzative e il ruolo delle tecnologie di coordinamento a livello intra-organizzativo e inter-organizzativo. In A. D'Atri (Ed.), *Innovazione organizzativa e tecnologie innovative* (pp. 5768). Milan, Italy: Etas.

Somasundaram, R. (2004). Diffusion of eprocurement in the public sector: Revisiting centralization versus decentralization debates as a twist in the tale. In T. Leino et al. (Eds.), *Proceedings of the 12th European Conference on Information Systems* (pp. 1546–1556). Turku, Finland: School of Economics and Business Administration.

Somasundaram, R., & Damsgaard, J. (2005). Policy recommendations for electronic public procurement. *The Electronic . Journal of E-Government*, *3*, 147–156.

Zulfiqar, K. A., Pan, S. L., Lee, J., & Huang, J. C. (2001). E-government: An exploratory study of on-line electronic procurement systems. In S. Smithson et al. (Eds.), *Proceedings of the 9th European Conference on Information Systems* (pp. 1010–1024). Bled, Slovenia: Moderna organizacjia.

This work was previously published in Cases on Managing E-Services, edited by A. Scupola, pp. 218-237, copyright 2009 by Information Science Reference (an imprint of IGI Global).

Chapter 8.11

Application of Unified Modelling Language (UML) to the Modelling of Health Care Systems:

An Introduction and Literature Survey

Christos Vasilakis
University College London, UK

Dorota Lecnzarowicz
University of Westminster, UK

Chooi Lee
Kingston Hospital, UK

ABSTRACT

The unified modelling language (UML) comprises a set of tools for documenting the analysis of a system. Although UML is generally used to describe and evaluate the functioning of complex systems, the extent of its application to the health care domain is unknown. The purpose of this article is to survey the literature on the application of UML tools to the analysis and modelling of health care systems. We first introduce four of the most common UML diagrammatic tools, namely use case, activity, state, and class diagrams. We use a simplified surgical care service as an example to illustrate the concepts and notation of each diagrammatic tool. We then present the results of the literature survey on the application of UML tools in health care. The survey revealed that although UML tools have been employed in modelling different aspects of health care systems, there is little systematic evidence of the benefits.

INTRODUCTION

Health care systems are known to be complex and, as a result, difficult to analyse and re-engineer (Berwick, 2005). Health system engineers often rely on computer modelling and simulation to assist with the analysis of existing systems and the pretesting of suggested changes. To this extend, a variety of software engineering techniques and tools have been employed (Jun, 2007). Examples include data flow diagram (Pohjonen et al., 1994), state transition diagram (Mehta, Haluck, Frecker, & Snyder, 2002), entity relationship diagram (Kalli et al., 1992), integrated definition or IDEF (Hoffman, 1997), and more recently, Unified Modelling Language, commonly known as UML (Object Management Group, 2005).

UML provides a comprehensive set of tools that can be used for documenting the analysis of a system and for developing model requirements. UML diagrams are graphical depictions that demonstrate the flow of events within the system (Object Management Group, 2005). Depending on the perspective chosen for the study (e.g., actor oriented, activity oriented), different tools are available to the analyst. Due to its versatility and the ability to analyse systems from different perspectives, UML is said to be effective in describing and evaluating the functioning of complex systems such as health care (Kumarapeli, De Lusignan, Ellis, & Jones, 2007). However, there seems to be very little systematic evidence on its benefits.

The focus of the article is to review the literature on the application of UML tools to the analysis and modelling of health care systems. To this end, we first briefly introduce four of the most common UML diagrammatic tools, namely use case, activity, state, and class diagrams. We use a simplified surgical care service as an example to illustrate the notation and concepts of each diagrammatic tool. Next, we present the results of the literature survey on the application of UML in health. The survey revealed that studies of the benefits of UML to health evaluation are an exception and most studies have used UML without an evaluative component. We conclude with a brief discussion of the results.

UML DIAGRAMMATIC TOOLS

UML 2.0 has 13 types of diagrams, which can be categorised hierarchically as follows (Object Management Group, 2005):

- Structure diagrams used to represent the elements of the system being modelled. They include class, component, composite structure, deployment, object, and package diagrams.
- Behaviour diagrams that allow the representation of what happens in the modelled system in the activity, state, and use case diagrams.
- Interaction diagrams, a subset of behaviour diagrams, that allow the representation of the control and data flow among the elements of the system being modelled. These are communication, interaction overview, sequence, and timing diagrams.

We briefly introduce here the four UML diagrammatic tools that appear in the surveyed literature, namely, use cases and use case diagram, activity, state, and class diagram. A full description of the concepts and syntax of UML diagrams is beyond the scope of this article. A plethora of user guides and technical notes are available on the subject, with the monograph by Ambler (2004) a particularly useful introduction.

We illustrate the basic concepts and notation of each diagrammatic tool by presenting simple models of a simplified care process of surgical consultation with a patient in an outpatient clinic. In general, physicians refer patients for surgical consultation if they believe the underlying health problem is amenable to surgical intervention.

Following the referral, the outpatient clinic books the patient an appointment with the surgeon and also arranges for samples to be taken if further diagnostic tests are required. At the consultation, the surgeon assesses the need for an operation by evaluating symptoms and test results. Following a decision to operate, the patient's name is registered on a prioritised surgical wait list so that appropriate time can be booked at the operating theatre of a hospital. The patient may also be educated about the operation by a specialist nurse. If an operation is not deemed suitable, then the patient may be further referred for medical treatment.

Use Cases and UML Use Case Diagrams

In software and system engineering, a use case is a technique for capturing the functional requirements of a system (Object Management Group, 2005). Each use case provides one or more scenarios that convey how a specific part of the system interacts with the users (called actors) to achieve a business goal or function. There is no standard format for detailing use cases but some tabular layout is commonly used.

The UML use case diagram, on the other hand, allows the graphical representation of a set of use cases. The UML standard sets out a specific graphical notation (Object Management Group, 2005). Use cases and UML use case diagrams not only provide clarity in terms of actors and sequence of steps involved in the event but also serve as a useful tool to present details of the actor's progression in the system.

Figure 1 shows a use case diagram depicting the process of surgical consultation with a patient in outpatient clinic. Actors are represented by stick figures and use cases by ovals. Associations between actors and use cases are depicted by edges. The "uses" arrow points to a use case that is always invoked, while the "extends" to a use case that is conditionally invoked. In the example, the surgeon always evaluates the patient's symptoms and the test results. The outpatient clinic nurse may order additional tests when booking the appointment, which in turn, may require taking samples (e.g., blood) from the patient. The actor "Patient requiring surgical consultation" is a type of the generic actor "Patient", an example of the common construct of specialisation/generalisation.

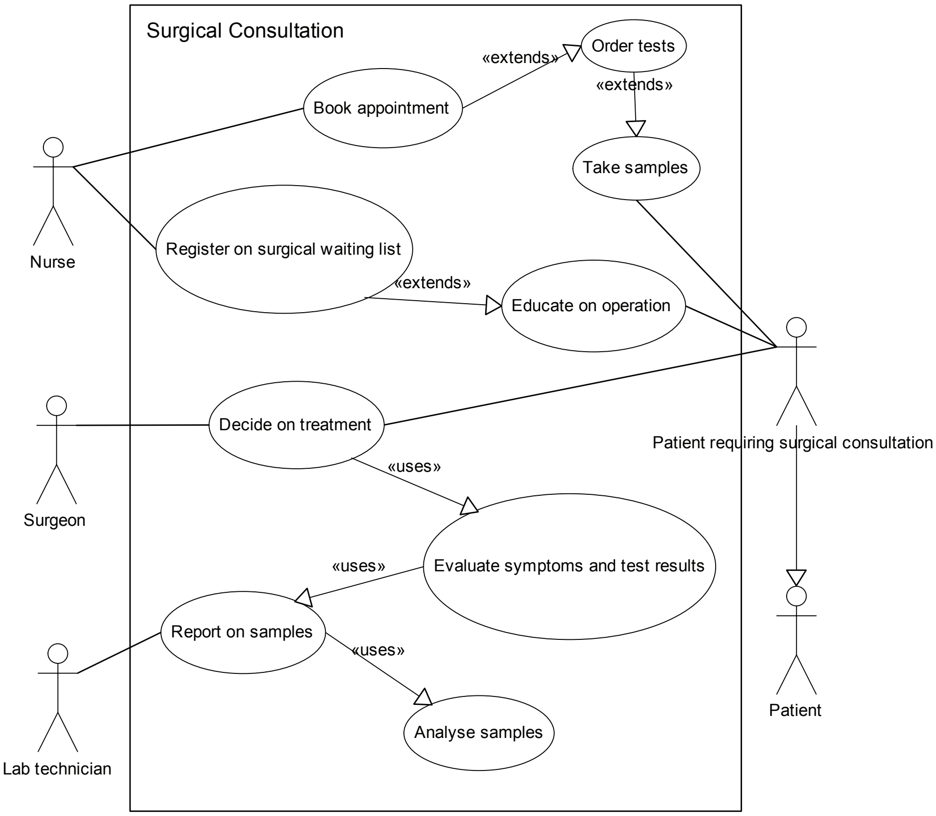
UML Activity Diagram

The purpose of the activity diagram is to depict the procedural flow of actions that are part of a larger activity (Object Management Group, 2005). In projects in which use cases are generated, activity diagrams can model a specific use case at a more detailed level. Activity diagrams can be also used independent of use cases for modelling a function, such as admission to hospital or discharge procedure. They can also be used to model system functions, such as computerised physician order systems, and complete patient pathways, such as from admission to hospital to discharge. Activity diagrams also allow the depiction of parallel activities that often occur in health systems.

In the UML activity diagram, which is based on the semantics of Petri nets, each activity is represented by a rounded rectangle. An arrow represents the transition from one activity to another. The starting point is represented by a filled-in circle and the endpoint by a bull's-eye. Activities enclosed within parallel bars happen at the same time. Diamond shaped objects denote a decision mandated by conditions stated in the brackets above the arrows.

Figure 2 shows a UML activity diagram that models the exemplar surgical care process. Following the referral to the outpatient clinic, booking the appointment and ordering of the diagnostic tests happen in parallel (for the purposes of this example). Depending on the outcome of the consultation, the patient's name is registered on the surgical waiting list if operation is deemed necessary and the patient may receive education about

Figure 1. UML use case diagram of a simplified surgical care service (surgical consultation in outpatient clinic)



the operation, otherwise the patient is referred for medical treatment.

UML State Diagram

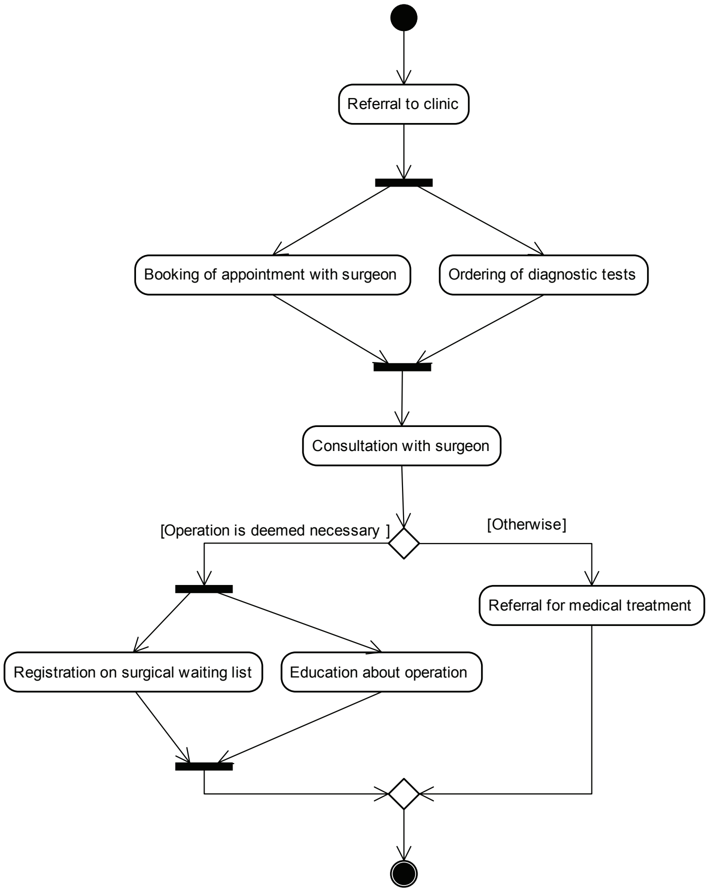
The UML state diagram is essentially a Harel (1987) Statechart with standardized notation that can describe any system that is (or can be conceptualised as) reactive, from computer programs to business processes. In this context, a reactive system—as opposed to a transformational system—is a system that constantly responds to internal and external stimuli by changing states or by performing some action.

Like state machines, a UML state diagram includes state-transition diagrams that represent the operations of a system through discrete states and transitions from one state to another. In addition, state diagrams include notions of state hierarchy, parallelism, and event broadcasting (Sobolev, Harel, Vasilakis, & Levy, 2008).

In UML state diagrams, rectangles represent states and arrows represent transitions. An arrow may have a transition label that controls the transition. The label includes the events that trigger the transition, and the condition that needs to be true for the transition to occur in square brackets. The actions associated with the transition also appear on the labels following the forward slash. Drawing states inside other states represents hierarchy. Dashed rectangles symbolise parallel states.

Figure 3 shows a UML state diagram of patient states in the example of surgical care service. Following the referral to clinic, the initial substates called "pending" of parallel states "appointment" and "diagnostic tests" are activated. When the

Figure 2. UML activity diagram of the care process of a simplified surgical care service (surgical consultation in outpatient clinic)



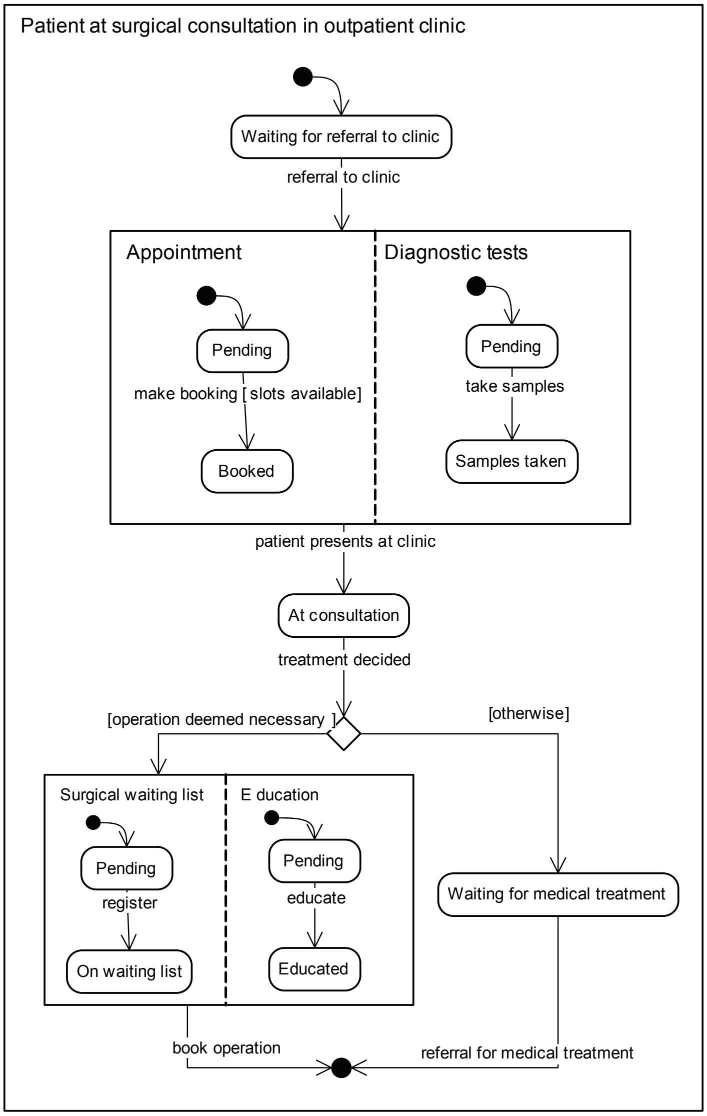
event "make booking" is fired and if there are available slots in the clinic, the patient is considered to have the appointment booked. Once the treatment has been decided and depending on the outcome, the patient state transitions to "surgical waiting list" and "education," or to "waiting for medical treatment."

UML Class Diagram

A class diagram describes the static structure of a system by showing the system's classes, their attributes and methods, and the relationships between the classes (Object Management Group, 2005).

