Advances in Experimental Medicine and Biology 989

Panayiotis Vlamos *Editor*

# GeNeDis 2016

## Geriatrics

Springer

# Advances in Experimental Medicine and Biology

Volume 989

More information about this series at http://www.springer.com/series/5584

Panayiotis Vlamos
Editor

# GeNeDis 2016

## Geriatrics

Springer

*Editor*
Panayiotis Vlamos
Department of Informatics
Bioinformatics and Human
Electrophysiology Laboratory
Ionian University
Corfu, Greece

ISSN 0065-2598 ISSN 2214-8019 (electronic)
Advances in Experimental Medicine and Biology
ISBN 978-3-319-57347-2 ISBN 978-3-319-57348-9 (eBook)
DOI 10.1007/978-3-319-57348-9

Library of Congress Control Number: 2017948943



Printed on acid-free paper

This Springer imprint is published by Springer Nature
The registered company is Springer International Publishing AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

# Contents

# Mobile Applications Improve Quality of Life on Citizens with Disorientation: The 'NeverLost App' Paradigm

**Sotirios Fotiou and Panayiotis Vlamos**

**Abstract** Mobile technology has been evolved as an important tool in healthcare. Mobile applications are being designed in order to assist patients in their everyday life and also to play a vital role on the improvement of their everyday activities and quality of life. Meanwhile students use advanced techniques in order to design and implement high quality applications that aim to introduce them to the advantages of the mobile technology. In this paper we present the steps for the creation of the application NeverLost that was inspired, designed, created and tested by students of the Secondary Education. NeverLost is an Android application that helps individuals (mainly children) with disabilities, as well as older patients with lack of orientation manage their day-to-day activities. A research of the general benefits that students using this app is presented, as well as their future proposals for the evolution of the app in other aspects of healthcare and quality of life of senior citizens or patients with neurodegenerative diseases.

**Keywords** Collaborative learning • Mobile application • Team-based learning • Group work • Assistive technology • Mobility • Disorientation • Assistive systems • Alarm systems • Assisted living

## 1 Introduction

New technology combining the use of computers, smartphones, wearable devices etc. is being used the last years for the improvement of the quality of life of citizens as well as monitoring their health on their everyday activities. Also an increased number of patients are being monitored and being helped in their every day needs or difficulties.

S. Fotiou (✉)
Department of Informatics, Ionian University, Corfu, Greece
e-mail: fotiousotirios@yahoo.gr

P. Vlamos
Department of Informatics, Bioinformatics and Human Electrophysiology Laboratory, Ionian University, Corfu, Greece
e-mail: vlamos@ionio.gr



P. Vlamos (eds.), *GeNeDis 2016*, Advances in Experimental Medicine and Biology 989, DOI 10.1007/978-3-319-57348-9_1

According to official data in 2014 almost 22% of the global population used a smartphone while the prediction for the year 2019 is at 34%. To date, it is estimated that there are roughly 2 billion smartphone users in the market, with this number to increase another 12% in 2016 to top 2.16 billion people globally. That means that for the first time more than a third of the world's population will all posses a smartphone device.

The increasing number of smartphone devices can be attributed to a number of factors. Technological innovation, improved usability and accessibility of the users, but for many the growth has been heavily attributed to a decrease in price. The same time the penetration of the smartphone in the age of 13–17 years old is 18%, at the age of 65+ 38% with the highest penetration at the ages of 25–34 years old with a 62% [1].

Simultaneously with the increase at the usage of smartphones in our society, a large number of universities and schools introduce application development to their students. As Powell and Wimmer [2] mentions on his work, teaching programming and mobile application development can be a great challenge for teachers; however, teaching an interdisciplinary class with students from different levels strengthens this challenge. To encompass a broad range of students, many teachers tried to improve their lessons and methods by introducing group/team programming in their classes. The study of Powell and Wimmer [2] was conducted to understand what is the opinion of the students' regarding the effectiveness of their group/team experience and whether or not they learned better by developing a mobile application. The results were favorable towards using group work for mobile application development learning, productivity, enjoyment and confidence of quality.

In their research [3] indicated that Mobile-learning (M-learning) is a promising pedagogical technology that can be employed in higher educational studies. Generally, mobile technology helps students to be more aware in the new technology, to be able to make conversations, to join social media, or even to find answers to their questions. The students can also collaborate better, share their knowledge, and as a result to leverage their learning outcomes. In particular, M-learning can help students with disabilities and motivate them to be part of classes remotely with the use of their mobile devices.

Mobile learning can be applied in all stages of education and can be used from standard schools to special education schools. In their work [4] state that education is one of the fields that information and communication technologies (ICTs) are considered very important underlining their use in primary education where is thought significant for this crucial age. Also equal opportunities and advantages in computer technology use should be provided for all individuals forming the society [5].

Lombardi [6] states that learning by doing is generally considered the most effective way of learning. The Internet and a variety of emerging technologies such as telecommunications, audiovisual and underwriting technologies now make it possible to provide students with authentic learning experiences ranging from experimentation to real world problem solving.

A successful solution used to attract students in computer science is the introduction of programming through educational environments that promote game programming, thus arousing the pupils' imagination [7].

Extensive surveys and studies have shown that students learn more effectively when they actively participate in the process of learning. Regardless of cognitive object, students who work in small groups, they tend to learn more and retain the knowledge longer time than other forms of teaching. Additionally, students who work together in groups seem to be more satisfied with the teaching [8–10].

As Cohen noted [11] on his research that many advantages also exist in the coexistence of normally developing children with children with pervasive developmental disorders. Normally developing children can "act" as teachers or even be excellent role models. If a child is learning by observing other children then it can learn in many different ways of acting and doing things from his fellow students. According to a study by Gresham and MacMillan [12], Preschool children with disabilities experienced higher rates of social interaction when working in an integration class rather than in a separate class. Also another study [13] showed that autistic behavior can be reduced when they are present typically developing children of the same age. Children with disabilities working in a regular classroom, will not be confronted with the stigma to be isolated in the special education structures, and thus problems of fallen morale and low self-confidence can be eliminated.

The joint interaction activities of general education students and students with disabilities can install bridges between the two school communities on a sustainable basis. Recent studies on the use of ICTs in special education claim that can provide children with many different opportunities for rich learning activities that are close to their age and also they have positive effects when taking into consideration their learning difficulties [14]. Additionally, [14] states that ICT can play a main role in achieving the goals of the curriculum in all areas and subjects if the provided developmentally appropriate software tools are inserted in suitable educational scenarios.