A class, indicated by a rectangle, can be thought of as a blueprint for defining similar objects. Each object is an instance of a class and encapsulates both state, in terms of attributes, and behaviour, in terms of methods. Attributes (or properties) are shown in an optional compartment below the class name. Each attribute is shown with at least its name, and optionally with its type, initial value, and other information. The class methods (or operations) appear in a second optional compartment. Each method is shown with at least its name, and additionally with its parameters and return type. The association between two classes is indicated by a line. The number of objects participating in the association, known as multiplicity, is given by an optional notation at each end of the line

Figure 3. UML state diagram of patient states in a simplified surgical care service (surgical consultation in outpatient clinic)



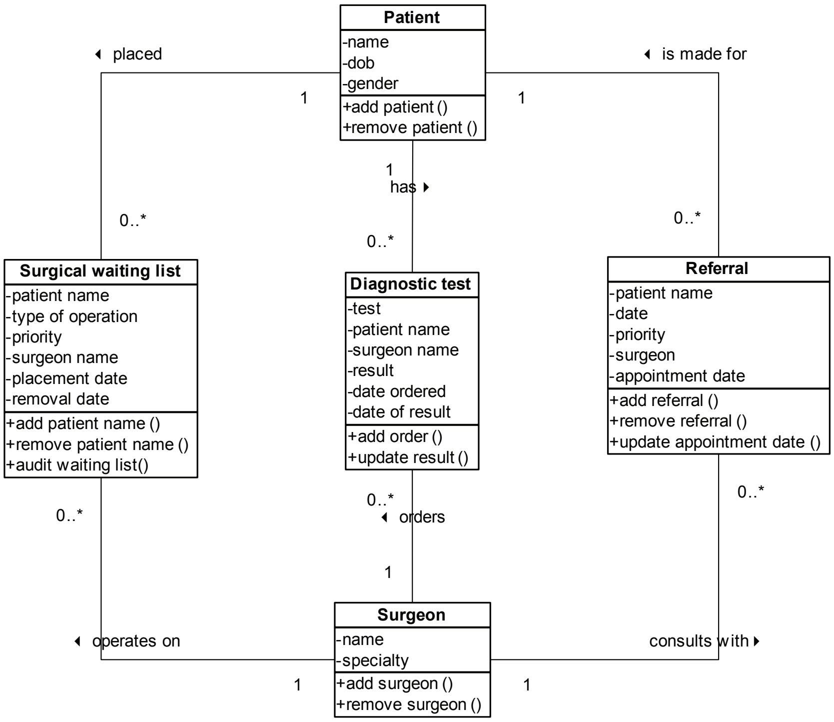
("0..1" if none or only one object participates in the association, "1" exactly one, "0..*" zero or more, "1..*" at least one).

In the example shown in Figure 4, a patient may have none, one, or more referrals (on different dates). Each referral has a priority, is made to the named surgeon, and the appointment slot is updated once it has been scheduled. Patient names are placed on the surgical list of a surgeon following the consultation. A surgeon may be associated with no patients or many. A class diagram may convey a lot more information that is omitted here in the interests of brevity.

Application of UML Tools to Health Care

For the literature survey, we searched the medical literature for articles that demonstrate the application of UML tools to the broad area of health

Figure 4. UML class diagram of a simplified surgical care service (surgical consultation in outpatient clinic)



care. We included all articles that demonstrated the application of any of use case and UML use case diagram, UML activity diagram, UML state diagram, and UML class diagram. Eighteen papers were identified to be relevant to this review, found via published (as listed in Pubmed) and grey literature search. The literature survey identified use cases and use case diagrams (11 papers), and activity diagrams (13) as the most common UML tools of the four included in this survey used in health system analysis. Some studies have reported on the use of class diagrams (3) but none on the use of UML state diagrams. The search yielded very little evidence of a systematic evaluation of the benefits of using UML in the analysis of health care systems.

The retrieved literature can broadly be classified into three categories according to the application domain: modelling health care processes, evaluating and modelling clinical guidelines, and evaluating and generating requirements of information systems in health care. We now briefly review each collected article according to the these categories.

Modelling Health Care Processes

Recent work by Jun (2007) and Jun, Ward, and Clarkson (2005) aimed at providing the effective application of various modelling methods to health care with the end goal of enabling professionals and managers to understand care processes more clearly, manage risk, and as a result improve patient safety. Among the modelling methods evaluated was the swim lane activity diagram, which is a variation of UML activity diagram where activities are grouped according to the actors involved or in a single thread. Three case studies were used to illustrate the methods: patient discharge, diabetic care process in GP practise, and prostate cancer diagnosis process in the hospital. The findings of the case studies were evaluated against benchmark goals of enhancing understanding and validated via key user review of findings.

Cruz, Gramaxo Silva, Soares, Oliveira, Serrano, and Paulo Cunha (2002) reported on the experience of the using UML use case diagrams as a tool to optimise hospital processes. The diagrams were developed at two levels of abstraction: a global use case diagram to represent the main processes of the care services examined, and detailed use case diagrams to study parts of the system seen as critical bottlenecks. Activity diagrams were to be developed in subsequent project phases to model dynamic concepts of each detailed use case. Although Cruz et al. (2002) concluded that UML helped in communication, discussion, and validation of the different steps of the project, there was no evaluation of these benefits.

Goossen et al. (2004) looked at the feasibility of mapping and modelling of nursing care process information to some international standards. They represented the nursing care process as a dynamic sequence of phases, each containing information specific to the activities of the phase, and used UML to represent this domain knowledge in models. A UML activity diagram was developed as a model of a generic nursing care process. After creating a structural model of the information collected at each stage of the nursing process, various working groups mapped that information to other standards as a means of validation. An activity diagram of a generic nursing process was also developed as a problem solving approach to patient care and a UML class diagram enhanced this view and demonstrated further the care process from a nursing perspective. The authors concluded that their study produced a good model of the nursing care process but that improvements could still be made. However, despite the self critique of the study, the authors did not evaluate the UML activity and class diagram benefits and drawbacks as a means to study health care processes.

Spyrou, Bamidis, Pappas, and Maglaveras (2005) proposed an extension of UML to model processes in the health care domain using workflow modelling techniques. The work presented in the article extends the UML activity diagram to support workflow characteristics as well as standardised clinical documents that are handled by the processes. The extended notation was then used to model the flow of patients in a regional health system. No evaluation of the benefits was reported.

Lyalin and Williams (2005) aimed at improving the way cancer registration and other processes are described through enhancements in the notation of UML activity diagrams. The article illustrates a UML activity diagram used to describe the process of cancer registration and which was enhanced by allowing the depiction of timeline, duration for individual activities, responsibilities for individual activities, and descriptive text. The authors claim that this provides for clarification of the process of cancer registration and can broaden its understanding among different specialists. Lyalin and Williams (2005) included an extensive description of benefits and weaknesses of activity diagrams and a comprehensive activity diagram of death clearance process at cancer registry. The authors conclude that the enhancements add value to the tool and cite the positive response they received after using the enhanced UML activity diagrams in a cancer registry best practices development workshop.

Similarly, Saboor, Ammenwerth, Wurz, and Chimiak-Opoka (2005) aimed at improving UML activity diagram by developing and testing a process modelling method which included details of clinical processes necessary for a systematic and even semiautomatic quality assessment. The premise of the authors' work was that UML is only a descriptive tool that does not allow for comprehensive quality assessment. Subsequently, Saboor et al. (2005) proposed a new modelling method based on the UML activity diagram with extra notations to allow for evaluation. The method was validated by modelling various versions of the process of ordering a radiological examination. It was suggested that further evaluation of improvements on the UML activity diagram were needed.

Evaluating and Modelling Clinical Guidelines

Sutton, Taylor, and Earle (2006) developed a computerised system to allow hypertensive patients to be monitored and assessed without visiting their family doctors. The Web-based system, created using PROforma, made recommendations for continued monitoring and for changes in medication. PROforma is a language that allows clinical guideline to be expressed in a computer-interpretable manner. The study concluded that PROforma proved adequate as a language for the implementation of the clinical reasoning but lacked notational convenience. Hence, UML activity diagrams were employed instead to create the models that were used during the knowledge acquisition and analysis phases of the project. Sutton et al. (2006) also reported on the application of UML activity diagram to represent the clinical guidelines in the management of hypertensive patients. The authors praised the notational convenient of UML but did not systematically evaluate its benefits.

In similar fashion, Hederman, Smutek, Wade, and Knape (2002) compared a technique for representing and sharing clinical guidelines (GLIF) with UML activity diagram. The authors concluded that there are clear potential benefits in using a mainstream modelling language such as UML as opposed to a specific clinical guideline representation technique such as GLIF. The potential benefits include availability of modelling tools, the ability to transfer between modelling tools, and to automate via business workflow technology. However the authors provided no systematic evaluation of the benefits of employing UML tools in health systems, but rather focused on the utility of UML activity diagram in general.

Evaluating and Generating Requirements of Information Systems

Maij, Toussaint, Kalshoven, Poerschke, and Zwetsloot-Schonk (2002) looked at the problem of alignment between information and communication technology (ICT) infrastructure and business processes in health care organisations. The paper investigated whether the combination of Dynamic Essential Modelling of Organisations, that is a business process modelling methodology, with UML can solve the problem. It used the example of a screening case study on the management of preoperative centres and focused on developing an efficient information system. Maij et al. (2002) used UML use cases to derive the functionality of the information systems. It also provided a use case diagram and description for a transaction at the preoperative centre. The authors concluded that the combination of the two techniques is useful in aligning business processes and functional features of ICT infrastructure and should help the end-user to develop a better understanding with regards to the relationship between the two areas. Although the paper did include a brief discussion of UML, it did not provide a systematic assessment of its utility in health care.

Lee, Bakken, and John (2006) briefly reported on the use of UML tools (use case, activity, and sequence diagrams) to store and present the functional requirements of a handheld-based decision support system for morbid obesity screening and management. The authors stated that UML is useful in depicting processes related to management of clinical based guidelines, facilitating discussion and agreement in developing data model, and in aiding the design of Web-based prototype.

Lunn, Sixsmith, Lindsay, and Vaarama (2003) reported using UML activity diagram to model various processes of monitoring care and use case diagrams to generate requirements for the development of an information system intended to support planning in the provision of elderly care services. The study is a good example of the application of UML tools in health but provides little guidance in terms of actual benefits and weaknesses.

Weber et al. (2001) aimed at developing a tool to support clinical trial centres in developing trial specific modules for the computer-based documentation system of paediatric oncology. The research carried out an object-oriented business process analysis for a clinical trial conducted at a German hospital. The results comprised a comprehensive business process model consisting of UML diagrams and use case specifications, which included use case diagrams ("manage trial," "plan trial," "conduct trial," "document course of therapy," and documentation view of the latter) and an example of use case specification. Weber et al. (2001) concluded by recommending the use of object-oriented analysis in the context of therapeutic trials but did not carry out the an evaluation.

LeBozec, Jaulent, Zapletal, and Degoulet (1998) described a UML approach to the designing of a case-based medical imaging retrieval system for pathologists. The authors created UML use case and class diagrams to illustrate the steps of the case-based reasoning systems methodology used to develop sound knowledge systems in pathology. The diagrams were used to visualize the relevant objects and to evaluate the model before implementation, and included use case diagram of the image retrieval system and use case with corresponding scenarios chart. The authors concluded that, although further evaluation is required, UML seems to be a promising formalism improving the communication between the developers and users.

Aggarwal (2002) highlighted the benefits of the UML in specifying, visualising, constructing, documenting, and communicating the model of a health care information system. It illustrated the usage of use cases and use case diagram, activity and class diagram by employing simplified examples of a nurse submitting a blood-count order, a physician order system, and of an emergency room.

Ganguly and Ray (2000) discussed the development of a methodology for the design of interoperable telemedicine systems based on UML. Their research focused on the feasibility of the development of agent-based interoperable telemedicine systems and used the example tele-electrocardiography in the case study. Among the tools suggested for system design, Ganguly and Ray (2000) used a UML use case diagram to describe a distributed electrocardiogram system.

Finally, Hoo, Wong, Laxer, Knowlton, and Wan (2000) had as an objective to develop software that facilitates more efficient and effective utilisation of medical images and associated data in biomedical research. The area of focus was assisting clinicians in presurgical evaluation of patients with medically refractory epilepsy as an example. The authors drafted use cases to summarize operational scenarios of clinicians using the system and used UML class diagrams to describe object-oriented concepts of the system.

DISCUSSION

In this article, we introduced four common UML diagrammatic tools (use case, activity, state, and class diagrams) and used original models of a simplified example of surgical service to illustrate their usage. We also presented the findings of a literature survey on the application of these tools to the modelling of health care systems. The survey identified a number of articles in which UML tools were used but very limited systematic evaluation of their benefits.

One notable exception is the recent work by Jun (2007) where a variety of modelling methods, including a variation of UML activity diagrams, was evaluated for their utility in modelling health systems. Jun (2007) identified that only a limited number of modelling methods have been considered or evaluated for purpose of use in health care settings. Following systematic evaluation by health care professionals, Jun (2007) concluded that there is no single method preferred by all users or applicable to all areas but there is a strong case for using a variety of modelling techniques in enhancing the understanding of care process among practitioners. This work is, to our knowledge, the only comprehensive evaluation of different process mapping tools in health care and provided a clear insight to the benefits those methods can offer to the system, practitioners, and the patient. Similar evaluation may also be needed for all UML tools before firm recommendations can be made as to their applicability.

Despite the obvious analytical applicability, also pointed out by Jun (2007), state diagrams have not been used in the analysis of health care systems. The closest case is in an analysis of biological systems by Roux-Rouquie, Caritey, Gaubert, and Rosenthal (2004), where the utility of UML state diagrams to describe and specify biological systems and processes was examined. Roux-Rouquie et al. (2004) mapped biological concepts to UML ones and presented state diagrams with states and substates of the active and inactive enzymes, and with concurrent substates at molecular and phenotype levels. Outside the UML notation, the original Statecharts notation that forms the basis of the UML state diagram notation has recently been used in the modelling and simulation of a cardiac surgical service (Sobolev et al., 2008; Vasilakis, Sobolev, Kuramoto, & Levy, 2007).

CONCLUSION

It is apparent from this literature survey that UML has a role in the analysis of health care systems. There are clear benefits, especially in terms of clarity of communication and repeatability, if a standardised and rigorous notation is employed broadly. However, the application of UML to the modelling of health care systems is probably not as prevalent as in other application domains, at least as it is documented in the medical literature. Therefore, it is essential to conduct a thorough evaluation of the use and potential benefits of UML in a health care context if more wide spread application is to be recommended.

ACKNOWLEDGMENT

This work was partially supported by an award from the Strategic Promotion of Ageing Research Capacity (SPARC) initiative. The authors acknowledge the support they received from the Harrow School of Computer Science, University of Westminster, as well as the generous advice they received from Prof. Peter Millard, Prof. Peter Lansley, and Dr. Elia El-Darzi.

REFERENCES

Aggarwal, V. (2002). The application of the unified modeling language in object-oriented analysis of healthcare information systems. *Journal of Medical Systems, 26,* 383-397.

Ambler, S. (2004). *The object primer: Agile modeling-driven development with UML 2.0.* Cambridge: Cambridge University Press.

Berwick, D.M. (2005). The John Eisenberg lecture: Health services research as a citizen in improvement. *Health Services Research, 40,* 317-336.

Cruz, I.A., Gramaxo Silva, A., Soares, P., Oliveira, I., Serrano, J.A. V., & Paulo Cunha, J. (2002). Modelling the hospital into the future with UML. *International Journal of Healthcare Technology and Management, 4,* 193-204.

Ganguly, P., & Ray, P. (2000). A methodology for the development of software agent based interoperable telemedicine systems: A tele-electrocardiography perspective. *Telemedicine Journal, 6,* 283-294.

Goossen, W., Ozbolt, J., Coenen, A., Park, A., Mead, C., Ehnfors, M., et al. (2004). Development of a provisional domain model for the nursing process for use within the health level 7 reference information model. *Journal of the American Medical Informatics Association: JAMIA, 11,* 186-194.

Harel, D. (1987). Statecharts: A visual formalism for complex systems. *Science of Computer Programming, 8,* 231-274.

Hederman, L., Smutek, D., Wade, V., & Knape, T. (2002). Representing clinical guidelines in UMl: A comparative study. *Studies in Health Technology and Informatics, 90,* 471-477.

Hoffman, K.J. (1997). Demystifying mental health information needs through integrated definition (IDEF) activity and data modeling. *Journal of the American Medical Association, Symposium.l,* 111-115.

Hoo, K.S., Wong, S.T.C., Laxer, K.D., Knowlton, R.C., & Wan, C. (2000). Design patterns in medical imaging information systems. *Proc. SPIE Medical Imaging, 3980*, 256-263.

Jun, G.C.T. (2007). *Design for patient safety: A systematic evaluation of preocess modelling appraoches for healthcare system safety improvement,* PhD Thesis. Cambridge: University of Cambridge, Department of Engineering.

Jun, G.C.T., Ward, J.R., & Clarkson, P.J. (2005). Mapping the healthcare process in order to design for patient safety. In *International Conference on Engineering Design (ICED 05)* (pp. 353-364).

Kalli, S., Ambroso, C., Gregory, R., Heikela, A., Ilomaki, A., Leaning, M., et al. (1992). Inform: Conceptual modelling of intensive care information systems. *International Journal of Clinical Monitoring and Computing, 9,* 85-94.

Kumarapeli, P., De Lusignan, S., Ellis, T., & Jones, B. (2007). Using Unified Modelling Language (UML) as a process-modelling technique for clinical-research process improvement. *Medical Informatics and the Internet in Medicine, 32,* 51-64.

LeBozec, C., Jaulent, M.C., Zapletal, E., & Degoulet, P. (1998). Unified modeling language and design of a case-based retrieval system in medical imaging. In *AMIA Annual Symposium Proceedings* (pp. 887-891).

Lee, N.J., Bakken, S., & John, R. (2006). Functional requirements specification and data modeling for a PDA-based decision support system for the screening and management of obesity. In *AMIA Annual Symposium Proceedings* (pp. 1002).

Lunn, K., Sixsmith, A., Lindsay, A., & Vaarama, M. (2003). Traceability in requirements through process modelling, applied to social care applications. *Information and Software Technology, 45,* 1045-1052.

Lyalin, D., & Williams, W. (2005). Modeling cancer registration processes with an enhanced activity diagram. *Methods of Information in Medicine, 44,* 11-13.

Maij, E., Toussaint, P.J., Kalshoven, M., Poerschke, M., & Zwetsloot-Schonk, J.H. (2002). Use cases and DEMO: Aligning functional features of ICT-infrastructure to business processes. *International Journal of Medical Informatics, 65,* 179-191.

Mehta, N.Y., Haluck, R.S., Frecker, M.I., & Snyder, A.J. (2002). Sequence and task analysis of instrument use in common laparoscopic procedures. *Surgical Endoscopy, 16,* 280-285.

Object Management Group. (2005). *Unified Modeling Language: Superstructure. Version 2.0.* OMG Inc.

Pohjonen, H., Bondestam, S., Karp, P., Kinnunen, J., Korhola, O., Sakari, P., et al. (1994). Quality assurance of the bedside chest radiography process. *Acta Radiologica, 35,* 235-243.

Roux-Rouquie, M., Caritey, N., Gaubert, L., & Rosenthal, S. (2004). Using the Unified Modelling Language (UML) to guide the systemic description of biological processes and systems. *Biosystems, 75,* 3-14.

Saboor, S., Ammenwerth, E., Wurz, M., & Chimiak-Opoka, J. (2005). MedFlow - improving modelling and assessment of clinical processes. *Studies in Health Technology and Informatics, 116,* 521-526.

Sobolev, B., Harel, D., Vasilakis, C., & Levy, A.R. (2008). Using the statecharts paradigm for simulation of patient flow in surgical care. *Health Care Management Science, 11,* 79-86.

Spyrou, S., Bamidis, P., Pappas, K., & Maglaveras, N. (2005). Extending UML activity diagrams for workflow modelling with clinical documents in regional health information systems. In *Proceedings of MIE2005* (pp. 1160-1165).

Sutton, D.R., Taylor, P., & Earle, K. (2006). Evaluation of PROforma as a language for implementing medical guidelines in a practical context. *BMC Medical Informatics and Decision Making, 6,* 20.

Vasilakis, C., Sobolev, B., Kuramoto, L., & Levy, A. R. (2007). A simulation study of scheduling clinic appointments in surgical care: Individual-surgeon vs. pooled lists. *Journal of the Operational Research Society, 58,* 202-211.

Weber, R., Knaup, P., Knietig, T., Hauz, R., Merzweiler, A., Mludek, V., et al. (2001). Object-oriented business process analysis of the cooperative soft tissue sarcoma trial of the German Society for Paediatric Oncology and Haematology (GPOH). In *Proceedings of the 10th World Congress on Medical Informatics (MEDINFO 2001)* (pp. 58-62).

This work was previously published in International Journal of Healthcare Information Systems and Informatics, Vol. 3, Issue 4, edited by J. Tan, pp. 39-52, copyright 2008 by IGI Publishing (an imprint of IGI Global).

Chapter 8.12

Coding and Messaging Systems for Women's Health Informatics

David Parry
Auckland University of Technology, New Zealand

ABSTRACT

Recording information about symptoms, observations, actions, and outcomes is a key task of health informatics. Standardization of records is vital if data is to be used by different groups, and transferred between organizations. Originally, coding focused on causes of death and other outcomes. Such systems include the international classification of diseases (ICD). However, more recently the need to allow communication between health organizations has encouraged the development of standards such as health level seven (HL7). Further work has focussed on vocabularies such as systematic nomenclature of medical terms (SNOMED), which allow standardised recording of any health-related information. Coded data is necessary to allow computers to assist in decision making and for audit purposes. With the rapid development of computer networks and the Internet, there has been a growing effort to include semantic information with computer data so that the meaning of the data can be bound to the data store. The chapter discusses these standards and the areas that are undergoing rapid development.

DOI: 10.4018/978-1-60566-078-3.ch003

INTRODUCTION

"We need three types of clinical information standards: document structuring standards; term lexicons; and ontologies"(Gardner, 2003)

Coding and messaging systems allow the standardisation and systemisation of information storage and transmission in healthcare. They allow the accurate and structured representation of information which can be used to impart a common understanding. The aim of this chapter is to introduce some of these systems along with the theory that underlies them and the uses to which they are put. These approaches are particularly important in women's health informatics for a number of reasons:

- In pregnancy it is common for women to be cared for by a number of healthcare professionals, and communication between them should be precise and efficient
- Past outcomes and complications often have a great influence on the care plans for women in subsequent pregnancies, and this information is much more effective if standardised. Information recorded in previous pregnancies may be useful for risk prediction if presented in a suitable format.
- Government agencies and healthcare organisations require accurate and extensive information in order to fulfil their information needs. Information relating to births has been collected for centuries, and improvement in morbidity and mortality can only be noted with standardised recording.
- Funding and fee for service are often related to the case mix of the institutions providing the care.
- Health Surveillance and audit of outcomes is particularly important for screening programmes and also to understand long-term trends such as the general rise in operative deliveries.
- Research in the area of women's health often requires re-examination of clinical records generated in the past. Accurate coding allows the selection of suitable records and patients for research studies as well as linkage between history, intervention and outcomes.
- An exciting area of research is the development and use of decision support tools that use historical data to provide patients and clinicians with guidance concerning the likely outcome of clinical decisions and the natural history of disease. This sort of decision support is covered in more detail in Chapter XV.

For all these reasons, coding of clinical events, diagnoses and interventions is an important part of an information system designed to support women's health.

At it's heart, coding is a systematic and reproducible method of recording pertinent information for the improvement of management of healthcare. Messaging involves the transmission of healthcare information in a standardised and efficient format within and between information systems that are involved in the care of people.

In terms of system efficiency, coding can dramatically reduce the amount of data stored, and also increase the usefulness of this data for analysis. However the coding process is demanding and requires care and understanding of the principles of the coding system being used.

The next section of this chapter gives some background to the development of modern coding and messaging system. The main varieties of coding systems in use currently (ICD, READ, DRG) are described in the coding systems section. Messaging systems are then described including health level 7 (HL7) and Digital Imaging and Communications in Medicine (DICOM). More complex and complete systems for recording information including some controlled vocabularies such as SNOMED and ontologies are then described. Finally a discussion of the state of the art, and some future areas of development is contained in the final section.

BACKGROUND AND HISTORY

Medicine has grappled for many years with the need to have efficient means of communicating data about patients, diseases and treatments. From the time of Hippocrates, writing down clinical information has been a major part of health care. Comparison between patients, and agreement on diagnosis and symptoms requires agreed recording and communication standards. Medical language has been sometimes seen as a barrier between professionals and lay people, but precision and flexibility are vital even if a private language appears to be in use. Precision and comprehensibility are not mutually exclusive. When computers are involved the need for standards becomes even more important despite valiant efforts over many years in attempting to teach computers to understand natural language (Rosenfeld, 2000). Indeed medical work can be seen as concerned primarily with information communication, storage and transformation. Unambiguous and precise communication of information is vital and a major issue in healthcare (Coiera & Tombs, 1998).

Coding clinical observations has a long history in women's health, for example the "Bishop Score" (Bishop, 1964), derived as a scoring system using various observations in order to aid decision making in induction of labor.

A very precise and often formalised natural language, including a large number of specialised words and compounded terms is taught to clinicians in training. This allows precise description of anatomical features, symptoms etc. and also the construction of new descriptors by combination of existing ones. Although this process is dynamic, for example the term "Gestational proteinuria and hypertension" has recently replaced "Pre-Eclampsia" in many units it does not usually cause difficulties in communication. However, the general tendency as in many fields is to avoid ambiguity rather than encourage standardisation. Thus, a great many synonyms are used and often the preferred term is different in different specialities or countries. This issue makes data processing related to medicine difficult, and for that reason a large number of coding systems have been proposed and a number are currently in use. Ultimately, any coding system is based around an ontology – although this may not be made explicit to the user of the system.

There are 3 main types of coding system:

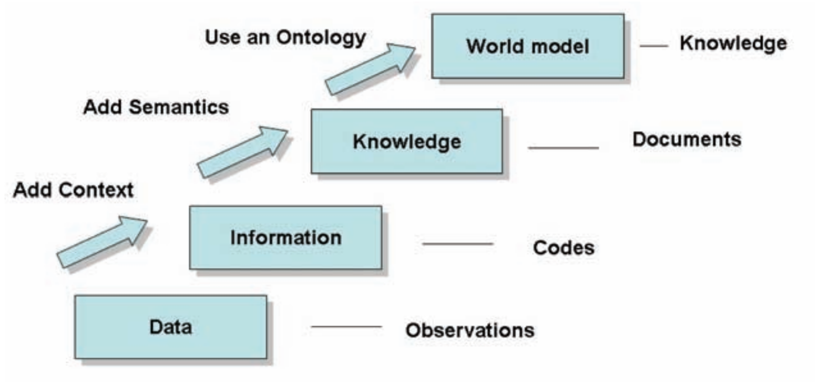
1. Hierarchical systems with fixed codes or terms determined by some central body, for example the International Classification of Disease version 10 (ICD10) (World Health Organization, 2001). In most cases these systems allow a patient to have membership of more than one code simultaneously, although many systems, such as Diagnostic related groupings (DRG's) require the identification of a Primary ICD diagnosis code. Sometimes membership of more than one lowest level code in the same branch is not allowed. Medical Subject Headings (MeSH) are another example of this type of coding system (U.S. National Library of Medicine, 2001).
2. Format-based systems, that specify the allowed format without giving a complete lexicon of the terms – for example the health level 7 (HL7) messaging system. Interestingly the 3rd version of this standard is beginning to include semantic information and standards. (Health Level Seven Inc)
3. Vocabulary systems such as SNOMED that allow the construction of descriptors from primitive elements (American College of Pathologists, 2000).

Often only type 1 is given as a "true" coding system. However, such systems are less useful than the others at communicating a dynamic status, for example in the case where a patient's diagnosis is not yet definitive, or when symptoms may or may not be significant.

Semantics of Coding

Ultimately all coding systems attempt to represent clinical information in a way that can be understood by humans and/or computers. The job of coding involves a standardised representation of a particular significant piece of information. However coding systems are beginning to go beyond the concept of simply being controlled vocabularies or dictionaries, and instead focussing on the importance of meaning, and use. Much of this work can be linked to the concepts of "the semantic web"(Berners-Lee, Hendler, & Lassila, 2001),

Figure 1. Data to knowledge



although work in the medical domain actually preceeded this initiative. As defined on the WWW consortium website (http://www.w3.org/2001/sw/) "The Semantic Web is about two things. It is about common formats for integration and combination of data drawn from diverse sources, where on the original Web mainly concentrated on the interchange of documents. It is also about language for recording how the data relates to real world objects". The semantic web, then involves being able to extract the useful data from complex documents that are generated from heterogeneous sources, and provide a method to allow this data to be analysed and made useful. It also allows data to be related to the real world.

In terms of practical implementation, sematic web research involves the manipulation transfer and analysis of documents written in a suitable format across the Internet.

In the context of healthcare, this means that all records, messages and documents can contribute to a picture of the state of the patients, without the need for overarching single electronic health record. The key to semantic interoperability is that the definitions for what things mean are common, if this is done then every piece of information around the patient can in theory be accessed assuming there are suitable procedures, controls and interfaces. In the case of the semantic web, this common understanding has been built on the basis of standard data type diagrams (DTD's) for XML documents, and some approaches such as HL7 level 3 are implemented in XML(Dolin et al., 2001).

A general model of the role of coding and semantics is shown in Figure 1.

Because observations can be converted to a standard form or code, many observations can be represented in a single document, and assuming that the mapping between observation and code is consistent, then a collection of documents can be represented within a world model.

Coding, Messaging and Workflow

By allowing consistent formatting and transmission of information, the process of transferring information between systems and users can be simplified. Coding of diagnosis for example, allows protocols to be set up that distribute information in a way that supports appropriate patient care. Thus coded data about symptoms, diagnosis or treatment can act as metadata to a fuller description of a current patient state, their likely prognosis and the protocols that need to be followed to ensure appropriate care. For these reasons, early, accurate coding is important.

Traditionally coding has been a post-event activity, often based around the discharge summary, and performed by trained clinical coders. Associations of clinical coders such as the Professional Association of Clinical Coders PACC-UK (http://codeinfo.org/paccuk/index.html), and the American Association of clinical coders and auditors (http://codeinfo.org/paccuk/index.html). Post-event coding has the advantage that the diagnoses and procedures are more likely to be certain at this stage, and there may be written artefacts to guide the coder. This approach is particularly attractive when coding is primarily a source of information for reimbursement to the treating institution, as it allows a holistic view to be taken of activity, along with income from that activity. However the disadvantages of this approach include the fact that coded data is then not available to the clinical team during the event, that mistakes or misunderstandings can be generated by the need of coders to interpret non-coded information, often from a wide variety of sources, and the disruption to clinical practice of having paper records being sent to the coding department.

As electronic health records have become more common, coding at the point of care, or near to the point of care has become attractive. This obviously reduces the time taken to produce codes, can reduce data storage requirements in clinical records, and can allow the codes to be used immediately in decision support applications such as PRODIGY(Wilson, Purves, & Smith, 2000) (now known as CKS). Disadvantages of this approach include the need to train clinical users in often complex coding schemes, the lack of time in many clinical encounters and the danger of propagating uncertain diagnoses through a system.

Accuracy of coding by non-experts can be improved by using specific paper templates or electronic systems to support selection of the correct code. These have been shown to produce results comparable with that of expert coders(Silfen, 2006). The time taken to code can also be reduced by using cascading menu approaches, where the user navigates through the hierarchy that is present in many codes such as Read or ICD10, for example choosing first the system or site and then being presented with intermediate context-sensitive choices. By using this approach, decisions on coding and the required precision can be made more easily with less risk of grossly inaccurate codes and a better understanding of the subtle differences between them (see Figure 2).

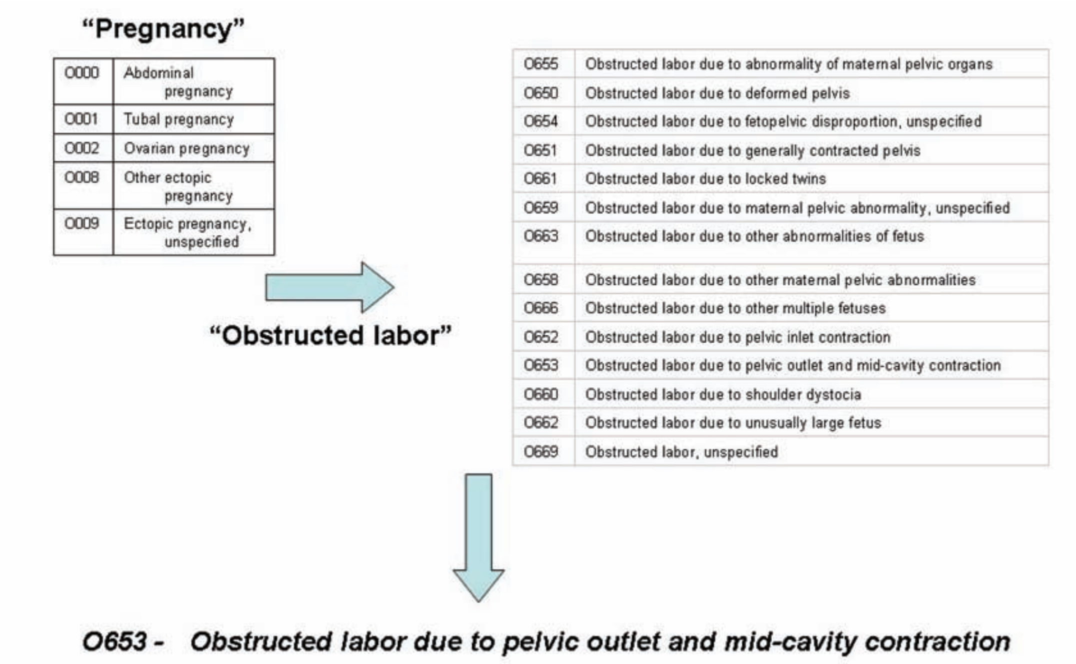
Users of Information

Clinical staff actually treating the patient are major users of information. In addition, there is a need for communication between hospital staff and community care professionals including GP's, Pharmacists and family planning professionals. Non-clinical cares including social services may also require information. Insurance companies, charity funders and governmental organisations require data in the form of activity reports and for statistical purposes. Obviously the patients themselves can use their own information Efficient and effective coding allows large scale databases to be constructed, which can be anonymised to allow statistical analysis, for example in terms of prescribing trends. An example of such a database is the UK General Practice Research Database (Walley & Mantgani, 1997). Similar databases can be used as sources of recruitment for clinical trials, or for audit purposes.

In the US a major user of coded information is the Medicaid system, and this has used Diagnostic Related Groups (DRG's) to identify the severity and hence expected cost of treatment of patients. Software –GROUPER – is used to convert diagnosis and procedure information into a DRG, in this case a case mix index. (CMI). Health care facilities can then calculate their actual costs, compared to the reimbursement derived from funding sources.

Along with clinical and research uses coding assists with accurately describing the mix of patients being seen, auditing of the outcomes compared with other centres and estimation of effort. Other scoring systems measure the likelihood of survival in intensive care – for example

Figure 2. Choice of appropriate code



O000	Abdominal pregnancy
O001	Tubal pregnancy
O002	Ovarian pregnancy
O008	Other ectopic pregnancy
O009	Ectopic pregnancy, unspecified

O655	Obstructed labor due to abnormality of maternal pelvic organs
O650	Obstructed labor due to deformed pelvis
O654	Obstructed labor due to fetopelvic disproportion, unspecified
O651	Obstructed labor due to generally contracted pelvis
O661	Obstructed labor due to locked twins
O659	Obstructed labor due to maternal pelvic abnormality, unspecified
O663	Obstructed labor due to other abnormalities of fetus
O658	Obstructed labor due to other maternal pelvic abnormalities
O666	Obstructed labor due to other multiple fetuses
O652	Obstructed labor due to pelvic inlet contraction
O653	Obstructed labor due to pelvic outlet and mid-cavity contraction
O660	Obstructed labor due to shoulder dystocia
O662	Obstructed labor due to unusually large fetus
O669	Obstructed labor, unspecified

APACHE, and have been shown to be good at predicting outcome (Beck, Taylor, Millar, & Smith, 1997), fortunately, although not specifically designed for women's health. There are a number of systems to measure nursing intensity or worklaod – for example the therapeutic intervention scoring system (TISS)(Keene & Cullen, 1983), although these systems are not necessarily very useful for calculating nurse/patient ratios (Adomat & Hewison, 2004).