According to Sharples et al. [15], the implementation to any educational technology should consist of three parts: the learner, the educator and the technology itself. This is what the project NeverLost tried to create. The coexistence and harmonic cooperation of the involved parties on the project.

## 2 Comparison Study

There are numerous applications available in the google play store or presented in articles that aim to help seniors with dementia or disorientation. The most of them on their approached use location based services LBS to track people with Mild cognitive impairment (MCI). The applications use the characteristics of the mobile phone in order to monitor the route of the patient and to notify the caregivers if the patient deviates from a predicted route. Using this approach applications with the names OutCare [16] and iRoute [17] was designed.

Application LaCaSa uses a more complex system that applies Markov models on persons with MCI and using context information, like current location, noise or known locations using device's wi-fi connectivity decides if the patient is wandering [18]. In the same approach using GPS data Lin et al. [19] and Robinson et al. [20] with OAED and KITE systems respectively they try to facilitate the communication between persons with MCI and their caregivers. Both of them they seem to use effective and efficient methods in detecting wandering behaviors. Also the iWander project introduced by Sposaro et al. [21] presents an application capable of determining if the person is wandering depending on device's GPS sensor. The use of additional data like the time of the day, the weather condition and safe zones helps to navigate the patient to a safe location, notify the caregivers, or even call 911.

In contrast with all previous mentioned applications, NeverLost app uniqueness was that it was designed and implemented not by university students but by secondary education students and also the fact that the main purpose of the design was the simplicity of the use of the application with just two clicks. Trying to use bioethics and the independence of the persons with MCI or the children with disabilities, NeverLost app is easily accessible only when the person want it. This was one of the points that the students wanted to follow on their initial approach on this special issue.

## 3 Project Implementation

The main difficulty of the teachers that designed the project was the initial stimulus of the children towards working for a common good. The stimulus thought came unexpectedly easily. The students see other children or seniors nearby their homes, finding hard to do some activities that the most of the "normal" people think that are easy. During the first approach for the project, the students with the use of the brainstorming technique they came up with the idea of creating a mobile application, in order to help other children with special needs in their need for help.

Students were already introduced to the design of two simple applications for mobiles using Android with the use of the software App Inventor. The choice of App Inventor promotes a new era of personal mobile computing in which people are empowered to design, create, and use personally meaningful mobile technology solutions for their daily lives, in endlessly unique situations. App Inventor's intuitive programming metaphor and incremental development capabilities allow the developer to focus on the logic for programming an app rather than the syntax of the coding language, fostering digital literacy for all [26]. The above mentioned features made us decide to introduce App Inventor for Computer Science teaching in Secondary Education, with results that surprised even ourselves.

The goal of cooperation between different stages of the typical Secondary education was achieved easily due to the need of different ages, programming skills

and syllabus. In total 90 students from 4 different schools (1 gymnasium, 2 high schools and 1 vocational school) covering all stages of typical secondary education in Greece worked as a team.

The cooperation of students of the typical education with students of the special education was thought the biggest challenge of all. Since the students in typical school had the idea of helping the kids with special needs at their local special school it was the turn of these kids to give the answers that rose from the initial proposal of the project. So the students at the gymnasium wrote the questions and the students at the special school gave the answers to their teacher. Questions like, if they own a smartphone, if they know how to use it or make simple tasks, if their parents are using smartphone technology, or what they do on their free time, were answered and gave the necessary stimulus to us all for the completion of this ambitious project.

Students during the implementation of the application faced real problems that come up when any project is assigned to a team, and gained valuable experience on how they should organise the project, the implementation steps and the communication with other groups (which were responsible for the remaining pieces of the development process).

The logic of App Inventor showed that it pushes the students to understand the essence of programming and logic to solve problems without stress or errors of syntax of the programming language. Throughout the development of the application the students could by using their mobile phones to proceed with direct control of the code (blocks) accelerating process of development and implementation of the application. The involvement of teachers in the process was minimal with selective interventions as appropriate.

## 4 Results

The result of the student collaboration was the creation of an application for use by children of Special Gymnasium and their parents. The name given to the application is NeverLost, and their goal was to create an application that a child with special needs (or any other child with similar difficulties) can use in the event that was in danger (lost) and want call for help of his parents. Their main goal was the simplicity of the application and what was achieved was that the user needs not to make more than two clicks in order to seek for help. In a stressful situation a child in panic can use the application and call for help without having to search the directory (contacts) or the need to write a message. The design includes five buttons on the home screen, named as: Make a call, Send Message, See your location, Send your location with SMS and Send your location on a map. The naming of the buttons focused on the simplicity and clarity of the available functions (Fig. 1).

The most demanding part of students' work from a programming point of view, was the function of the button "Send your location on Map" which uses latitude and longitude values in order to create a message (hyperlink) that will show his guard the exact geographical point that he is via the use of Google maps.

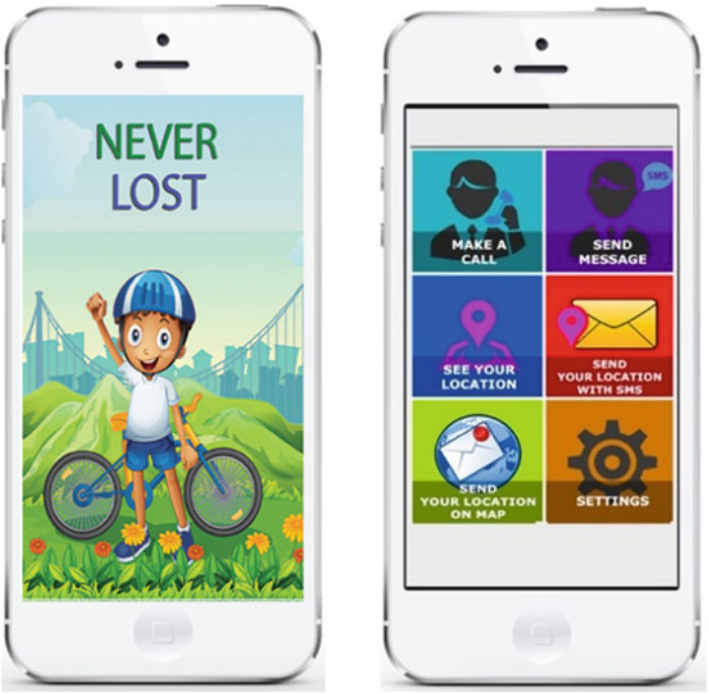


**Fig. 1** The graphical user interface of the application

Students also created social media accounts and were responsible for the promotion of the application in order to be a useful tool for as many children and families as possible.