Clinical staff can use historical coded information to audit their practice, as well as comparing their Casemix with other professionals and linking input to output. Pregnancy care is particularly interesting in this regard- especially in terms of the decision to intervene. The problem is difficult to analyse because outcomes for mother and baby are usually good whatever the decisions made. Essentially, if an intervention is made, comparison with a group where intervention has not been made is difficult because the outcome set is very unbalanced, with good outcomes in the vast majority of cases. By looking at large series of deliveries and analysing the decisions made, then there has been some understanding of the decision making process, but this remains an area of active research (E.C. Parry, Parry, & Pattison, 1999).

CODING SYSTEMS

Coding systems in medicine exist to remove ambiguities, simplify representation, assist with audit and outcome analysis and support decision making as well as having a major role in administration of healthcare systems. Historically, the coding of disease and especially cause of death has been intimately linked to the collection of statistics. Coding systems can trace back their origins to at least the "Bertillon Classification of Causes of Death," which was introduced at the end of the 19th century. Generally, coding occurs at the end of an episode, for example the method

Table 1. ICD 10 procedure codes

ICD10 Code	Description
10D07Z3	Extraction of Products of Conception, Low Forceps, Via Natural or Artificial Opening
10D07Z4	Extraction of Products of Conception, Mid Forceps, Via Natural or Artificial Opening
10D07Z5	Extraction of Products of Conception, High Forceps, Via Natural or Artificial Opening
10D07Z6	Extraction of Products of Conception, Vacuum, Via Natural or Artificial Opening
10D07Z7	Extraction of Products of Conception, Internal Version, Via Natural or Artificial Opening

of delivery of a baby is coded after the baby is delivered.

ICD10

The international classification of diseases is currently in its tenth version (World Health Organization, 2001). This system is administered by the World Health Organisation and is free to use. ICD10 covers a vast range of diagnoses as well as procedures and modifiers. IC-10-CM (clinical modification) which is used for diagnosis includes alpha numeric codes that are 1 to 7 digits long, based largely around anatomical site, followed by disease process and then modifiers. ICD-10-CM is available from the Centres for disease control (http://www.cdc.gov/nchs/about/otheract/icd9/icd10cm.htm) and contains over 68,000 codes in the July 2007 release. Pregnancy codes begin with an 'O' and the modifier generally relates to the trimester.

Gynaecologic disorders do not have their own initial letter but are classified according to the site or type of illness. ICD10 PCS (procedure coding system) is as the name suggests a means of coding procedures. Previous releases of ICD combined the procedures and the clinical descriptions but these are now separate. There are over 86,000 procedures listed in the July 2007 release. Some examples of codes relating to obstetric procedures are shown in Table 1.

ICD codes are designed so that they are increasingly precise from left to right so that when searching for particular diagnoses, one can use select a portion of the code to give the correct degree of precision. For example, looking at Table 2 it can be seen that a search for O104.1* would give all the secondary hypertension patients no matter which trimester they were in.

Read

Read codes were developed for the primary care sector by Dr. James Read in the UK and version 3 was delivered in 1995 (O'Neil, 1995). Read codes are not free to use, but many countries have purchased a licence for use in their healthcare system. Their use is widespread in the UK and has enabled the general practice research database to be built up, containing anonymised data about eight million people(Walley & Mantgani, 1997). This large dataset has been used for investigations into women's health issues, for example (Bromley, Vries, & Farmer, 2004) on the use of hormone replacement therapy. Read codes come in a number of varieties but are generally related to an hierarchy in which successive characters of the code identify the anatomic location or the condition or the procedure more precisely. In many countries Read codes are being superseded by SNOMED CT.

Diagnostic Related Groups (DRG)

DRG's were originally developed to compare casemix between hospitals, so that health providers with more complex cases were not penalised compared to those with simpler workloads. Because of

Table 2. Examples of ICD-10-CM codes with descriptions

ICD10 Code	Description
O104.11	Pre-existing secondary hypertension complicating pregnancy, first trimester
O104.12	Pre-existing secondary hypertension complicating pregnancy, second trimester
O104.13	Pre-existing secondary hypertension complicating pregnancy, third trimester
O104.19	Pre-existing secondary hypertension complicating pregnancy, unspecified trimester

this role, DRG's are linked closely to values for cost of care and length of stay. DRG's comprise a much smaller list of categories than other coding systems- for example in the Austalian DRG system there are only 17 Obstetric codes and 20 Gynaecological ones. Perhaps surprisingly, this reduced granularity and focus on severity of illness or difficulty of treatment can make coding difficult as the code use terms such as "catastrophic" or "severe" complications, which may be difficult to impliment. Recent work in Australia has shown wide variations in the reporting of DRG's (Coory & Cornes, 2005), and this has implications for the idea of paying standard fees per DRG, rather than the calculated cost of service. Similar problems exist if using DRG 's to measure quality of outcome, or level of care. In the obstetric domain, a particular problem is that there is not always a causal link between the risk to mother and baby, the procedure performed, or the outcome of the procedure. For example, a "ceasarian section with catastrophic complications" (O01A) can occur in a pregnancy that is assessed as low risk, whereas an "Vaginal Delivery without Catastrophic or Severe complications" (O60B), can occur after extensive efforts in pregnancy evaluated as being at high-risk of complications.

The DRG system grouper can accept ICD10 codes as an input. Recently work in Taiwan (Yang & Reinke, 2006) has demonstrated that a severity score comparable to DRG can be calculated directly from the ICD10 values.

MESSAGING SYSTEMS

Role of Messaging Systems

Messaging systems allow transfer of information between health information systems. It is very common to have multiple organisations dealing with the care of a woman, during a particular episode. Communication between organisations, and hence between information systems is therefore vital. Such communication occurs in many domains outside healthcare, and is seen as an important factor in increasing efficiency (H.R.Johnston & M.R. Vitale, 1988). Messaging systems allow information to be transferred between systems by using interfaces rather than a common system. Therefore if one part of the system changes, then only the interface needs to change rather than the whole system. However, it is attractive to extend the role of messaging systems to become document storage and management systems., and this expansion has occurred in the case of the most commonly used system – Health level 7(HL7).

HL7

HL7 is so called because it sits at the top of the International standards organisation (ISO) Open system interconnect (OSI) standard . This means that HL7 is associated with the *application* layer, which is the highest one of the model. This corresponds to the application layer of the TCP/IP protocol. In practical terms this means that HL7 messages can be transmitted by any system that is OSI compliant HL7 is administered by the HL7 organisation (http://www.hl7.org/) and is an American National Standards Institution (ANSI) standard. Originally HL7 was a simple messaging protocol, designed to encapsulate clinical information by providing standardisation of formats and minimum data sets. In this approach it has been very successful, with large-scale adoption across many countries and systems, particularly in the area of pathology results and pharmacy orders. Within the message format the vocabulary used is dependent on the application but the Logical Observation Identifier Names and Codes (LOINC) Vocabulary (Huff et al., 1998) is often used.

Health level 7 version 3 has been developed since 2001 to incorporate a clinical document architecture based around XML representations of clinical notes (Dolin et al., 2001). This representation is much more semantically rich than previous approaches and has caused some debate as to whether this will improve the standard or reduce its applicability.

OTHER SYSTEMS

Medical Subject Headings (MeSH)

Medical subject headings (MeSH) are the index terms used by the National library of Medicine (USA). MEDLINE covers more than 11 million journal articles, published since the 1960's and beyond. Historically, MEDLINE can trace its heritage back to the work of Dr. John Shaw Billings (1838-1913) who served as a surgeon in the American Civil War and the director of the National Library of Medicine between 1865 and 1895. During this time "INDEX Medicus" was first published (1879). Index Medicus is an expanding, regularly updated, bibliography covering many medical journals, containing information about author, source, subject and often an abstract of the article. MEDLINE has acted as a successor to this effort. Around 500,000 articles are added to MEDLINE every year, from more than 5000 journals. MEDLINE is accessible via a number of sites including "PubMed" and "Ovid". MEDLINE is available via CD ROM and via the Internet in the PubMed format at no cost to users. Other related databases such as CINHAL (mostly nursing–related) and PSYCHLIT are available from the National Library of Medicine. (Table 3)

MeSH codes are of the form <A00.000...> where A represents an alphabetic character and 0 is a digit between 0-9. As the name suggests MeSH is a hierarchy, with branches being represented by adding 3 digit combinations separated by full stops. Up to 4 extra XXX digit sets can be included.

It is important to note that MeSH is a bibliographic indexing scheme rather than a coding system for describing disease. Thus the choice of index terms is driven by the need to categorise documents, rather than clinical activity. Although arranged as a hierarchy, terms can occur in

Table 3. Root headings for terms taken from MeSH

Code	Description
C13	Female Genital Diseases and Pregnancy Complications
A16	Embryonic Structures
A01.673	Pelvis
A16.378	Fetus
A16.254	Embryo
A16.759	Placenta
A16.950	Zygote
A16.631	Ovum
C02.800	Sexually Transmitted Diseases
C13.371	Genital Diseases, Female
C13.703	Pregnancy Complications
E04.520	Obstetric Surgical Procedures
F03.600	Mood Disorders
F03.800	Sexual and Gender Disorders
G08.520	Reproduction
M01.438	Multiple Birth Offspring

multiple locations, which raises issues with the disambiguation of terms if MeSH is used for the analysis of documents or ontology construction (D. T. Parry, 2006).

DICOM

Digital Imaging and Communication in Medicine (DICOM) is a standard that was jointly developed by the American College of Radiologists and the National Electrical Manufacturers Association(NEMA) in the early 1980's. Currently NEMA holds the copyright for the standard – available from its website http://medical.nema.org/, and although the standard is version 3 the latest revision is known as the 2007 version. DICOM covers the representation, transport and storage of images, originally mostly X-rays, but now extending to ultrasound, MRI, waveforms and other data. DICOM at its simplest level is a file format, which combines patient and other data with the image. In essence the clinical information and patient information are inseparable from the image. This approach is used to avoid non-identifiable images, or wrongly identified images, being produced. Each DICOM file has only one image, but this can be composed of a number of frames which allow for the production of Cineloops. The DICOM standard allows a number of image formats including JPEG, MPEG and lossless JPEG to be used in the file. In terms of transporting the data, DICOM 3 supports transport over TCP/IP, and there are a number of HTTP based approaches, so that conventional web services can be used. DICOM can also deal with files that are transferred or stored on CD's DVD's and other physical transfer media. Some work has been done on assessing the image quality of images compressed using lossy and non-lossy methods(E.C. Parry, Sood, & Parry, 2006),in the context of transfer of obstetric ultrasound images via cheap memory sticks.

The DICOM standard includes "structured reporting", so that the radiology report is included in the file. Recent work (Zhao, Lee, & Hu, 2005) has shown that this can be represented in a XML format, thus increasing the portability and verifiability of the reports.

Because of its origins, DICOM is an extremely precise standard, designed to allow accurate reproduction of images in various formats.

Unified Medical Language System (UMLS)

UMLS is an extremely large repository of concepts and related terms for use in biomedical science. Developed by the National Library of Medicine (NLM), it includes not only its own subject hierarchy (MeSH), but also the metathesaurus, which incorporates ontologies from other sources (Nelson, Schopen, J., & N., 2001). These have lead to the identification of currently over 800,000 strings, with about 330,000 unique concepts. The NLM is to be congratulated for not only providing an extremely large lookup table for these concepts (MRCON), but also providing a list of the relations between them (MRREL). The UMLS also contains the SPECIALIST lexicon, of medical and non-medical terms and the semantic network, that allows complex semantic relations to be checked and constructed. The recent releases of UMLS (Anantha Bangalore, Karen E. Thorn, Carolyn Tilley, & Lee Peters, 2003) have incorporated a new object model and implementation of the system using Java and XML.

Ontologies

An ontology acts as guide to the relationship between concepts in a domain, which may or may not themselves represent physical objects. An ontology is useful for purposes of knowledge sharing and reuse, in fact an ontology can "express formally a shared understanding of information" (Noy et al., 2001) page 60. That is, by understanding the relationships between objects then the interaction between objects, the operations that can be performed on them, and the appropriate position of new objects becomes easier. Tacit ontologies seem to exist in everyday life, as people generally appear able to share knowledge of relations in normal activities. An ontology employs a richer set of relations than a hierarchy, which normally just consists of "is-a" relations. For example one can say in a anatomical ontology that the uterus is contained within the abdomen, and that the fetus is contained within the uterus in normal pregnancy. Hence the fetus is contained within the mother's abdomen. However other relations are possible – so for example the uterine artery can be said to be supplying the fetus via the placenta. Many ontologies have extremely rich sets of relations available e.g. Unified Medical Language System (UMLS), WordNet, PROTÉGÉ. The relations for UMLS are described in Chapter 2. There has been a great deal of interest recently (Musen, 2001) in the construction of ontologies for representing medical knowledge. In many ways an ontology is similar to an XML document, or a class in an object-orientated programming language (Ensing, Paton, Speel, & Rada, 1994). The representation encodes a hierarchical structure, with inheritance of properties from root to branch, with additional attributes at each level. The advantage over the fixed hierarchy of say ICD10 is that such ontologies can be modified with the inclusion of new branches or leaves, and the location of such a new item can give information about it even to users that are not aware of the new terms used. This approach has been encoded in XML, for use in clinical guidelines (Harbour & Miller, 2001) and anatomy. Effectively an ontology allows the users to agree on quite complex relationships between items, and what the consequence of those relationships are – thus in the relationship above, if an item supplies another item then if the original item is disrupted, this may affect the final one – so reduction in blood flow in the uterine artery leads to reduction in blood supply to the fetus.

Systematized Nomenclature of Medicine-Clinical Terms (SNOMED CT)

SNOMED CT is a clinical vocabulary currently administered by the international health terminology standards development organisation (IHTSDO) http://www.ihtsdo.org/. Member countries are; Australia, Canada, Denmark, Lithuania, The Netherlands, New Zealand, Sweden, United Kingdom and United States. SNOMED CT (**S**ystematized **No**menclature of **Med**icine-**C**linical **T**erms) was originally developed by the American College of Pathologists, and contains more than 600,000 concepts. SNOMED is organised as an "is-a" hierarchy. Exploring the SNOMED hierarchy is a very good way to begin to understand its power and browsers such as cliniclue (www.cliniclue.com) and SNOB are freely available within the countries that are part of IHTSDO. Synonyms for concepts are also included, and there are concepts that link concepts, across the hierarchy. Concepts are futher categorised into observable entities, diagnoses etc. For example "Pregnancy" code 289908002 is an observable entity and lies below " Female genital tract functions" (289907007) in the hierarchy. Conceptual Relations to other concepts – including disorders of pregnancy etc. are also available. As a vocabulary SNOMED can be used to generate documents using standardised terms – just like natural language, two parties need to use the same vocabulary in order to understand each other.

Evaluation of coverage(Penz JF, 2004) has demonstrated that SNOMED-CT was able to code 90% of previously unresolved narratives, using automated tools. Other recent work has shown that by using SNOMED, coding of free-text clinical documents may be amenable to automation (Patrick, Wang, & Budd, 2007). This demonstrates that the coverage and arrangement of SNOMED concepts is sufficient to allow understanding, and opens the prospect of electronic health records that combine the ease of use of free-text by humans while storing data that can be analysed by machine.

DISCUSSION

Coding and messaging systems can be seen as part of a continuum of semantic richness, beginning with controlled vocabularies and ending with complex semantically rich documents. The essential role of coding and messaging systems is to enable sharing of both information and understanding. This is particularly important in the area of women's health where patients are often cared for by a wide variety of clinical workers, sometimes coming from different organisations. Conversion between systems will remain an important function for informaticians for the foreseeable future, along with extension and refinement of such systems. Perhaps most importantly the choice of the correct standards to use will continue to challenge system developers and health providers. With the replacement of READ by SNOMED CT in the UK as part of the major "connecting for health" initiative, a more stable landscape seems to be emerging.

Efficient and effective coding and messaging offer the vision of a "world minimum dataset" sharing information between the national and regional datasets that exist around the planet. International comparisons, but more importantly use of such data to identify and support best-practice may lead to improved care especially for particularly rare conditions or combinations of them. However tt should always be remembered that the woman is at the centre of women's health and these tools, while useful, should not mask the individual. Perhaps there is a role for "coding for clients", so that the experiences of women can be recorded and given the attention it deserves. Coding does not replace care, but it can support it.

FUTURE RESEARCH DIRECTIONS

Undoubtedly there has been an enormous effort in the fields of coding and messaging. Two challenges still exist, the need for organizations to adopt and use these standards and agreement on the combination of standards to use. HL 7 appears to be the strong front-runner in the messaging field, and with version 3 seems to be merging into the world of web services and the semantic web. Similarly SNOMED CT appears to be the future of controlled vocabularies, although world-wide adoption relies on governments joining the standards organization, which may be a rate-limiting step. The example of the WHO maintaining and developing ICD may be an example of the way forward in the future. Moving from proprietary to open standards is a theme across computing, and with the development of the semantic web and interoperability, health care will move the same way. Indeed if women are to control the use of their health data, means of coding and decoding health information for consumers of health may be a major issue in the next few years.

REFERENCES

Adomat, R., & Hewison, A. (2004). Assessing patient category/dependence systems for determining the nurse/patient ratio in ICU and HDU: A review of approaches. *Journal of Nursing Management*, *12*(5), 299–308. doi:10.1111/j.1365-2834.2004.00439.x

American College of Pathologists. (2000, 2000). About SNOMED. Retrieved January 11, 2002, from http://www.snomed.org/about_txt.html

Bangalore, A., Thorn, K. E., Tilley, C., & Peters, L. (2003). *The UMLS Knowledge Source Server: An Object Model For Delivering UMLS Data.* Paper presented at the AMIA Annual Symposium, Washington.

Beck, D. H., Taylor, B. L., Millar, B., & Smith, G. B. (1997). Prediction of outcome from intensive care: A prospective cohort study comparing Acute Physiology and Chronic Health Evaluation II and III prognostic systems in a United Kingdom intensive care unit. *Critical Care Medicine*, *25*(1), 9–15. doi:10.1097/00003246-199701000-00006

Berners-Lee, T., Hendler, J., & Lassila, O. (2001, May). The Semantic Web. *Scientific American*, 29–37.

Bishop, E. H. (1964). Pelvic Scoring for Elective Induction. *Obstetrics and Gynecology*, *24*(2), 266–268.

Bromley, S. E., Vries, C. S., & Farmer, R. D. T. (2004). Utilisation of hormone replacement therapy in the United Kingdom. A descriptive study using the general practice research database. *BJOG: An International Journal of Obstetrics and Gynaecology*, *111*(4), 369–376. doi:10.1111/j.1471-0528.2004.00082.x

Coiera, E., & Tombs, V. (1998). Communication behaviours in a hospital setting: An observational study. *British Medical Journal*, *316*(7132), 673–676.

Coory, M., & Cornes, S. (2005). Interstate comparisons of public hospital outputs using DRGs: Are they fair? *Australian and New Zealand Journal of Public Health*, *29*(2), 143–148. doi:10.1111/j.1467-842X.2005.tb00064.x

Dolin, R. H., Alschuler, L., Beebe, C., Biron, P. V., Boyer, S. L., & Essin, D. (2001). The HL7 Clinical Document Architecture. *Journal of the American Medical Informatics Association*, *8*(6), 552–569.

Ensing, M., Paton, R., Speel, P. H., & Rada, R. (1994). An object-oriented approach to knowledge representation in a biomedical domain. *Artificial Intelligence in Medicine*, *6*, 459–482. doi:10.1016/0933-3657(94)90025-6

Gardner, M. (2003). Why clinical information standards matter. *BMJ (Clinical Research Ed.)*, *326*(7399), 1101–1102. doi:10.1136/bmj.326.7399.1101

Harbour, R., & Miller, J. (2001). A new system for grading recommendations in evidence based guidelines. *British Medical Journal, 323*(11 August), 334-336.

Health Level Seven Inc. (2001). HL7 Version 3 (Draft). Retrieved 11 January, 2002, from http://www.HL7.org/Library/standards_non1.htm

Huff, S. M., Rocha, R. A., McDonald, C. J., De Moor, G. J. E., Fiers, T., & Bidgood, W. D. Jr (1998). Development of the Logical Observation Identifier Names and Codes (LOINC) Vocabulary. *Journal of the American Medical Informatics Association*, *5*(3), 276–292.

Johnston, H. R., & Vitale, M. R. (1988). Creating Competitive Advantage with Interorganizational Information Systems. *MIS Quarterly*, *12*(2), 153–165. doi:10.2307/248839

Keene, R., & Cullen, D. (1983). Therapeutic Intervention Scoring System: Update 1983. *Critical Care Medicine*, *11*(1), 1–3. doi:10.1097/00003246-198301000-00001

Musen, M. (2001). *Creating and using Ontologies: What informatics is all about.* Paper presented at the Medinfo 2001, London.

Nelson, S., Schopen, M. J. S. & N., A. (2001). *An Interlingual Database of MeSH Translations*. Retrieved October, 2003, from http://www.nlm.nih.gov/mesh/intlmesh.html

Noy, N., Sintek, M., Decker, S., Crubézy, M., Ferguson, R., & Musen, M. (2001). Creating Semantic Web Contents with Protégé-2000. *IEEE Intelligent Systems*, (March/April): 60–71. doi:10.1109/5254.920601

O'Neil, M. P., & Read, C. J. (1995). Read Codes Version 3: A User Led Terminology. *Methods of Information in Medicine*, *34*(1/2), 187–192.

Parry, D. T. (2006). Evaluation of a fuzzy ontology based medical information system. *International Journal of Healthcare Information Systems and Informatics*, *1*(1), 40–49.

Parry, E. C., Parry, D. T., & Pattison, N. (1999). Induction of labour for post-term pregnancy: an observational study. *Australian and New Zealand Journal of Obstetrics and Gynaecology*, *38*(3), 275–279. doi:10.1111/j.1479-828X.1998.tb03065.

Parry, E. C., Sood, R., & Parry, D. T. (2006). Investigation of optimization techniques to prepare ultrasound images for electronic transfer [Abstract]. *Ultrasound in Obstetrics and Gynecology, 28*(4), 487-488(482).

Patrick, J., Wang, Y., & Budd, P. (2007). *An automated system for conversion of clinical notes into SNOMED clinical terminology*. Paper presented at the Conference Name.

Penz, J. F., Carter, J. S., Elkin, P. L., Nguyen, V. N., Sims, S. A., & Lincoln, M. J. (2004). *Evaluation of SNOMED coverage of Veterans Health Administration terms.* Paper presented at the Medinfo. Amsterdam.

Rosenfeld, R. (2000). Two decades of statistical language modeling: where do we go from here? *Proceedings of the IEEE*, *88*(8), 1270–1278. doi:10.1109/5.880083

Silfen, E. (2006). Documentation and coding of ED patient encounters: An evaluation of the accuracy of an electronic medical record. *The American Journal of Emergency Medicine*, *24*(6), 664–678. doi:10.1016/j.ajem.2006.02.005

U.S. National Library of Medicine. (2001, 15 November 2001). Medical Subject Headings. Retrieved 11 January, 2002, from http://www.nlm.nih.gov/mesh/

Walley, T., & Mantgani, A. (1997). The UK General Practice Research Database. *Lancet*, *350*(9084), 1097–1099. doi:10.1016/S0140-6736(97)04248-7

Wilson, R. G., Purves, I. N., & Smith, D. (2000). Utilisation of computerised clinical guidance in general practice consultations. *Studies in Health Technology and Informatics*, *77*, 229–233.

World Health Organization. (2001, 14 November 2001). ICD-10: The International Statistical Classification of Diseases and Related Health Problems, tenth revision. Retrieved 11 January, 2002, from http://www.who.int/whosis/icd10/

Yang, C.-M., & Reinke, W. (2006). Feasibility and validity of International Classification of Diseases based case mix indices. *BMC Health Services Research*, *6*(1), 125. doi:10.1186/1472-6963-6-125

Zhao, L., Lee, K., & Hu, J. (2005). Generating XML schemas for DICOM structured reporting templates. *Journal of the American Medical Informatics Association*, *12*(1), 72–83. doi:10.1197/jamia.M1519

ADDITIONAL READING

IHTSDO Web site. www.ihtsdo.org/

Informatics, B. Computer Applications in Health Care and Biomedicine (Health Informatics) by Edward H. Shortliffe and James J. Cimino HL 7 Web site: www.hl7.org

This work was previously published in Medical Informatics in Obstetrics and Gynecology, edited by D. Parry and E. Parry, pp. 38-52, copyright 2009 by Medical Information Science Reference (an imprint of IGI Global).

Chapter 8.13

The S'ANT Imperative for Realizing the Vision of Healthcare Network-Centric Operations

Nilmini Wickramasinghe
Illinois Institute of Technology, USA

Rajeev K. Bali
Coventry University, UK

ABSTRACT

In the information-intensive environment of healthcare, the networkcentric approach has been proffered as one that allows free and rapid sharing of information and effective knowledge building required for the development of coherent objectives and their rapid attainment. This article asserts that if we are to realize such a vision it is imperative to draw upon strong rich analysis tools and techniques and thus calls for the application of Social Network Analysis combined with Actor-network Theory (S'ANT).

INTRODUCTION

Environmental complexity of healthcare operations is often magnified by the presence of multiple actors (agencies, governmental bodies, global organizations, etc.) who perform within the same space, but use a wide variety of independent and non-intercommunicating platformcentric tools. As a consequence of the resulting chaos, the attainment (mission) of healthcare goals (objectives) is uncertainty – rather than being information-driven (von Lubitz and Wickramasinghe, 2005; 2006e). In response to the inefficiency of the highly fragmented programs to address even the most urgent aspects of healthcare across the globe, a demand for the development of a new rule set (Barnett, 2004; Onen, 2004; Olutimayin, 2002; Banjeri, 2004) governing the future actions began to emerge – the quest for the "doctrine of global health."

In response to this void von Lubitz and Wickramasinghe (2006b-e) proffered the doctrine of networkcentric healthcare. This doctrine finds its operational predecessor in the military application of information and decision support system networks based on uniform and widely distributed access, collection, processing, and dissemination standards (Cebrowski and Garstka, 1998). The doctrine calls for the development of interconnected information grids that, together, constitute a powerful and well-structured network that facilitates information sharing among all participants within the operational continuum (space, see Cebrowski and Garstka, 1998; Stein, 1998). Consequent to improved information sharing is the enhancement of its quality and integrity which, in turn, escalates the level of situational awareness that is the foundation for efficient, real-time collaboration among the involved entities, their self-synchronization, and operational sustainability. The overall operational effect of networkcentricity was a dramatic increase in mission effectiveness (Cebrowski and Garstka, 1998) whose success, even at the earliest trial stages, led to the adaptation of networkcentric concepts by several armed forces across the globe. For the same reason, the doctrine begins to find its place in the modern, ICT-driven business world (ibid).

THE CONCEPTUAL BASIS FOR NETWORK-CENTRIC OPERATIONS

The cardinal details of the networkcentric doctrine of healthcare operations have been described in detail by von Lubitz and Wickramasinghe (2006b-e). The doctrine is rooted in the pioneering work of Boyd (1987) (see also von Lubitz and Wickramasinghe, 2006b-ed-e) who analyzed the process of decision making and the fundamental principles of interaction with, and control of, a fast paced and dynamic environment. Critical research-based projects (as applicable in the area of information systems and health) have a growing tradition of qualitative inquiry. Despite its relativist ontology, actor-network theory places a strong emphasis on empirical inquiry and so actor-network theory is ideally suited to the generation of detailed and contextual empirical knowledge (Doolin B and Lowe A, 2002). Following its initial military applications, Boyd's OODA Loop as it is presently known, found many adherents and practical uses in a wide variety of civilian applications including medicine (von Lubitz et al., 2004 von Lubitz and Wickramasinghe, 2006a-e).

THE NATURE AND DEFINITION OF THE DOCTRINE OF NETWORK-CENTRIC HEALTHCARE

Following the inate nature of actor-network theory, the intricate and mutually constitutive character of the human and technology (in the processes and relationships of illness and health) has been demonstrated (Prout, 1996). In addition to this "micro" example, successful interaction with complex sets of macro-environments (macro-environment galaxies) such as global healthcare (which comprises a vast array of independently identifiable macro-environments) presents an insurmountable task *unless assisted by a highly sophisticated, multilayered network of ICT that incorporates a full range of telecommunication platforms, sensors, data storage elements, analytical nodes, and dispersed access points, the operation of which provides flexible command and control and rapid response capabilities.*

The doctrine of networkcentric healthcare has its roots in networkcentric computing (von Lubitz and Wickramasinghe, 2006b-e) whose practical development has been greatly facilitated by the rapid progress of various areas of ICTs (e.g., HTML, TCP/IP, Web, JAVA, XTML, etc (– refs Hironaka, 1992, Valdes et al., 2003)). The principal task of networkcentricity in healthcare operations is to develop the state of *information superiority.*

The state of information superiority provides the actors with the critical *operational advantage* that allows them to determine and dictate the direction and tempo of all activities in a collaborative, highly coordinated manner which, in turn, reduces the time needed to reach the preset objectives in the most effective and economical manner. Even the sketchy and largely anecdotal reports of the events surrounding Hurricane Katrina operations indicate quite clearly that the absence of the state of information superiority was one of the principal culprits in the resultant leadership failures, absence of coordination, and a number of avoidable post-hurricane fatalities (e.g., CNN News, ABC)

Unsurprisingly, in order to be executed efficiently, healthcare operations must be conducted within the intersecting territory of three mutually interconnected and functionally related domains (von Lubitz and Wickramasinghe, 2006b-e; Garstka, 2000):

- The *physical domain* which encompasses the structure of the entire environment healthcare operations intend to influence directly or indirectly, e.g., elimination of disease, fiscal operations, political environment, patient and personnel education, etc. Information within this domain is the easiest to collect, analyze, and disseminate.
- The *information domain* contains all elements required for generation, storage, manipulation, dissemination/sharing of information, and its transformation and dissemination/sharing as knowledge in all its forms. It is here that all aspects of command and control are communicated and all sensory inputs gathered.
- The *cognitive domain* relates to all human factors that affect operations, such as education, training, experience, political inclinations, personal engagement (motivation), "open-mindedness," or even intuition of individuals involved in the relevant activities. Difficulties in metrics relevant to the cognitive domain notwithstanding, a body of experimental studies begins to emerge that will, ultimately, provide close quantitative relationships to other domains that govern healthcare operations space (e.g. Bodner et al., 1986; Roberts and Clifton, 1992; Back and Oppenheim, 2001; Newby, 2001; Wetherell et al., 2002; Abel-Smith, 1989).

Hence, fundamental to the doctrine of networkcentric healthcare operations (HNCO) is "*unhindered networking operations within and among all three domains that govern all activities conducted in healthcare space and are based on free, multidirectional flow and exchange of information without regard to the involved platforms or platform-systems and utilizing all available means of ICTs to facilitate such operations.*

THE PHYSICAL CONSTITUENTS OF THE WORLDWIDE HEALTHCARE NETWORK

The essential and enabling element of HNCO is the Worldwide Healthcare Information Grid (WHIG) that allows full and hindrance-free sharing of information among individual domains, their constituents, and among constituents across the domains. In order to perform such a function, the WHIG must consist of an interconnected matrix of ICT systems and capabilities (including communication platforms, data collection, storage, manipulation/dissemination, and sharing), associated processes (such as information and knowledge storage and retrieval, management and their dissemination/sharing), people (e.g. healthcare providers/investigators, administrators, economists, politicians, lawyers, ICT personnel), and agencies (governmental and NGOs (Non-Governmental Organizations) at local/national/international level).

The required technology (von Lubitz et al., 2005) and individual components of WHIG already exist (von Lubitz and Wickramasinghe, 2006b-e), and their role and interactions in the context of networkcentric operations described in a greater detail elsewhere (von Lubitz and Wickramasinghe, 2006b-e), the grid itself needs yet to be constructed based on universally accepted and shared operational and security standards and protocols that will allow free and unfettered access to all actors within the healthcare space Once developed, the Grid will facilitate information sharing and enable joint development of objectives, precise characterization of missions necessary to attain these objectives, allocation of adequate resources, and continuing monitoring of progress. The latter will, in turn, permit not only timely intra-operational interventions (e.g., modifications of the mission profile, changes in resource allocation) but, even more significantly, assist in the development of the unified command structure necessary for the synchronization of currently non-related and often disorganized and discordant efforts conducted within the same segment of healthcare space. That such controls are required in very large scale operations is demonstrated by several studies showing that, in the developing countries in particular, the currently disorganized conditions of healthcare aid often result in inefficiency and inappropriate application of the available resources (Abel-Smith, 1989; Howard, 1991; Collins and Green, 1994; Schneider and Gilson, 1999; Buse, 1999). However, as demonstrated by the activities related to Hurricane Katrina, even in a highly developed and technologically advanced nation like the US similar errors appear to prevail. The reasons for the prevalence of these difficulties have been discussed elsewhere (von Lubitz and Wickramasinghe, 2006e).

Access to the WHIG is facilitated through "smart" portals (described in detail in von Lubitz and Wickramasinghe, 2006b-e) that provide the gateway to all operationally pertinent information existing within the network. Operational (pertinent) knowledge support is derived through a semi, or fully automated search of WHIG by the information processing capabilities and decision support capabilities of the smart portal, followed by the equally semi, or fully automated assembly, analysis, and pertinent knowledge derivation. Based on agent technologies, and contrary to the majority of the existing portal systems, the "smart portal" is fully active, and its operations provide relevant data, information, and knowledge based on cross-domain objective analysis of all relevant facts rather than those that may be, often erroneously and subjectively, classified as relevant by the human operator.

One of the critical attributes of the smart portal is the ability of its agents to navigate easily and autonomously throughout the entire grid system. Navigation of such type must be based on a well structured grid map that will assist in determination of the source of the incoming information, its nature, validity, pertinence, and ultimate destination. Some of the involved processes have been described in a prior paper devoted to network-based simulation training of First Responders (von Lubitz et al., 2004.) Presence of universal standards is among the fundamental prerogatives determining the ability of the smart portal and its agent to locate, analyze, transform, and disseminate all relevant information and knowledge located throughout the WHIG network. Absence of such standards appears to be among the principal reasons that perpetuation of platformcentricity in the existing decision support systems. As a consequence, vital information existing within healthcare-irrelevant networks remains hidden from its potential users. Once again, the operational difficulties caused by the lack of across-the-board standards governing information acquisition, storage, analysis, dissemination, and retrieval are well exemplified by the problems encountered by healthcare personnel in the immediate aftermath of Hurricane Katrina.