A promotional video was directed and created by the students, a web page for the app was made, a press release was written and the final publish of the App on Google Play Store took place. All parts of the project gave students a feeling of completion that they never met before.

The result was that the application was awarded in a world contest by the Computing Science Teachers Association by the Education Business Awards in Greece—Innovation in Teaching and by many different public bodies. Thought all of the participants in the project strongly believe that their biggest award was the eyes of the children of the special school when we presented the application in a special ceremony. Also the parents of the children with special needs were happy because as they said it was the first time that their children were in the same project with regular kids and that the application was something that they always wanted for their children safety.

## 5 Connection with Neurodegenerative Diseases

The outdoor or the social activities are cognitively demanding and they require emotional support. Alzheimer's disease which is the most frequent cause of dementia, early effects the skills of the patient for spatial orientation while at the same time it impedes his planning and error compensation ability [22, 23]. As Koldrack et al. [22, 23] also mentions, people with dementia slowly limit their life-space and variety of activities since they care more about their security. The best thing is to provide appropriate guidance when the patient will be disorientated in order to avoid dangers, while at the same time not, complicating his normal mobility. The best outcome will have the result of maintaining a person's life-space, his activity spectrum and why not his cognitive health.

Quite a lot of the projects which students designed to date to help patients with dementia exist. As Yamagata et al. [24] states, the use of service-learning courses, help the students to develop an easy-to-use application for mobile devices to help older adults with disabilities to use the technology more effectively. A student application called Candoo utilizes Google's voice recognition and synthesis engine to navigate the web, provide the weather, and supply pill reminder alerts. Another application allows families to electronically send photographs, video clips, and favorite music from anywhere to loved ones for enjoyment. Such mobile apps could allow dementia persons to become less stressed and be able stay alone in their homes more time, while also providing awareness and positive change of attitude by those the previous generations towards the elderly [24].

Students at the end of NeverLost project were asked two questions and they had 45 min to think and write an answer. The first question was designed to ascertain the level of satisfaction of each student by his participation in the final result, the overall degree of success of the project, and whether they consider that received considerable knowledge useful for their future. The results were quite positive. All of the 90 students (100% of total) were happy with the final result, they thought that the knowledge they gained will be useful in their future academic life and they were feeling great with their involvement in the project.

The second question was designed to study how they thought a probable development of the project, or what else they would like to do the next school year. The majority of the answers (90%) described a project that will make an application for seniors that face problems with lack of orientation. On our questions why they proposed an application with these characteristics, the answer was that some of them have their grandparents living in their house and that they face these problems daily, while the rest of the students have noticed on the TV many notices for elderly people who are lost and sought from their own relatives, so they think that an evolvement of NeverLost could help these people.

## 6 Conclusion

The main goal of this study is to present the way that a project—even at low grade education—can introduce the students in creations with the aim of offering for the common good. NeverLost app has shown that students want to cooperate and to create in order to be able to help their fellow human beings facing difficult situations.

Also the introduction and use of new programming tools with the use of mobile devices (being used everyday by most of the students) has significant effects on the final product of the students.

Regarding the use of M-learning in education future aim is to include on projects students and teachers from primary, secondary and higher education in a project that will be able to break into smaller pieces suitable for every stage, syllabus and special characteristics of the cooperative groups. Consequently, other surveys can be conducted for examining the student's and educator's attitudes and ways of interaction on large projects.

As a future direction, we intent to improve the application with our students in order to be applicable for seniors with Alzheimer disease or other neurodegenerative diseases that causes disorientation problems. Its main characteristics will be the simplicity of its use, the connectivity of the application with wearable devices and also the necessity of the automatic notification of the caregivers. Since, care-giving for a dementia patient is associated with increased risk of psychological and physical health problems [25] tools that promote patient safety and as a result peace of mind for caregivers they are necessary more than ever. Especially nowadays that most of the houses and people living in, are connected to the internet and most of them can use low cost electronic mobile devices daily.

Finally due the large number of units monitoring the position of citizens nowadays, a survey of the quality characteristics of the different technologies used by each device—with the purpose of use in health applications and the quality of life of patients—would be of particular interest.

## References

1. SmsGlobal. 2016. Smartphone Ownership, Usage and Penetration by Country. http://thehub.smsglobal.com/smartphone-ownership-usage-and-penetration. Accessed 2 Sep 2016
2. Powell, L.M., and H. Wimmer. 2016. Evaluating Students' Perception of Group Work for Mobile Application Development Learning, Productivity, Enjoyment and Confidence in Quality. *Information Systems Education Journal* 14 (3): 85–95.
3. Al-Emran, M., H.M. Elsherif, and K. Shaalan. 2016. Investigating Attitudes Towards the Use of Mobile Learning in Higher Education. *Computers in Human Behavior* 56 (2016): 93–102.
4. Florian, L., and J. Hegarty. 2004. *ICT and Special Educational Needs: A Tool for Inclusion*. New York: McGraw-Hill International.
5. Williams, P., H.R. Jamali, and D. Nicholas. 2006. Using ICT with People with Special Education Needs: What the Literature Tell Us. *ASLIB Proceedings* 58: 330–345.

6. Lombardi, M.M. 2007. Authentic Learning for the 21st Century: An Overview. Educause Learning Initiative.
7. Psomos, P., and M. Kordaki. 2013. Analysis of Educational Digital Storytelling Environments: The Use of the "Dimension Star" Model. In *Information Systems, E-learning, and Knowledge Management Research*, Communications in Computer and Information Science, vol. 278, 317–322.
8. Beckman, M. 1990. Collaborative Learning: Preparation for the Workplace and Democracy. *College Teaching* 38 (4): 128–133.
9. Chickering, A.W., and Z.F. Gamson, eds. 1991. *Applying the Seven Principles for Good Practice in Undergraduate Education. New Directions for Teaching and Learning*. San Francisco: Jossey Bass.
10. Goodsell, A., M. Maher, V. Tinto, et al. 1992. *Collaborative Learning: A Sourcebook for Higher Education*. University Park: National Center on Postsecondary Teaching, Learning, and Assessment, Pennsylvania State University.
11. Cohen, S. 2006. *Targeting Autism: What We Know, Don't Know, and Can Do to Help Young Children with Autism and Other Related Disorders*. Los Angeles, CA: University of California Press.
12. Gresham, F.M., and D.L. MacMillan. 1998. Early Intervention Project: Can Its Claims be Substantiated and Its Effects Replicated? *Journal of Autism and Developmental Disorders* 28 (1): 5–13.
13. Schopler, E., A. Short, and G. Mesibov. 1989. Relation of Behavioral Treatment to "Normal Functioning". *Journal of Consulting and Clinical Psychology* 57 (1): 162–164.
14. Westwood, P. 2006. *Teaching and Learning Difficulties: Cross-curricular Perspectives [online]*. Camberwell, VIC: ACER Press, ix, 164 p. ISBN: 9780864314932.
15. Sharples, M., J. Taylor, and G. Vavoula. 2005. Towards A Theory of Mobile Learning. *Proceedings of mLearn* 1 (1): 1–10.
16. Wan, J., C. Byrne, G.M.P. O'Hare, and M.J. O'Grady. 2011. Orange Alerts: Lessons from an Outdoor Case Study. 2011 5th International Conference on Pervasive Computing Technologies for Healthcare (PervasiveHealth) and Workshops, Dublin, 446–451.
17. Hossain, S., K. Hallenborg, and Y. Demazeau. 2011. iRoute: Cognitive Support for Independent Living Using BDI Agent Deliberation. In *Trends in Practical Applications of Agents and Multiagent Systems*, 41–50. Berlin, Germany: Springer.
18. Hoey, J., X. Yang, E. Quintana, and J. Favela. 2012. LaCasa: Location and Context-Aware Safety Assistant. Proceedings of the 6th International Conference on Pervasive Computing Technologies for Healthcare (Pervasive Health) and Workshops 2012, San Diego, CA, 171–174.
19. Lin, Q., D. Zhang, X. Huang, H. Ni, and X. Zhou. 2012. Detecting Wandering Behavior Based on GPS Traces for Elders with Dementia. Proceedings of the 12th International Conference on Control Automation Robotics & Vision (ICARCV), Guangzhou, 2012, 672–677.
20. Robinson, L., K. Brittain, S. Lindsay, D. Jackson, and P. Olivier. 2009. Keeping in Touch Everyday (KITE) Project: Developing Assistive Technologies with People with Dementia and Their Carers to Promote Independence. *International Psychogeriatrics* 21 (3): 494–502.
21. Sposaro, F., J. Danielson, and G. Tyson. 2010. iWander: An Android Application for Dementia Patients. Proceedings of the 2010 Annual International Conference of the IEEE Engineering in Medicine and Biology, Buenos Aires, 3875–3878.
22. Koldrack, P., R. Henkel, F. Krüger, S. Teipel, and T. Kirste. 2015. Supporting Situation Awareness of Dementia Patients in Outdoor Environments. Proceedings of the 2015 9th International Conference on Pervasive Computing Technologies for Healthcare (PervasiveHealth), Istanbul, 245–248.
23. Koldrack, P., R. Henkel, F. Kruger, S. Teipel, and T. Kirste. 2015. Supporting Situation Awareness of Dementia Patients in Outdoor Environments, PervasiveHealth 2015, May 20–23, Istanbul, Turkey.

24. Yamagata, C., J.F. Coppola, M. Kowtko, and S. Joyce. 2013. Mobile App Development and Usability Research to Help Dementia and Alzheimer Patients. Paper Presented at the 9th Annual Conference on Long Island Systems, Applications and Technology, LISAT 2013.
25. Ho, L., P.A. Bloom, J.G. Vega, S. Yemul, W. Zhao, L. Ward, and G.M. Pasinetti. 2016. Biomarkers of Resilience in Stress Reduction for Caregivers of Alzheimer's Patients. *Neuro Molecular Medicine* 18 (2): 177–189.
26. Pokress, S.C., and J.J.D. Veiga. 2013. MIT App Inventor: Enabling Personal Mobile Computing. PRoMoTo 2013 Proceedings.

# Performance Management in Healthcare Organizations: Concept and Practicum

**Panagiotis E. Dimitropoulos**

**Abstract** Organizational performance can create and sustain competitive advantages for corporations and even improve their sustainability and future prospects. Health care organizations present a sector where performance management is structured by multiple dimensions. The scope of this study is to analyze the issue of performance management in healthcare organizations and specifically the implementation of the Balanced Scorecard (BSC) methodology on organizations providing health services. The study provides a discussion on the BSC development process, the steps that management has to take in order to prepare the implementation of the BSC and finally discusses a practical example of a scorecard with specific strategic goals and performance indicators. Managers of healthcare organizations and specifically those providing services to the elderly and the general population could use the propositions of the study as a roadmap for processing, analyzing, evaluating and implementing the balanced scorecard approach in their organizations' daily operations. BSC methodology can give an advantage in terms of enhanced stakeholder management and preservation within a highly volatile and competitive economic environment.

**Keywords** Performance management • Balanced scorecard • Healthcare organizations • Performance measurement • Health system

## 1 Introduction

Organizational performance has gained significant interest from both academics and practitioners, since it can create and sustain competitive advantages for corporations and even improve their sustainability and future prospects [1, 2]. Despite the fact that performance management was initially developed for profit organizations, it was soon adopted by several not-for-profit organizations including public organizations such as municipalities, hospitals, universities

P.E. Dimitropoulos (✉)
Department of Sport Management, University of Peloponnese, Sparta, Greece
e-mail: dimitrop@uop.gr



P. Vlamos (eds.), *GeNeDis 2016*, Advances in Experimental Medicine and Biology 989, DOI 10.1007/978-3-319-57348-9_2

and other forms of public organizations. The reason for the implementation of performance management mechanisms on the public services sector was the fact that organizational success is a multi-dimensional concept that the classic financial performance measures could not grasp [3].

Health care organizations present a sector where performance management is structured by multiple dimensions since they have many stakeholders with conflicting or overlapping interests [3]. Practically there is a separation between the consumers of the health services (patients), the ones who pay the services (taxpayers) and the providers of the services (hospitals etc.) [3]. Moreover, health care organizations face an even greater pressure to implement effective management tools nowadays since the state's budgets have been significantly diminishing creating serious hurdles to health care organizations on their daily operations [4]. Consequently, the implementation of performance management mechanisms on health care organizations can provide significant assistance on tracking non-value creating activities, control expenses and enhance the efficient utilization of scarce resources.