While portal automation does not free the human controller from the process of definitive decision-making, the portal serves as a powerful decision support system capable of more complex analysis of pertinent facts and of the determination of outcomes resulting from a large number of the possible permutations of these facts. Metcalfe's Law predicts that linking of smart portals and their individual computing/analytical capabilities to the WHIG will produce massive increase of the available decision support power and accuracy that will be readily available to the actors within the healthcare operational space. Still absent from the scene of large scale, combined healthcare operations, networked smart portals find their rapidly growing implementation in military operations (e.g., battle space analysis and situation-relevant mission assignment) and, on a much smaller scale, in the pharmaceutical industry (e.g., Novartis, see Markoff and Schenker, 2003.) The complexities of networkcentric operations are invariable linked to the issues of security and data/information integrity and, given the total access to WHIG provided by the smart portal to all actors within the operational space, it is vital that the highest level of security protocols are maintained at all times.

RICH ANALYSIS TOOLS AND TECHNIQUES

In order to design, develop and thereby successfully realize the vision of networkcentric healthcare it is vital that rich analysis tools and techniques are fully utilized. If we look in the social theory literature, two appropriate candidates include Social Network Analysis (SNA) and Actor-Network Theory (ANT).

Social Network Analysis (SNA)

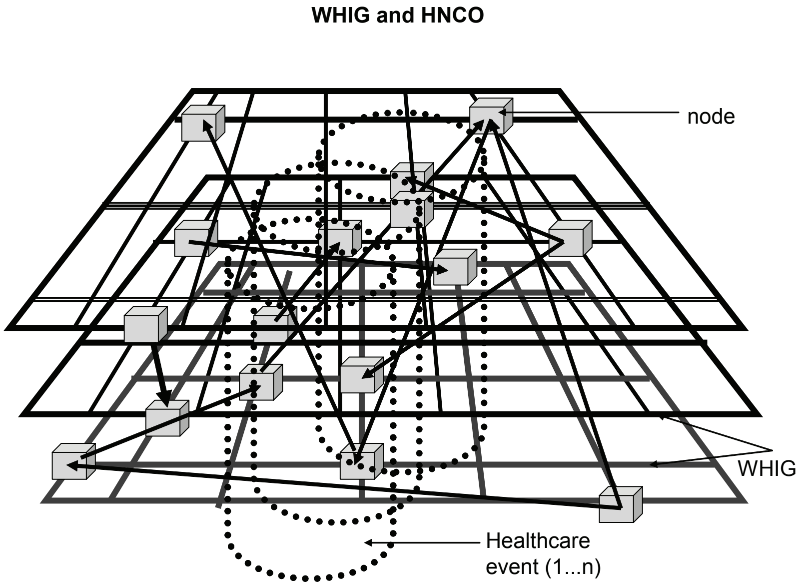
SNA is a technique that facilitates the mapping and measuring of relationships and flows between people, groups, organizations, systems as well as all information/knowledge processing organizations and thereby enhances metacognition with respect to the representation of organizational knowledge in networks (Wasserman and Faust, 1994; Niessen 2007). People and groups are represented as nodes while the relationships or flows are represented by links. Taken together this analysis of nodes and links builds the network under consideration. The location of actors in such a network is critical to a deeper understanding of the network as a whole and the participation of individual actors. Location is measured by finding the centrality of the node.

In terms of centrality three considerations become important in any SNA; degree of centrality – in other words how many people connect with you, betweenness – or whether or not you are located between two key actors in the network and thus may play a "broker" role, and closeness – or ones position relative to others (especially key players) in the network. In addition, it is important to note if there exist boundary spanners: actors who bridge or overlap into different networks, or peripheral players: actors who are perceived as unimportant.

One way to improve the current state-of-the-art in SNA is to develop new ways to produce interval/ratio measures of relations between the various individuals in the organization to determine the strength of their ties (Liebowitz, 2005). Analysts of social networks are interested in how the individual is embedded within a structure and how the structure emerges from the micro-relations between individual parts (Hanneman, 2002).

To illustrate the value for SNA within HNCO let us look at Figure 1. Within the WHIG structure various healthcare events (denoted by cylinders labeled healthcare event 1…n) have been highlighted. If we return to the earlier discussion of Hurricane Katrina, it is possible to think of one of these events as Hurricane Katrina. In this context the nodes (cubes on WHIG) represent various actors. What becomes of crucial importance in the emergency and disaster state of Hurricane Katrina is the distance or centrality of key actors since the key actors are the important decision makers and in such a context rapid prudent decision

Figure 1.



making can save lives. Clearly, in such a context the understanding of who/where the boundary spanners are as well as the betweenness and closeness constructs are key in designing a superior network that will enable at all times appropriate and speedy decision making to ensue. It is also useful to note that SNA can be used in post facto analysis to facilitate necessary lessons learnt that can be applied to the future state. Thus the incorporation of SNA into the continuous design and development of HNCO is going to facilitate the realization of a well structured network that will indeed support all the complex and dynamic operations in healthcare.

Actor-Network Theory

As noted earlier healthcare is a complex domain. Specifically, the roles of different healthcare players including payers, providers, healthcare organizations and regulators as well as their respective interactions with WHIG and how WHIG in turn might facilitate, modify or even impede their tasks. To facilitate a superior understanding a sufficiently rich and dynamic lens of analysis can be found from the application of Actor-network Theory (ANT).

ANT embraces the idea of an organizational identity and assumes that organizations, much like humans, possess and exhibit specific traits (Brown, 1997). Although labeled a "theory", ANT is more of a framework based upon the principle of generalized symmetry, which rules that human and non-human objects/subjects are treated with the same vocabulary. Both the human and non-human counterparts are integrated into the same conceptual framework.

ANT was developed by British sociologist, John Law and two French social sciences and technology scholars Bruno Latour and Michel Callon (Latour, 1987, 2005; Law and Hassard, 1999; Law, 1992, 1987; Callon, 1986. It is an interdisciplinary approach that tries to facilitate an understanding of the role of technology in specific settings, including how technology might facilitate, mediate or even negatively impact organizational activities and tasks performed. Hence, ANT is a material-semiotic approach for describing the ordering of scientific, technological, social, and organizational processes or events.

CONCEPTS OF ACTOR-NETWORK THEORY

Table 1 presents the key concepts of ANT and their relevance to network-centric healthcare operations.

THE S'ANT APPROACH TO RESEARCHING NETWORK-CENTRIC HEALTHCARE

The S'ANT approach is a hybrid approach that combines the respective strengths of SNA and ANT in order to facilitate the realization of HNCO. Such an approach requires the identification and tracing of specific healthcare events and networks to "follow the actors" (Latour, 1996) and investigate all the relevant leads each new actor suggests. The first step is thus to identify these actors (or actants), remembering that an actor is someone or something that can make its presence individually felt and can make a difference to the situation under investigation. Thus, in HNCO the actors would include: medical practitioners, nurses, medical instruments, healthcare organizations, regulators, patients, equipment suppliers, medical administrators, administrative computer systems, medical researchers, and so on. In a particular operation (or event) it is important to identify all relevant actors before proceeding further.

The next step is to 'interview' the actors. With human actors this is, of course, quite straightforward, but with non-humans it is necessary to find someone (or something) to speak on their behalf. For an item of medical technology this might be its designer or user, or it might just be the instruction manual. The aim of this step is to see how these actors relate to each other and the associations they create – to identify how they interact, how they negotiate, and how they form alliances and networks with each other. These 'heterogeneous networks' consists of the aligned interests held by each of the actors.

Human actors, such as medical practitioners, can 'negotiate' with non-human actors such as X-Ray or dialysis machines by seeing what these machines can do for them, how easy they are to use, what they cost to use, and how flexible they are in performing the tasks required. If negotiations are successfully completed then an association between the medical practitioner and the machine is created and the machine is used to advantage – the network has become durable. If the negotiations are unsuccessful then the machine is either not used at all, or not used to full advantage.

Once this is developed it is then important to apply the techniques of SNA to map the flows of pertinent information and germane knowledge throughout this network and thereby not only enhancing the metacognition of the system but also the ability to rapidly extract and utilize the critical knowledge to support prudent decision making and at always a state of being prepared and ready (Wickramasinghe and von Lubitz, 2007; von Lubitz and Wickramasinghe, 2006 a;f)

The main advantage of the S'ANT approach to considering HNCO is in being able to identify and explore the real complexity involved. Other approaches to technological innovation, Innovation Diffusion for example, put much stress on the properties of the technology or organisation themselves, at the expense of looking at how these interact. Unfortunately in doing this they often tend to oversimplify very complex situations and so miss out on a real understanding. The ANT approach of investigating networks and associations provides a useful means to identify and explain these complexities as well as track germane knowledge and pertinent information. This

Table 1. Key concepts of ANT

Concept	**Relevance to HNCO**
Actor/Actant: Typically actors are the participants in the network which include both the human and non-human objects and/or subjects. However, in order to avoid the strong bias towards human interpretation of Actor, the neologism Actant is commonly used to refer to both human and non-human actors. Examples include humans, electronic instruments, technical artifacts, or graphical representations.	In HNCO this includes the web of healthcare players such as provides, healthcare organizations, regulators, payers, suppliers and the patient as well as the clinical and administrative technologies that support and facilitate healthcare delivery.
Heterogeneous Network: is a network of aligned interests formed by the actors. This is a network of materially heterogeneous actors that is achieved by a great deal of work that both shapes those various social and non-social elements, and "disciplines" them so that they work together, instead of "making off on their own" (Latour, 2005).	WHIG is clearly the technology network for HNCO. However it is important to conceptualise the heterogeneous network not as WHIG alone but as the aligning of the actors with WHIG so that it is possible to represent all interests and thereby provide the patient with superior healthcare delivery. Given the scope of healthcare operations and the global nature of HNCO there will be numerous power dynamics within and between groups of actors. This will be a critical barrier to enabling the well functioning of networkcentric operations. The key is to carefully align goals so that healthcare delivery is truly patient centric at all times.
Tokens/Quasi Objects: are essentially the success outcomes or functioning of the Actors which are passed onto the other actors within the network. As the token is increasingly transmitted or passed through the network, it becomes increasingly punctualized and also increasingly reified. When the token is decreasingly transmitted, or when an actor fails to transmit the token (e.g., the oil pump breaks), punctualization and reification are decreased as well.	In HNCO this translates to successful healthcare delivery, such as treating a patient in a remote location by having the capability to access critical information to enable the correct decisions to be made. Conversely, and importantly, if incorrect information is passed throughout the network errors will multiply and propagate quickly hence it is a critical success factor that the integrity of the network is maintained at all times.
Punctualization: is similar to the concept of abstraction in Object Oriented Programming. A combination of actors can together be viewed as one single actor. These sub actors are hidden from the normal view. This concept is referred to as Punctualization. An incorrect or failure of passage of a token to an actor will result in the breakdown of a network. When the network breaks down, it results in breakdown of punctualization and the viewers will now be able to view the sub-actors of the actor. This concept is often referred to as depunctualization.	For example, an automobile is often referred to as an unit. Only when it breaks down, is it seen as a combination of several machine parts. Or in HNCO the uploading task of one key actor, be it a provider or a regulator is in reality a consequence of the interaction and co-ordination of several sub-tasks. This only becomes visible when a breakdown at this point occurs and special attention is given to analyse why and how the problem resulted and hence all sub-tasks must be examined carefully.
Obligatory Passage Point: broadly refers to a situation that has to occur in order for all the actors to satisfy the interests that have been attributed to them by the focal actor. The focal actor defines the OPP through which the other actors must pass and by which the focal actor becomes indispensable (Callon, 1986).	In HNCO we can illustrate this by examining the occurrence of a disease or catastrophe. A recent pertinent example is SARS which caused a major epidemic crisis and required a united, co-ordinated global response to focus on finding a cure and treating affected victims. A similar co-ordianted immediate response was required in the aftermath of Hurricane Katrina or the Tsunami that struck the countries of the Indian ocean in December 2004. Such incidents form the catalyst for developing shared goals and united focus of effort so necessary to effect superior healthcare delivery.
Irreversibility: Callon (1986) states that the degree of irreversibility depends on (i) the extent to which it is subsequently impossible to go back to a point where that translation was only one amongst others and (ii) the extent to which it shapes and determines subsequent translations.	Given the very complex nature of healthcare operations (von Lubitz and Wickramasinghe, 2006b-e) irreversibility is generally not likely to occur. However it is vital that chains of events are continuously analysed in order that future events can be addressed as effectively and efficiently as possible. This is at the very essence of HNCO.

is paramount if the doctrine of network-centric healthcare is to be successfully realised.

CONCLUSION

The presently disorganized state of global healthcare indicates the need for the development of an operational doctrine that will provide a unifying rule set for all future efforts. To address this void, the doctrine of networkcentric healthcare operations was proposed by von Lubitz and Wickramasinghe (2006e). This doctrine has several advantages: first, a similar concept is already implemented with significant success by the military establishment. Hence, the "lessons learned" can be readily adopted into the civilian environment. More importantly, however, by permitting free flow of information among currently disconnected entities and fields of healthcare operations, the networkcentric doctrine allows vast improvement in information management and use in all activities related to healthcare – from individual patient provider contact to massive, international relief operations as seen following the Tsunami of 2004. Moreover, networkcentricity permits generation of the currently absent comprehensive, multifaceted, and unified body of knowledge necessary to conduct healthcare activities in a manner addressing present inequalities through a consistent knowledge-based effort rather than, as it is presently done, through the erratic application of ever increasing funds.

The existing evidence from military applications and from the still limited e-business experience, indicates the soundness of networkcentric philosophy and the practical usefulness of the doctrine. In view of the already staggering costs of healthcare and continuing deficiencies of its delivery, the need for transformation is more than evident. Moreover, the dynamic drive of the European Union toward dissemination of large scale computing networks and toward their practical use in daily operations of the constituent nations (Markoff and Schenker, 2003) indicate clearly show the direction in which healthcare will also move with an ever increasing speed. We believe that networkcentric healthcare offers the most tangible and obtainable means of such transformation, and that, in similarity to science, business, and warfare (Smarr, 1999) every effort should be made to pursue the tenets of the doctrine as the platform for changing the face of the global healthcare. However, and most importantly, if HNCO is to become the new paradigm for healthcare delivery in the 21st century it is vital that a rich set of analysis tools and techniques be employed. To this regard we have presented the S'ANT approach, a hybrid analysis which draws together the strengths of two well established social theory techniques; namely social network analysis (SNA) and actor-network theory (ANT). We plan to engage in further exploration of the benefits of such a powerful analytic approach in our future research and close by encouraging other researchers to do likewise.

REFERENCES

Abel-Smith B, (1989), Health economies in developing countries, J. Trop. Med. Hyg. 92, 229-41.

Alberts DS, Garstka JJ, Stein FP, (2000), Network Centric Wardare: Developing and Leveraging Information Superiority, CCRP Publication Series (Dept. of Defense), Washington, DC, pp 1-284 (available at http://www.dodccrp.org/publications/pdf/Alberts_NCW.pdf).

Back J, Oppenheim C, (2001), A model of cognitive load for IR: implications for user relevance feedback interaction, Information Res. 2, (available at http://InformationR.net/ir/6-2/ws2.html).

Banjeri D, (2004), The people and health service development in India: a brief overview, Int. J. Health Serv. 34, 123-42.

Barnett TPM, (2004) The Pentagon's New Map, G.P. Putnam & Sons (New York), pp. 1-435.

Bodner GM, McMillen TLB, (1986), Cognitive restructuring as an early stage in problem solving, J. res. Sci. Teaching 23, 727-737.

Boyd JR, COL USAF, (1987), in "Patterns of Conflict", unpubl Briefing (accessible as "Essence of Winning and Losing", http://www.d-n-i.net).

Brailer DJ, Terasawa AB, (2003), Use and Adoption of Computer-Based Patient Records, California HealthCare Foundation, pp. 1-42.

Buse K, (1999), Keeping a tight grip on the reins: donor control over aid coordination and management in Bangladesh, Health Pol. And Plan. 14, 219-228.

Callon, M., (1986), "Some Elements of a Sociology of Translation: Domestication of the Scallops and the Fishermen of St Brieuc Bay." In John Law (ed.), Power, Action and Belief: A New Sociology of Knowledge (London: Routledge & Kegan Paul).

Cebrowski AK, Garstka JJ, (1998), Network-centric warfare: its origin and future, US Nav. Inst. Proc. 1, 28-35.

CNN News, September 2, (2005a), The big disconnect on New OrleansThe official version; then there's the in-the-trenches version.

CNN News, September 2, (2005b), New Orleans mayor lashes out at fedsNagin: 'They are spinning and people are dying'.

CNN News, September 2, (2005c), Bush faults recovery efforts as 'not enough' .

Collins C, Green A, (1994), Decentralization and primary health care: some negative implications in developing countries, Int. J. Health Serv. 24,459-75.

Doolin B and Lowe A (2002) "To reveal is to critique: actor–network theory and critical information systems research", Journal of Information Technology, Vol.17, No.2, June 2002, pp. 69-78(10)

Garstka JJ, (2000), Network Centric Warfare: an overview of emerging theory, Phalanx 4, 28-33

Hanneman, R. (2002), "Introduction to social network methods", available at: www.faculty.ucr.edu/hanneman/.

Hironaka W, (1992), We must tackle population problems, Integration, March 1992 (vol. 31), :27

Howard LM, (1991), Public and private donor financing for health in developing countires, Infect. Dis. Clin. North. Am. 5, 221-34.

Latour, B., (1987), *Science in Action: How to Follow Scientists and Engineers Through Society* (Milton Keynes: Open University Press).

Latour, B., (2005), *Reassembling the Social: An Introduction to Actor-Network-Theory* (Oxford: Oxford University Press).