The balanced scorecard methodology is a performance management system that has been implemented by several public organizations worldwide [5–7]. The balanced scorecard is focused on the effective performance measurement and the evaluation of successful implementation of organization's strategy through balancing financial and non-financial aspects of the organization [4, 8–10]. Several public organizations have employed the balanced scorecard and achieved an improvement on their daily operations, performance and sustainability. An increased number of researchers provide evidence on the above-mentioned argument in the healthcare sector [11, 12]. Application of the balanced scorecard on health care organizations in UK, Sweden, Greece and Canada have provided significant results on the improvement of financial performance, customer satisfaction and the creation of health equity across a national system of health services [3, 4, 13].

Under this framework the scope of this study is to propose specific steps that need to be taken for the preparation of the BSC methodology and to propose an indicative scorecard on a healthcare organization, based on previous studies on the field. Also our goal is to derive useful policy implications for health managers and public authorities for improving health services. The rest of the study is organized as follows: The second section describes in brief the various financial and non-financial performance measures evidenced in the literature. The third section describes the necessary steps for the preparation of the balanced scorecard and provides an indicative scorecard with strategic goals and performance indicators. The fourth section concludes the papers offering useful policy implications.

## 2 Performance Management Mechanisms

Previous studies have examined the effectiveness of financial and non-financial performance measures, in an effort to provide evidence on the appropriateness of these two categories in specific sectors and strategic contents. Several academics have

argued that the traditional performance mechanisms are narrow and short-term oriented, while on the contrary non-financial performance measures incorporate strategic priorities such as customer-focus, improvement of processes and are more flexible to business environment changes and adapt effectively to corporate needs and thus can provide significant strategic advantages to the organization [14]. Under this framework, several quality management tools have been developed for supporting the decision making process within organizations [15]. Those mechanisms include the business excellence model, Investor in People, benchmarking, balanced scorecard, ISO 9000 and charter mark. In accordance, the "performance prism" is a model adopting a stakeholder view of performance measurement [15] and has indicated that the application of the performance prism in a British charity assisted managers to identify the main drivers of performance in line with stakeholders needs [16].

Moreover, additional performance management frameworks are the integrated reporting framework (IR) which main focus in on value creation over time and can be utilized by non-profit organizations and the Business Process Re-Engineering method which was implemented by a public hospital in Sweden [17] with positive performance results. In addition, the Skandia navigator is another performance management mechanism with the scope to create business value and competitive advantage through the improvement of human capital, intangible assets and other organizational abilities [18]. However, the most famous model for non-financial performance management is the balanced scorecard [6, 7]. The balanced scorecard (BSC) has an advantage related to the previously mentioned methods which allow organizations to assess both their financial and non-financial performances under four main pillars that are structurally connected.

The BSC approach has been incorporated in day-to-day operation of many public and non-for-profit organizations during the last two decades and the main reasons for this shift are the new perspective of the state on strategic management and sustainability, the constrained resources towards public organizations and the increased demand for accountability on behalf of the stakeholders. The reason for the appropriateness of the BSC method for health organizations is the fact that it simultaneously links financial performance measures with customer focus, the improvement of internal processes and the enhancement of innovation and learning. Consequently, the present study aims to provide a significant assistance to managers in the process of the BSC development and implementation.

## 3 Building the BSC Methodology

The development process of BSC can be performed within seven basic steps. At first, the board of the organization may decide to create a preparation committee including a relative small number of employees (three to five if appropriate in order to facilitate communication and coherence among the team) and their main duty will be to take the necessary actions in order to facilitate the implementation of BSC method. In order to assist the committee's member achieving the required goal, they

must receive additional training on the BSC and to do so they must participate in seminars related to performance management and BSC implementation in particular. Since the effective implementation of the BSC method is proper training this step can be the cornerstone for success and has to be taken into serious consideration.

The next step is to determine the organization's mission, philosophy, strategic goals and perform a SWAT analysis. These details can form the raw material for the creation of the BSC, and further assist on the determination of the performance criteria and indicators in each pillar. On this stage the collection of appropriate data is another significant step towards BSC success. Data elements must include details on patient and caregiver characteristics (client income, level of disability, demographic information, current living situation etc), health care coverage (ability to cover local demand), relations with suppliers and partners (public insurance funds, private health care organizations and other institutions), long-term financial viability (operating performance, solvency) and change and innovation (innovative medical services, ability to adapt to changes etc.) [4, 13].

The following step is to set specific and clear objectives and ensure continuous connection of these objectives with the performance measurement indicators that have been set in the previous step. The sixth step is to integrate the BSC process in all divisions of the health organization. On this step we have to keep in mind that flexibility could be a significant ally on effective implementation of the BSC method. This means that each department must have the ability to modify the BSC goals and indicators based on their distinctive features but the departments' goals must be aligned with the organization's general strategic plan. The final steps included the collection and analysis of performance results (after the implementation of the BSC) and this feedback can help towards the formulation and implementation of future strategies in the organization. Finally, a periodic review for the appropriateness of the selected performance metrics is needed in order to adjust the performance indicators towards the goals if it is deemed necessary.

Based on the above discussion, the basic pillars of the scorecard refer to the growth improvement, innovation and customer loyalty and retention as the key elements of a scorecard within a health service organization. Those pillars include financial and non-financial performance indicators on specific strategic goals. Additionally, the scorecard perspectives (pillars) in a health service organization must include performance indicators regarding the return on taxpayer's utilization of resources, cost savings, (productivity of personnel etc.), the quality of the services (customer perspective), the improvement of internal management processes and the incorporation of improvements, innovations and new technologies (learning and growth perspective) [4]. Therefore, a potential balanced scorecard of a health care organization can take the following form as depicted in Table 1.

The financial objectives of the scorecard are focused on the financial performance and long-term viability of the organization [4]. Specifically the balanced scorecard can included strategic goals regarding the enhancement of revenues, the control of expenses within budgetary constraints which is more crucial for the health organizations of the public sector where resources are even scarcer and the settlement of debt obligations within acceptable levels. Regarding the customer perspective, the

**Table 1** Balance scorecard for a health care organization

| Perspective | Strategic goals | Performance indicators | Explanation/definition |
|---|---|---|---|
| Financial | Increase Revenue | Operating revenues/assets ratio | Indicates circulation of assets and efficient utilization |
| | | Net profit margin = net income/revenues | Measures operating efficiency |
| | Control expenses within the initial budget | Break—even result | Balancing revenues and expenses especially for public health care organizations |
| | | Operating expenses/operating revenues ratio | Measures managerial efficiency |
| | Control of debt obligations | Debt ratio | Measures the organization's leverage and viability |
| Customer | Quality of services | At least 80% of our customers to be satisfied from services and facilities | Number of satisfied customers based on questionnaire answers on detailed dimensions |
| | | Number of patient complaints | Extracted from the questionnaire or a day-to-day inspection |
| | | Waiting time | Diagnostics and not hospitalized patients |
| | Effectiveness of services | Hospitalization duration | Average days of days a patient is hospitalized |
| | | Cases transferred to other hospitals | Cases where the hospitals' know-how was not sufficient for treatment |
| Internal business | Employee loyalty and satisfaction | Employee satisfaction index | Number of satisfied employees of all sectors based on questionnaire answers on detailed dimensions |
| | | Employee absenteeism | Number of employees that deliberately are absent from work |
| | Resource utilization | Bed occupancy ratio | Percentage of occupancy on hospital beds or emergency rooms |
| Learning and Growth | Staff training and education | Percentage of employees in training programs & conferences | For administrative, nursing and medical staff |
| | Technological innovations | Amounts invested in new technologies | Investments and purchase of new technologies as a percent of total budget |
| | New treatments | Number of new treatments introduced in the organization | Continues testing and evaluation of new treatments and procedures |
| | Cooperation with the society | Projects with other organizations | Number of collaborations with universities, research centers, pharmaceutical companies etc. |

balanced scorecard sets objectives regarding the quality of the services provided to the public and the effectiveness of those services including the satisfaction of the patients, the waiting time for both hospitalized and mainly non-hospitalized customers, the duration of hospitalization and the number of cases needed to be transferred to other hospitals due to lack of the required know-how. These strategic goals are strongly related to the main objectives of the health organization and are also closely linked to the financial perspective of the scorecard. For instance customer satisfaction is closely related to bed occupation and this fact contributes to enhanced revenues and improved facilities utilization. Therefore, all pillars of the scorecard are interlinked suggesting that focusing on one or two pillars and neglecting others will not contribute to the overall success of the organization.

Moreover, the internal processes pillar is focused on the employee satisfaction and resource utilization. In the service sector, employees are the key mechanism for achieving strategic goals and implementing performance measurement models, since they actually affect almost all pillars of the BSC [19, 20]. This pillar focuses on employees' absenteeism and satisfaction as the main drivers of services quality. Also includes performance indicators on bed occupancy as an indication of resources utilization. These two strategic goals are closely connected to the quality of the services and cost control of the organization. Finally, the last pillar is dedicated to the learning and growth. This pillar focuses on the continuous training and development of staff (administrative, nursing and medical) by allowing them to participate in seminars, conferences and educational programs. Also includes indicators on the introduction and investment in new technologies, treatments and innovations and collaborations with third parties. The success on the strategic goals of this pillar will contribute to the future sustainability of the organization.

A projection of the potential benefits of BSC implementation would be the control of expenses within budgetary constraints and an increase of revenues and at the same time achieve high levels of customer satisfaction from health services and improving internal operations. The most important outcome from this procedure is that the management of health organizations may gain significant insight on how their most important stakeholder (patients-customers) perceive the quality of services and infrastructure and even highlights areas for potential improvement. For instance, a customer satisfaction survey may be carried out for specific health services indicating the level of satisfaction rate. This outcome will point that the BSC method is a useful performance tool for health organizations and contributes towards success in various levels (financial, organizational and customer satisfaction).s

In addition, staff will improve its skills and abilities by participating in training seminars which will have a significant impact on both the quality of health services and improvement of the internal operations. In general, the implementation of the balanced scorecard on a health care organization may set the basis for an effective performance management of the industry which can enhance its future sustainability. This fact may corroborate arguments that in the services sector, employees are the key mechanism for success since they actually affect almost all pillars of the BSC [21, 22].

## 4 Concluding Remarks

Modern health organizations have been developed in multileveled organizations facing significant pressures from several stakeholders like the state, patients, etc. In addition, the establishment of a managerial performance system within public health organizations, (which could satisfy the needs of citizens and other state authorities), is even more important today in order to sustain an adequate level of service quality. Especially in Greece (and other states with significant financial problems), public health organizations operate within a volatile financial environment yielding more pressure on managers to balance financial outcomes while at the same time sustain and even improve the quality of health services within budgetary constraints. Consequently, public health organizations (and even private health organizations) need to advance their thinking and strategic planning from a plain administrative process towards a responsible performance-based management approach.

The scope of this study is to demonstrate the process of the development of the most popular performance management approach, the balanced scorecard, within a health service organization. Despite the fact that some of those goals and performance indicators are developed for the public health organizations, the same principles could be applied for private (for-profit) health organizations. Managers of private and public health organizations could use the propositions of the study as a roadmap for discussing, analyzing, evaluating and implementing the balanced scorecard approach in the organizations' day-to-day operations. Additionally, the specifics of the BSC development process could be proved useful for managers regarding the steps and actions that they should take in order to prepare and implement the scorecard. Moreover, the strategic goals and performance indicators presented in Table 1 can also be used as a guide for setting relative goals and metrics for health organizations that wish to implement the BSC method or any other performance management methodology.

The organization's staff is the most significant factor for the successful application of a performance-based management methodology and requires further training and devotion towards this goal. The main reasons for the unsuccessful implementation of the BSC are the lack of dedication on behalf of the senior management team and inadequate training of the staff. The present study can provide the motivation for managers to steadily incorporate the BSC method in those health care organizations that their budgets are mainly funded by the state. Good preparation, education and training are very important for the implementation of BSC but the key is dedication towards performance management philosophy. This methodology can definitely give an advantage on these organizations in terms of enhanced stakeholder management and preservation within a highly volatile and competitive economic environment [4].