Law, J., and Hassard, E., (eds) (1999), *Actor-network Theory and After* (Oxford and Keele: Blackwell and the Sociological Review).

Law, J., (1992), "Notes on the Theory of the Actor-network: Ordering, Strategy, and Heterogeneity.", http://www.lancs.ac.uk/fss/sociology/papers/law-notes-on-ant.pdf

Law, J., (1987), "Technology and Heterogeneous Engineering: The Case of Portuguese Expansion." In W.E. Bijker, T.P. Hughes, and T.J. Pinch (eds.), *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology* (Cambridge, MA: MIT Press).

Liebowitz J (2005), "Linking social network analysis with the analytic hierarchy process for knowledge mapping in organizations", Journal of Knowledge Management, 9(1), pp.76-86.

Markoff J, Schenker JL, (2003), Europe exceeds US in refining grid computing, The New York Times, November 10.

Newby GB, (2001), Cognitive space and information space, J. Am.Soc.Info. Sci. Technol. 12, 1026-1048.

Nissen, M. (2007) Keynote paper: Enhancing Organisational metacognition – flow visualization to make the knowledge network explicit" Intl J Networking and Virtual Organisations vol 4 no. 4 pp. 331-350.

Olutimayin J, (2002), Communication in health care delivery in developing countries: which way out? Pac. Health Dialog. 9, 237-41.

Onen CL, (2004), Medicine in resource-poor settings: time for a paradigm shift? Clin. Med. 4, 355-60

Prout A (1996) "Actor-network theory, technology and medical sociology: an illustrative analysis of the metered dose inhaler", Sociology of Health & Illness, 18(2), 198–219.

Roberts LW, Clifton RA, (1992), Measuring the cognitive domain of the quality of student life: an instrument for faculties of education, Can. J. Educ. 2, 176-191.

Schneider H, Gilson L, (1999), Small fish in a big pond? External aid and the health sector in South Africa, Health Pol. and Plan. 14, 264-272

Smarr L, (1999), Grids in context, in Foster I, Kesselman C (Eds.), 1999, The Grid: Blueprint for a New Computing Infrastructure, M.Kaufman Publishers San Francisco), pp.1-14

Stein P,(1998), Observations on the emergence of network centric warfare, http://www.dodccrp.org/research/ncw/stein/_observations/steincw.htm

Sun-Tzu on the Art of War, (1910), (transl. Lionel Giles): Project Guthenberg, http://www.kimsoft.com.polwar.htm.

Valdes I, Kibbe D, Tolleson G, Kunik M, Petersen LA, (2003), Metcalfe's law predicts reduced power of Electronic Medical record software, AMIA Annu. Symp. Proc 2003, 1038.

von Lubitz , D. and N. Wickramasinghe (2006a) "Dynamic Leadership In Unstable And Unpredictable Environments Intl. J. Management and Enterprise Development vol 3 no. 4 pp 339-350.

von Lubitz , D., N. Wickramasinghe and G Yanovsky (2006) "Networkcentric Healthcare Operations: The Telecommuniucations Structure" Int. J. Networking and Virtual Organizations vol 3. no. 1pp. 60-85.

von Lubitz , D. and N. Wickramasinghe (2006b) "Networkcentric Healthcare: applying the tools, techniques and strategies of knowledge management to create superior healthcare operations" Intl. J Electronic Healthcare (IJEH) vol 4 pp. 415-428.

von Lubitz , D. and N. Wickramasinghe (2006c) "Key Challenges and Policy Implications for Governments and Regulators in a Networkcentric Healthcare Environment" Int. J. Electronic Government vol 3. no. 2 pp. 204-224.

von Lubitz , D. and N. Wickramasinghe. (2005) „Networkcentric Healthcare and Bioinformatics" Intl J. Expert Systems with Applications. Vol 30 pp.11-23.

von Lubitz , D. and N. Wickramasinghe. (2006d) „Networkcentric Healthcare: Outline of Entry Portal Concept" Intl. J. of Electronic Business Management (IJEBM) vol 1 pp. 16-28.

von Lubitz , D. and N. Wickramasinghe. (2006e) "Healthcare and Technology: The Doctrine of Networkcentric Healthcare" Intl. J Electronic Healthcare(IJEH) vol 4 pp.322-344.

von Lubitz , D. and N. Wickramasinghe, (2006f) Creating Germane Knowledge In Dynamic Environments" Intl. J. Innovation and Learning (IJIL) vol 3 no. 3 pp. 326-347.

Von Lubitz, D., et al., (2004). "Medical Readiness in the Context of Operations Other Than War: Development of First Responder Readiness Using OODA –Loop Thinking and Advanced Distributed Interactive Simulation Technology" Proceedings EMISPHERE 2004 Symposium, Istanbul, Turkey September 2004. For on-line version at the Defence and National Intelligence Network, see http://www.d-n-i.net/fcs/pdf/von_lubitz_1rp_ooda.pdf.

Wasserman, S and K. Faust, (1994) " Social Network Analysis" Cambridge: Cambridge University Press.

Wetherell JL, Reynolds CA, Gatz M, Pedersen NL, (2002), Anxiety, cognitive performance, and cognitive decline in normal aging, J. Gerontol (B) Psych. Sci. and Soc. Sci. 57, 246-255.

Wickramasinghe, N. and D. von Lubitz (2007) "Knowledge-Based Enterprise: Theories and Fundamentals" IGI Publishing, Hershey.

This work was previously published in International Journal of Actor-Network Theory and Technological Innovation, Vol. 1, Issue 1, edited by A. Tatnall, pp. 45-58, copyright 2009 by IGI Publishing (an imprint of IGI Global).

Chapter 8.14

Shifting Ground for Health Information Systems:

Local Embeddedness, Global Fields, and Legitimation

Gianluca Miscione
International Institute for Geo-Information Science and Earth Observation, The Netherlands

Knut Staring
University of Oslo, Norway

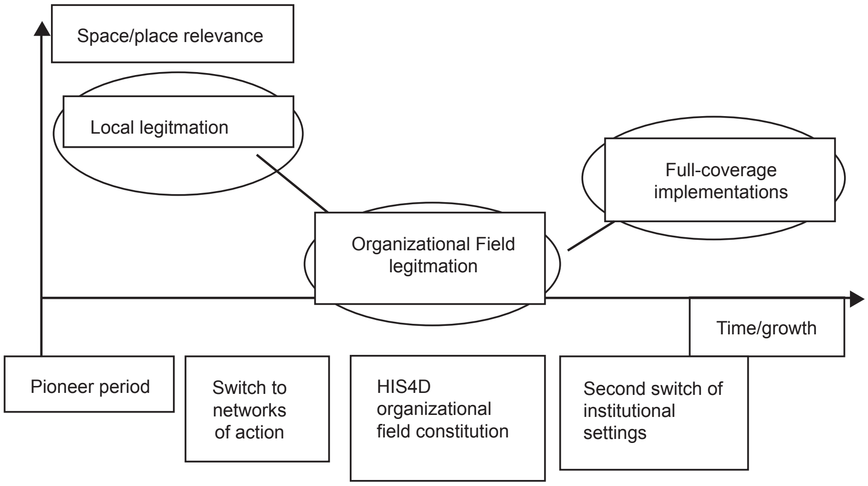
ABSTRACT

This article addresses the institutional scaling of information systems through the interplay of globally distributed free and open source software development with organizational processes. Through examining various phases of a long term project to implement information systems for the public health care sector in resource-poor countries, we highlight changing sources of acceptance and legitimation. The analysis centers on the balance between local and global levels, from pilot sites, through an emerging broader organizational field, to increasingly involving national level institutional settings. In parallel to the established view of the scaling of ICT implementations as relating to complexity and risk in the form of unintended side-effects of the growth of a system, the authors highlight the qualitative switch between regulatory contexts. Shifting relations to local institutions means that scalability requires actors to interact with quite different organizational cultures, accountabilities and communicative practices.

INTRODUCTION

ICT infrastructure and information systems have come to play a vital role in globalization. Walsham (2008) highlights three major aspects of this phenomenon: software outsourcing, virtual

Figure 1. A model to interpret shifts in PHIs over time



teams, and information system (IS) rollout. In this article we examine shifts over several years of globally distributed development and rollout of an open source information system targeted at the public health care sector in developing countries, which touches on all three aspects. In following the development of a system as it co-evolved with the various settings in which it was embedded, we highlight shifting sources of legitimation in institutional processes involved in health information systems implementation. The attention to changing sources of acceptance and legitimation frames our view on knowledge between local cultures and related stakeholders, in the interplay with global free and open source software (FOSS) development.

Paraphrasing Bowker (2000), health information systems operate simultaneously at the concrete level of design and implementation (fields in a database, capacity building, integration of datasets and organizational practices…) and at an abstract level (dealing with the relationships between information science, organization, public health, and global software development, among others). Thus, social studies of science and organization have a significant contribution to make to the process of growing information systems in order to create tools for health monitoring and policy making. For this, we need to historicize our action and its organization: "it is vital to dissolve the current disjunction between database (as technical storage medium) and policy (as way of acting in the world). The production of the database is productive of the new world we are creating." (ibid).

By examining the scaling of development and implementation of health information systems in developing countries, this article aims at understanding collaborative knowledge development across heterogeneous networks of local, national and global actors, and between public health workers and FOSS developers in dissimilar contexts. We will use "PHIs" as an acronym to refer jointly to PHI (Project for Health Information) and HIS (Health Information System, the principal software developed within the project). This hybrid acronym represents the socio-technical nature of the actor-network. PHIs began in South Africa in 1994 as health services underwent major restructuring post apartheid, aiming at standardization of information for local action. Subsequent international expansion underscored tensions between the local and the global (Rolland and Monteiro: 2002) related to knowledge gaps and communication practices affecting rollout and institutionalization. After nearly five years, the project to cross the South African border and be initiated in Mozambique. In the following two years, early prototype implementations were started in Malawi and India. Tanzania, Vietnam and Cuba (which was abandoned quickly) and Ethiopia followed in a couple of years. After 2002, a number of pilots flourished, mainly in South and East African countries, with different degrees of development and institutionalization. It is impossible to clearly delinate periods for all countries involved, because of the "karstic" dynamic of the project in most places: a pilot can be started, achieve some acceptance, remain dormant for indefinite time, be activated again depending on new conditions, and so on.

Figure 1 illustrates a model to interpret shifts in PHIs over time. The vertical axis indicates the intensity of relevance of specific places and local settings. The horizontal time line relates to the stages of PHIs evolution we have identified: pioneer, field constitution, and full-scale implementations, demarcated by 1) a switch of legitimation from local contexts to an organizational field, and 2) a further switch to legitimation relying on state structures.

FIRST SWITCH: FROM LOCAL BOUNDS TO ORGANIZATIONAL FIELD

This section aims at illustrating how changes to the PHIs are significant to understand the different set of regulatory forces which affect ICT development and implementation when shifting from accountability in a local context, to accountability in relation to the larger field constituted by organizations engaged in the same kind of activity.

PHIs engaged in bottom-up, participatory software prototyping to develop a district-based HIS with rapid iterations and a focus on flexibility (Braa and Hedberg: 2002). Legitimation at the local level was achieved by embedding the system into the organizational setting, and aligning with the needs of staff at all levels, as well as with local educational arrangements. Such sensitivity to local organizational cultures contrasted strongly with mainstream development strategies, and in turn provided a strong foundation for successful provincial and eventually national acceptance in South Africa in 1999. We open our empirical account with a quote from an implementer who was involved in the project from the early days:

South Africa in 1994 was at a turning point in the history of the country; a time of hope, uncertainty and potential chaos. People were both hopeful and fearful; hopeful of a more open, transparent and inclusive society, fearful of the way in which this change would happen. In the health services, major restructuring was happening across the board. Equity, redistribution and integration were central themes in the shift from a fragmented hospital based medical model to a Primary Health Care Approach driven by a nurse based community model within a district health system. New health worker cadres, managers and colleagues coupled with new services and systems created an atmosphere of chaos. Waves of consultative teams were making the rounds, asking questions about problems, but also promising sweeping reform. This was met by skepticism. Voluntary retrenchment, early retirement and 'new face' promotions were the order of the day. The users of the service were also more demanding. Health workers knew things were 'not right' and that different strategy and work practices were both required and desired. However, it seemed that there was a new way of doing the old job every other week. Everything was up for grabs; an opportunity for research by 'outsiders' who would come in, implement a new practice and leave staff with 'the mess'. Soon things would revert to the old tried and tested ways. It is into this chaotic arena that PHIS began to peddle its wares; not with the middle managers, but with health workers at facility and district levels. Would the tools, *models and practices advocated by PHIS have had the same impact a decade later? It is argued that 'timing was everything'; that the period of transition provided a crucial window of opportunity for the project*

Indeed, under apartheid, the South African health services were highly fragmented according to racial categories. Also, the health system had been oriented towards hospital services, with primary health care delivery poorly developed. This legacy meant that change in the organization of reporting became a major element in the processes of re-defining the health system after the fall of apartheid.

In addition to early experiences in Mongolia and South Africa, one of the project initiators drew upon prior experience from HIS research in Ghana, which had gone through a process of health system restructuring towards more action-oriented information management, developing the idea of rationalizing information. The proposed design strategy was based on the assumption that an IS consists of much more than the technical artifact, with a focus on local level and community based Participatory Design (PD). PD approaches were seen to be of particular importance as they may function as a means for community empowerment, and possible relations between community participation and PD as practiced in the Scandinavian tradition were explicitly explored. The Scandinavian PD tradition has had a focus on the workplace. However, discussing PD in a developing country context, the focus shifts from the workplace to the community (Titlestad and allTitlestad and all: in press). In referring to the three rationales for using PD approaches suggested by Greenbaum and Madsen (1993); i.e. the pragmatic, the theoretical and the political perspectives, it was proposed to add the community perspective. So PHIs developed a vision "to support the development of an excellent and sustainable health information system that enables all health care workers to use their own information to improve the coverage and quality of health services within our communities", and the process towards HIS was based on local management and community structures and addressed local needs. Motivation, commitment and the creation of a sense of ownership of the system by all interested parties were deemed to be of vital importance.

Based on the experiences in pilot projects, a six step model was developed within PHIs for health information system development and implementation:

1. Local team and commitment are crucial. Get people from the community on board and find concrete activities in which they can participate
2. Situation analysis (information audit)
3. Set objectives, targets and indicators
4. Create district based information system and structures
5. Training of staff - local empowerment; i.e. focus on data needed to make local decisions to improve coverage and quality of services
6. Creating a district information culture: i.e. the information needs to be used on a regular basis, allowing the IS to be improved gradually. Analysis of data should become a daily routine aimed at improving service delivery

By the turn of the millennium, HIS had been officially endorsed as a national standard in South Africa, and pilot projects were commenced in several provinces; KwaZulu-Natal, Mpumalanga, Northern Cape, and the North West Province. However, the project expansion was not only a internal to South Africa. Due to the relative success the project had experienced so far, it was believed that a similar approach and philosophy might be translated to other similar countries, and PHIs crossed the border to Mozambique. The launch of the project in Mozambique marked the beginning of what would later become a remarkable widespread geographical expansion of PHIs.

The initiation of PhD and Master study programs shared between the coordinating university and partner institutions in Mozambique represented a new way of gathering resources for project implementation while strengthening local education programs. The new organizational and cultural environment meant new challenges for the PHIs approach, both theoretically and empirically; e.g. as the relative success in South Africa had in part relied on a "window of opportunity" due to a general wish for change, in other countries existing systems and entrenched interests proved significant obstacles to smooth implementation of the system.

In the case of Mozambique, PHIs started as a pilot project in three districts. A distinct difference between South Africa and Mozambique was the required sources of legitimation of the project. Although the pilot projects created local interest, lack of top-level support hindered substantial results in the highly centralized decisionmaking structures of the public sector. In addition, contrary to what had been the case in South Africa, stability was valued over change. However, learning form the Mozambican experience with limited impact from pilots in small geographical areas, it was also acknowledged in the project that without sufficient coverage, both in terms of hierarchical geographical span and in relation to the various health programs, results were hard to obtain. To deal with need for scale and coverage, the actions of PHIs were expanded from three districts to three whole provinces. Despite formal support for this from ministry level, real change in the sense of approving the replacement of existing reporting routines never came through, with the effect that the PHIs initiatives always came as an additional burden to the standard routines for health staff. Lack of real top-level commitment in the centralized HIS context of Mozambique meant that the project lost a lot of momentum.

In South Africa, the initially community driven, bottom-up effort was transformed to an official national standard. The South African PHIS project itself went through a formalization and professionalization processes and was established as a separate legal entity. In Cuba, the very concept and method of user-participation – typical of the Scandinavian approach- did not fit well with the local context, thus the theoretically "context-sensitive" way of making robust systems was found to be highly incompatible with local conditions. Participatory design carries a strong democratic inscription which ran into severe obstacles within the public health hierarchy. Although the delivery of health services was decentralized in Cuba, the decision making power was not, and bottom-up approaches were seen as a threat to the political system as a whole. Health personnel proved uncomfortable with new powers, responsibility and risks of making decisions. In Ethiopia, initial successes in pilot regions proved hard to translate to the national level, and the ministry decided to rely on the expertise of a local company to develop their own system (incorporating many of the same principles), rather than relying on the open source PHIs network.

Still, over time, PHIs got acceptance in a number of countries with widely differing political and organizational cultures. Its bottom-up, not-for-profit approach legitimated pilots in Malawi, Cuba, Mongolia, and India. In all cases, the expansion was afforded through the alignment of health authorities, educational institutions, research centers, and FOSS philosophy and development practices (which provided affordances for such a diverse set of actors).The establishment of such relations linked local and global networks of actors, through a negotiating process which tended to be legitimized in local needs. At the same time, the formal education part of the network was significantly expanded by enrolling a significant number of master and PhD students.