## References


1. Rhodes, M.L., L. Biondi, R. Gomes, A.I. Melo, F. Ohemeng, G. Perez-Lopez, A. Rossi, and W. Sutiyono. 2012. Current State of Public Sector Performance Management in Seven Selected Countries. *International Journal of Productivity and Performance Management* 61 (3): 235–271.
2. Anderson, R., and H. Klaassen. 2012. The Fallacy of the Content: An Empirical Study of the Influence of the Context on the Use of Performance Management in the Public Sector. *International Journal of Productivity and Performance Management* 61 (5): 483–501.
3. Ballantine, J., S. Brignall, and S. Modell. 1998. Performance Measurement and Management in Public Health Services: A Comparison of UK and Swedish Practice. *Management Accounting Research* 9: 71–94.
4. Grigoroudis, E., E. Orfanoudaki, and C. Zopounidis. 2012. Strategic Performance Measurement in a Healthcare Organization: A Multiple Criteria Approach Based on Balanced Scorecard. *Omega* 40: 104–119.
5. Kaplan, R., and D. Norton. 1992. The Balanced Scorecard: Measures That Drive Performance. *Harvard Business Review* 70: 71–79.
6. ———. 1996a. Using the Balanced Scorecard as a Strategic Management System. *Harvard Business Review* 74 (1): 75–85.
7. ———. 1996b. *Translating Strategy into Action: The Balanced Scorecard*. Boston, MA: Harvard Business School Press.
8. Bean, L., and B.D. Jarnagin. 2002. New Cost Priorities: Using a Balanced Scorecard in Financial Reports. *The Journal of Corporate Accounting and Finance* 13 (3): 55–62.
9. Jacobsen, C.B., and L.B. Andersen. 2014. Performance Management in the Public Sector: Does it Decrease or Increase Innovation and Performance? *International Journal of Public Administration* 37: 1011–1023.
10. Buick, F., D.A. Blackman, M.E. O'Donnell, J.L. O'Flynn, and D. West. 2015. Can Enhanced Performance Management Support Public Sector Change? *Journal of Organizational Change Management* 28 (2): 271–289.
11. Aidemark, L., and E.K. Funck. 2009. Measurement and Health Care Management. *Financial Accountability and Management* 25 (2): 253–276.
12. Gurd, B., and T. Gao. 2008. Lives in the Balance: An Analysis of the Balanced Scorecard (BSC) in Health Care Organizations. *International Journal of Productivity and Performance Management* 57 (1): 6–21.
13. Nakaima, A., S. Sridharan, and B. Gardner. 2013. Towards a Performance Measurement System for Health Equity in a Local Integration Network. *Evaluation and Program Planning* 36: 204–212.
14. Perera, S., G. Harrison, and M. Poole. 1997. Customer-Focused Manufacturing Strategy and the Use of Operations-Based Non-Financial Performance Measures: A Research Note. *Accounting, Organizations and Society* 22 (6): 557–572.
15. Micheli, P., and M. Kennerley. 2005. Performance Measurement Frameworks in Public and Non-Profit Sectors. *Production Planning and Control* 16 (2): 125–134.
16. Adams, C., A. Neely, and P. Crowe. 2001. Performance Prism in Practice. *Measuring Business Excellence* 5 (2): 6–13.
17. Fälthlom, Y., and K. Nilsson. 2010. Business Process Re-Engineering and Balanced Scorecard in Swedish Public Sector Organizations: Solutions for Problems or Problems for Solutions? *International Journal of Public Administration* 33: 302–310.
18. Srimai, S., C.S. Wright, and J. Radford. 2013. A Speculation of the Presence of Overlap and Niches in Organizational Performance Management Systems. *International Journal of Productivity and Performance Management* 62 (4): 364–386.
19. Ittner, C.D., and D.F. Larcker. 2003. Coming up Short on Non-Financial Performance Measurement. *Harvard Business Review* 81 (11): 88–95.

20. Lau, C.M., and M. Solihin. 2005. Financial and Non-Financial Performance Measures: How do They Affect Job Satisfaction? *British Accounting Review* 37 (4): 389–413.
21. Niven, P.R. 2005. *Balanced Scorecard Diagnostics: Maintaining Maximum Performance*. Hoboken, NJ: John Wiley and Sons.
22. ———. 2006. *Balanced Scorecard Step-by-step for Government and Nonprofit Agencies*. 2nd ed. Hoboken, NJ: John Wiley and Sons.

# Musculoskeletal Problems Among Greek Perioperative Nurses in Regional Hospitals in Southern Peloponnese

## Musculoskeletal Problems in Perioperative Nurses

**Helen Bakola, Sofia Zyga, Apostolos Stergioulas, George Kipreos, and George Panoutsopoulos**

**Abstract** The surgery unit is a particularly labor-intensive environment in the hospital. Studies reflect the correlation of labor risk factors for musculoskeletal injuries among nurses but few have investigated the relationship to perioperative nurses. The purpose of this study is the identification and definition of ergonomic risk factors in the operating room and their connection with musculoskeletal disorders in perioperative nurses in regional hospitals in Greece. Forty four Greek perioperative nurses working in regional hospitals in southern Peloponnese participated. Anonymous self-administered questionnaire was used to collect the data, which consisted of three parts (investigating musculoskeletal symptoms, description of work, psychometric evaluation). The analysis was done with the statistical program SPSS.19. Symptoms of musculoskeletal problems emerged. Specifically, 54.4% in the lumbar, 47.7% in the neck, 45.5% in the shoulder, followed by smaller percentages of the hip, knee, elbow and ankle. 6.8% of participants indicated no musculoskeletal symptoms in the last year while 74.9% of those who had symptoms presented them in two or more areas. Activities rated as a major problem among others were the manual handling, tools with weight and vibration etc. 100% of respondents agreed that the work in the surgery unit is demanding and has anxiety. The lack of support from the government (81.8%), combined with the low perioperative nurses (6.8%) having the opportunity to participate in administrative decisions concerning them were related to problems in the organization and management of work. Apart from engineers target factors, a main aim should be the organization of work within the framework of a national policy based on European directives on the protection and promotion of the health and safety of workers.