Gradually, PHIs became a globally dispersed network of small scale IS implementations (with South Africa the only nation-wide rollout). A perspective on action research and actor network theory was developed, with the claim that "local interventions need to be part of a larger network to be robust" and handle the twin challenges of sustainability and scalability. Working in multiple contexts provides opportunities for cross fertilization in a network, whereas narrowing down on one best practice exposes the project to the risks of volatility, which usually characterizes the institutional environment in developing countries. This loosely-coupled organizational form was termed "Networks of Action" (Braa et al.Braa et al.: 2004), and provided agility and cross-legitimation, but also exposed a risk of spreading too thin, and missing institutionalization. Furthermore, alliances were formed with other players active in developing countries, such as projects on medical record systems and UN organizations. A couple of UN initiatives indicated the necessity of appraising the big picture and scoping out an architecture able to cover most of the functions carried out by health systems, from local clinical encounters via district and provincial administrations up to national and global monitoring and evaluation efforts. One approach to this is Enterprise Architecture (Stansfield et al 2008).The result was a switch of legitimation from local contexts to an emerging organizational field of HIS for development (HIS4D). Following a Neoinstitutional view (Powell and DiMaggio: 1991), organizational field denotes the frame of reference of organizations engaged in a specific activity, their interactions constituting a recognized area of activity.

The introduction of the HIS system could also have negative effects, and was seen by some to somewhat paradoxically divert attention from quality of care to data quality. The gradually closer influence of the organizational field and international organizations entailed a transition in emphasis from local participation to the production and use of information for broader monitoring, and also from management and quality of health care to management and quality of health information. The collected data elements were increasingly defined on the basis of international standard requirements. While in the first period of PHIs information was tightly coupled with local contexts, the expansion of the project produced a partly autonomous "information space" with specific issues not necessarily evident at the micro level, e.g. duplication of indicators. Therefore, the growth of the project itself, and of the related information sphere, implied a switch from emphasis on local legitimation processes to legitimation in more global socio-technical issues (such as technological choices, adoption of internationally accepted standards and datasets, relation to millennium development goals) embodied in international donor requirements.

To sum up, after the first switch from local legitimation to a more global organizational field as arena of activity, HIS began to inscribe a different context characterized by new priorities, where key players (software companies, international donors, health standards and goals) were no longer local, nor immediately perceptible from the implementation level.

SECOND SWITCH: FROM ORGANIZATIONAL FIELD TO FULL-SCALE ROLLOUT

The requirements and challenges involved by a full-scale roll-out are different from the tacit convergence, compliance, and isomorphism that organizational fields tend to produce. Indeed, full-scale roll-outs imply a return of influence from specific regulatory environments, although at a different scale and political level.

The challenges of scaling are usually seen as related to increasing demands in terms of workload, scope of the system, and range of functionalities that must be supported. Such escalation of complexity in turn produces a proliferation of side-effects. Awareness of this expanded risk is crucial, and tallies well with the PHIs case. However, beyond these challenges, scaling up from a pilot phase to full scale rollout also entails shifts in institutional setting. Whereas pilots are an institutionalized way to test the capabilities of a system in real life settings, a wider rollout is regulated by different rules and accountabilities. The involved actors must not only increase their capacity, but also learn to deal with very different institutional constraints, implying different values, orientations, and legitimated patterns of action.

A PHIs member stated:

it's very useful to use achievements on the ground to show the possibilities of the system. [...] The general problem is the lack of leader bottom-up activities didn't manage to get turned around on the top level." A number of recent cases within PHIs show that the bottom-up approach, which characterized the beginning of the project, was turning into a more top-down one. The South African story was still leveraged for negotiations, but local pilots no longer seemed as central: Having succeeded on a national level in South Africa and being tied into the organizational field globally provided the needed legitimacy for other goverenments to consider the software, but meant that less attention was given to the original philosophies propounded by the project. This aspect is quite clear in recent implementations, where local health authorities asked to shut off some of the functionalities of HIS, frequently the ones which make the system useful at local level (i.e. local data analysis). "They don't care about information for action" a PHIs action-researcher lamented. Even when pilots were started to test system viability in a country, power remained at the central level. Accordingly, decentralization and local empowerment no longer seemed determinant for PHIs action. A similar top-down focus was exemplified by the following comment from a key decisionmaker in an African country: "I would prefer a new system using the already accepted WHO indicators."

So, while focus gradually shifted to full-scale implementations to cover large areas like a state or a country, a re-allocation of resources was required to comply with the needs and requirements of the institutions responsible for health in those areas. Accountability was achieved by establishing national NGOs in South Africa, India and Vietnam, and countries like Malawi sought to emulate this. Contracts were entered into with national authorities and with the UN. While the ability to draw on the global network was of continuing importance, engagement with bureaucratic structures and politics became increasingly salient. Those aspects are now empirically presented.

For a longe time, there was a sustained push from the core software developers to introduce regularly scheduled and thoroughly tested stable releases, instead of having implementers constantly downloading and using untested source code directly from the FOSS repository and thus needing a lot of assistance. However, constant pressure from the field for improvements and new features made this impossible to enforce, and it was not until the fall of 2008, after extensive field trials in Sierra Leone, that the core team felt confident enough to declare a 2.0 "final" release (as opposed to the previous "milestones" and "beta"), and thus lending it legitimacy. However, in accordance the with FOSS philosophy (see e.g. Raymond: 1999), unpolished software that works can generate a lot of interest, and for a presentation at WHO headquarters in Geneva in May 2008, a rough solution was created to demonstrate how patient data in a medical record system could be aggregated into an increasingly accepted indicator exchange format and then imported into HIS. This helped raise the legitimacy of both solutions, as part of an emerging Country Health Toolkit of interoperating components - which in itself was thought of as a response to the needs of full rollouts: In several developing countries, the PHIs project was met with requests to also help set up patient records, and in one African country, the Ministry of the Interior wanted assistance from the Ministry of Health in coming up with a software solution for national person IDs, starting

Table 1. Changes in organizational characteristics in the second shift from networks of action to full coverage rollout

Networks of action	Full coverage rollout
bottom-up	top-down
centrifugal expansion	centripetal focus
agility	stable capacity
open communication	internal discussion
global scope and functionality	national and local customization
spreading thin	Consolidation
selection of favorable conditions for success of pilots	capacity to cope with the variety of situations that the state presents
occasional competition between pilots	one system (up-front competition for tender)
loosely structured	formal organizations

with newborns and patients visiting clinics, but gradually using the same for issuing passports, licenses etc.

In India, transition from pilots in one district and in individual states to national level operations made it possible to engage authorities in a thorough revision of what data should be collected and used to calculate key indicators, with a focus on the PHIs "information for action"-approach, which resulted in a new consensus around a dramatic reduction in the number of data items collected. However, cases such as Cuba and Tajikistan can serve as examples of local (national) settings resisting change and forcing accommodation to different institutional forms. As five year plans were already in place, emphasis was on replicating a very detailed statistical information gathering apparatus, rather than a South Africa style complete overhaul according to the philosophy of using information for district level action.

The full scale rollouts meant new challenges for the PHIs approach. The project became characterized by two paths to institutionalization, one through the health information infrastructure on which PHIs is active, the other within academia, with the issue of scalability as a common denominator. As such, health information infrastructure has not yet stabilized, and one may well ask whether for PHIs the research arena is the stage with the field action taking backstage, or if it is the other way around. We do not have a definitive answer to this, time and results will tell. For the time being, research forms a backstage for ministries of health of several developing countries, but -at the same time- they are backstage for the information system research community which reads about implementations and challenges in those contexts. Considering the potentially never ending retrospective reconstruction of the backgrounds of institutionalization, we do not propose a definitive judgment. Rather we highlight the intimate relation - and continuous interchange - between ideas and actions. This is particularly relevant for large technical systems, which co-evolve with the ideas they support and are supported by. We assume that this 'double hermeneutic' (Giddens: 1982) is pertinent for understanding the evolution of infrastructures. Paraphrasing Bowker (2000), we might say that the PHI-promoted information infrastructure operates simultaneously at the concrete level of participatory design and implementation (fields in a database, capacity building, integration of datasets and organizational practices) and at an abstract one (dealing with the relationships between information science, organization, public health, and global software development, among others).

The issue of scalability became an official topic in the research group which remained at the heart of the network. This is how it was spelled out in a manifesto draft:

We take a broader view on information infrastructures to include both the technical components such as the technologies and standards, and also the interconnected social and organizational elements such as work practices, human resource issues, politics, and other institutional conditions. [...] key research issues of the group:

- *Scalability, or how to generate and manage growth*
- *The tension between standardization and flexibility;*
- *How can global work processes and infrastructures be controlled (or managed) (e.g. practical as well as legal, regulatory and institutional systems around OSS issues)*
- *What kind of risks are involved (produced);*
- *How can learning and innovation take place and be supported and taken into account within global work processes and infrastructure development;*
- *How are information infrastructures different in the context of "third world" countries, and what different approaches and strategies are required for their cultivation to support socio-economic growth processes*
- *How are information infrastructures (or: how can information infrastructures be) maintained, sustained and institutionalised?*
- *And first of all: The interaction between these.*

More on the action side of this action-research effort: In 2006 one of the Indian team members said during a focus group that she was surprised by the short period it took in South Africa to gain the momentum for exponential growth. Although it can be misleading to compare post-apartheid South Africa to India, such differences raised a question both among PHIs coordinators and in the university corridors: "Can it be that the chances to bootstrap and establish an infrastructure depended so heavily on historical contingencies and causalities?"

In India, the presence of powerful software entities, both public and private, combined with a strongly hierarchical tradition to make it hard to pursue a bottom-up approach. In one state, while the local team was putting its efforts in the health facilities, an agreement of the state health department with a national public company resulted in an intermittent halt to all activities. A conference about information technologies for development provided an opportunity to discuss with a broad audience of researchers and practitioners: one of the issues pinpointed was that the halt may have marked a crisis of the PHIs bottom-up approach to HIS development and implementation. If so, it is important to understand why top-down agreements coexist with bottom-up rhetoric (one of the sparking questions of this submission). Our interpretation is that the HIS4D organizational field had become much more crowded, and this necessitated situating the project in relation to a number of new actors, moving and affecting considerably more resources. Negotiations tend to be at state level, and this is where the balance between different approaches has to be explicitly and tacitly negotiated.

The case of a southern state of India is of particular interest, both because of a strong tradition of self-reliance and independence from both global and national trends (which made the organizational field less crucial in comparison to local considerations), and PHIs use of FOSS (which facilitated alignment with official state policy). Indeed, the state government official policy documents state:

ICT has opened up the possibility of radically different information exchange patterns by facilitating faster and more efficient dissemination of information. It can play a vital role in sustaining the

> *democratic ethos of the Indian society and ensuring a high level of transparency and accountability in governance [...] The Government has a comprehensive view of ICT as a vehicle for transforming Kerala into a knowledge-based, economically vibrant, democratic and inclusive society. By the term "inclusive," the Government means that the benefits of the socioeconomic transformation possible through ICT should reach every single citizen of the State. This policy document defines the Government's vision, mission and strategy for achieving the same. [...] The Government's vision is to turn Kerala into a knowledge society with sustainable economic growth, social harmony and high quality of life for all. The Government realizes that Free Software presents a unique opportunity in building a truly egalitarian knowledge society. The Government will take all efforts to develop Free Software and Free Knowledge and shall encourage and mandate the appropriate use of Free Software in all ICT initiatives.*

This state policy identifies a meso-level between global trends and local specificity, which is crucial in situating full coverage implementations of HIS. Indeed, FOSS technologies are what make PHIs an acceptable vector of ICT-based transformation, because they promise inclusion and democratic development. Practically, the software is expected to be more under control of local authorities and developer teams. Both philosophically and practically, the state government maintains that FOSS can be used to enact cooperation and communal property, which is more consistent with its own ideological dispositions and long term development strategies.

Table 1 summarizes the second shift in software and organizational characteristics.

DISCUSSION

The notion of "counter networks" (Mosse and Sahay 2003) draws upon Castells' (1996) argument that social development in the context of globalization is related to the use of ICT, and determined by the ability to establish synergistic interaction between technological innovation and human values. Central in this connection is communication between "nodes" in a network. Marginalized groups may counter their exclusion through the creation of such counter networks. This is the line that PHIs explicitly followed, focusing on education, research, improvement of communication practices both inside the health care hierarchy and with the population in general.

The opening figure illustrates the fluctuating relevance of local legitimation: in the fledgling period, it was crucial. As the influence of the organizational field strengthened, global trends began to dominate. Finally, state-wide implementations again required an emphasis on specific conditions, though differently from in the pilot stage. Commonly, the challenges of scaling ICT implementations are seen as related to escalation of complexity in terms of workload, functions, and scope, combining to trigger proliferation of side-effects and risk. In parallel to this view, we highlight the qualitative switch between regulatory contexts, on top of the quantitative growth of a system. Shifting relations to local institutions (organizational culture, public authorities, politics etc) means that scalability requires actors to be able to relate to quite different cultures, accountabilities and communicative practices. From the case presented here, we can see how the accepted scope shifted from local health facilities needs in post-apartheid South Africa (when the aim was consolidation of health systems for different races through the integration of information flows for local action) to the identification of common problems and converging resources from a variety of settings. Such networks of action supported the expansion of the project. But interlinked pilots needed another kind of institutional legitimation to expand. So to avoid the risk of spreading thin, state decision makers had to be involved, to support broader implementations. At that point, information requirements from health systems were more rooted in basic routines, rather than experimental implementations. In the second switch, from the networks of action to full, centrally sanctioned rollouts, the requirements were qualitatively different. To roll out, there is an expectation of something more robust and smoother. The software must be intuitive and user friendly, capable of handling large datasets, professional quality manuals must exist, and extensive training conducted (at one extreme, training involved 24 000 people in one Indian state). Such changes explain the adoption process by linking it to the socio-technical capacity of matching diverse institutional settings. Looking at the oscillation between different sources of legitimation, we can understand how the transformative role of ICT (Avgerou, 2007) actually played out in the different phases of the scaling. The qualitative shifts between phases counteract a linear conception of ICT diffusion.

We can note a re-positioning of the PHIs strategy: from the original bottom-up approach, things have been steered more towards a top-down focus, which shifted from the community and health facility to ministerial levels. It is claimed within the network that pilots are still organized at district level. This is surely characterizing PHIs approach to localization of its interventions. Nevertheless, it has to be acknowledged that local appropriation and empowerment of health personnel is currently not the driving force of adoption, as it was initially in South Africa. "Cultivation" is still an important element of PHIs action, but capacity building and incremental change are not pursued directly at the district or community level, but rather at the ministerial level in most infrastructural hubs. Consequently, the 'seeds' are different: graduate health informatics programs, system coverage of wide regions and numerous health programs (TB, malaria, reproductive health etc), relations between public administrators and internationally active organizations, the constitution of software developer teams, etc.

In this sense, efforts to establish a health information infrastructure can be seen as institution building activities, changing according to available sources of legitimation.

REFERENCES

Avgerou, C. (2007). *Information Systems in Developing Countries: a Critical Research Review.* London School of Economics and Political Sciences, Innovation Group, Working Papers Series

Bowker, G. C. (2000). Biodiversity Datadiversity. *Social Studies of Science*, *30*(5), 643–683. doi:10.1177/030631200030005001

Braa, J., & Hedberg, C. (2002). The struggle for district-based health information systems in South Africa. *The Information Society*, *18*(2), 113–127. doi:10.1080/01972240290075048

Braa, J., Monteiro, E., & Sahay, S. (2004). Networks of Action: Sustainable Health Information Systems across Developing Countries. *MIS Quarterly.*

Castells, M. (1996). *The Rise of the Network Society.* Malden, MA: Blackwell.

Mosse, E., & Sahay, S. (2003). Counter networks, communication and health information systems: A case study from Mozambique. In M. Korpela, R. Montealegre, & A. Poulymenakou (Eds.), *Proceedings of the The IFIP TC8&TC9/WG8.2+9.4Working Conference on Information Systems Perspectives and Challenges in the Context of Globalization* (pp. 35–51), Athens, Greece.

Powell & DiMaggio. (1991). *New Institutionalism in Organizational Analysis*. University of Chicago Press.

Raymond, E. S. (1999). *The cathedral and the bazaar.* Available from http://www.tuxedo.org/»esr/writings/cathedral-bazaar

Rolland, K. H., & Monteiro, E. (2002). Balancing the local and the global in infrastructural information systems. *The Information Society*, 18(2), 87–100. doi:10.1080/01972240290075020

Stansfield, S., Orobaton, N., Lubinski, D., Uggowitzer, S., & Mwanyika, H. (2008). *The Case for a National Health Information System Architecture; a Missing Link to Guiding National Development and Implementation*. Health Metrics Network.

Titlestad, O. H., Staring, K., & Braa, J. (in press). Distributed development to enable user participation: Multilevel design in the HISP network. Forthcoming in the *Scandinavian Journal of Information Systems*.

Walsham, G. (2008). ICTs and Global Working in a non-flat World. In M. Barrett, E. Davidson, C. Middleton, & J. DeGross (Eds.), IFIP International Federation for Information Processing, Volume 267, *Information Technology in the Service Economy: Challenges and Possibilities for the 21st Century* (pp. 13-25). Boston: Springer.

This work was previously published in International Journal of Sociotechnology and Knowledge Development, Vol. 1, Issue 4, edited by E. Coakes, pp. 1-12, copyright 2009 by IGI Publishing (an imprint of IGI Global).

Index