H. Bakola (✉) • S. Zyga • G. Panoutsopoulos
Department of Nursing, Faculty of Human Movement and Quality of Life Sciences, University of Peloponnese, Sparta, Greece
e-mail: bakolaelena@hotmail.com

A. Stergioulas • G. Kipreos
Department of Sports, Organization and Management, University of Peloponnese, Tripoli, Greece



P. Vlamos (eds.), *GeNeDis 2016*, Advances in Experimental Medicine and Biology 989, DOI 10.1007/978-3-319-57348-9_3

**Keywords** Musculoskeletal problems • Perioperative nurses • Hospital • Southern Peloponnese • Symptoms • Disorders

## 1 Introduction

Studies conducted by the European Agency for Safety and Health at Work (OSHA) highlight musculoskeletal disorders (MSDs) as the most common health problem associated with the work in Europe [1, 2]. Risk factors related to musculoskeletal disorders at work is the lack of time [3], lack of influence or control over the job, the vibration [4], temperature [4, 5], the repetitiveness and pace of work, the manual handling of loads [6–8], such as lifting, pushing, pulling [9], the awkward postures and repetitive movements [6, 10], the lack of or poor communication, the monotonous tasks and low support of the administration [10]. Prolonged standing [4, 11–13] leads to back pain, venous blood concentration in the legs, pain, swelling and fatigue [14].

Musculoskeletal injuries affect a large proportion of workers in hospitals [4, 15, 16]. Schall et al. [17] reviewed 36 nurses with no previous history of MSDs assessing physical activity at work by using four sensors in an effort to investigate the relationship of physical risk factors in the workplace with MSDs. A high prevalence of musculoskeletal disorders among nurses internationally has been reported with back pain as the most common symptom [18–22]. In Greece, in a sample of 212 nurses and assistant nurses of the Social Insurance Institution, 33.5% of the respondents reported having MSDs in the spine, particularly in loin, attributed to the working conditions, while 78.8% felt pain during labor or afterwards [21]. In a similar study, 85% of nurses working in public general hospitals showed musculoskeletal disorders during the last 6 months at the lumbar spine (62.73), and the knee joints were found as the second frequency point of MSDs (40.75%) [20].

In China, 77.9% of nurses reported back pain [18] while in Turkey among intensive care nurses, the number stands at 81.31% [19]. The Koreans nurses report a high rate of musculoskeletal disorders (93.6%), in any area of their body [22]. A similar survey conducted in 15 hospitals in Italy found that 71% of healthcare workers reported at least one musculoskeletal disorder related to work [23]. Because of musculoskeletal pain experienced in neck, shoulder and back, a percentage of nurses referred they were changing jobs [8].

The prevalence of musculoskeletal disorders (MSDs) presents an increasing trend worldwide [24]. There is a relationship between type of work and specific activities predisposing risk for developing MSDs, while the risk is higher in developing countries than in developed [25]. Between healthcare providers and especially the nurses, the prevalence of musculoskeletal disorders has been studied in the literature. In recent years, some safe lifting rules [26, 27] and prevention of musculoskeletal problems [28–30] were developed but in Greece special emphasis has been given on ergonomic organization of work in the operating room in order to reduce the movements of flexion, rotation and overweight [31]. Efforts were made

by the Greek Institute of Hygiene and labor safety [32] as well as the Association of Operating Room Nurses [33], but despite legislation [34], it is remarkable that in the regional hospitals no organized services for Occupational Health had surveyed.

Among perioperative nurses (PN) and the association of labor risk factors for MSDs, few studies have been conducted internationally [4] and in accordance with the above, the investigation of them in Greek hospitals is of great importance for the protection of health, the record frequency of occurrence and [35] of occupational accidents involving them in order to determine the protective measures to be taken.

The purpose of this study is the identification and definition of ergonomic risk factors in the operating room and their connection with musculoskeletal disorders among perioperative nurses in regional hospitals in Greece. An attempt takes place to determine the size and characteristics of musculoskeletal complaints of perioperative nurses, the frequency and results of their work-related to musculoskeletal disorders due to prolonged standing, lifting, pushing and painful positions.

## 2 Materials and Methods

In the current study, 44 perioperative nurses (9 men and 35 women) took part in with a mean age of 42.7 years (SD $\pm$ 5.5 years). Regional hospitals of the Southern Peloponnese participated having three operating rooms. The response rate was about 98%, and all participants gave written consent. A self-administered questionnaire was given to participants consisted of three parts (a) musculoskeletal symptoms in nine areas of the body (neck, shoulders, upper back, elbow, wrist, low back, hip, knee and ankle) (b) job description and activities on the work that contribute to pain/injury and (c) classified/rated broad categories of factors. Finally, they received and evaluated information with a psychometric questionnaire regarding the organization and job satisfaction among perioperative nurses.

This is a prospective study (descriptive and correlation) conducted from October 2014 to November 2015. In order to conduct this study, extensive literature review took place searching for relevant articles in Greek and English language.

### *2.1 Data Collection*

For data collection an anonymous self-administered questionnaire was used consisting of three parts, revised by Sheikhzadeh et al. [4]. Permission for the use of this questionnaire was obtained and it was translated from the source language (English) to the target language (Greek). Then it was given to be completed by ten surgical nurses in order to identify its relevance to the perioperative nurses and Greek surgical units. Specifically, they were requested to write down their comments

regarding the content and the relevance of the questionnaire in the Greek reality. The questionnaire was found quite satisfactory, based on the feedback of perioperative nurses in the clarity of the questions/instructions, form and their response to the Greek interface.

Initially perioperative nurses were asked to identify their own musculoskeletal symptoms in nine areas of the body (neck, shoulders, upper back, elbow, wrist, low back, hip, knee and ankle) and to make their labor agents who believe that contribute to them. Questions concerning the job description were also included, taking information about jobs and carrying out activities in various poses to assess occupational risk factors. Four main representative categories that can contribute to musculoskeletal disorders and work-related factors (environment, tools and instruments, personal preferences, policies and procedures) were categorized and ranked by perioperative nurses' analogues with gravity. Finally, a psychometric questionnaire was used including questions about the organization and job satisfaction among perioperative nurses.

## *2.2 Data Analysis*

The mean values (mean), standard deviations (Standard Deviation = SD), the median (median) and interquartile ranges (interquartile range) were used for the description of the quantitative variables. Absolute (N) and the relative (%) frequencies used for the description of qualitative variables. The index Cronbach's a was used for checking the reliability of psychometric evaluation questionnaire. The psychometric assessment questionnaire has four dimensions in which the Cronbach's a reliability index was high and above the acceptable limit of 0.7. For the full questionnaire the Cronbach's a coefficient was equal to 0.75. For analysis SPSS 19.0 statistical program was used.

## *2.3 Ethical Considerations*

Before conducting the study, permission from the Scientific and Administrative Council in each hospital was requested and obtained. In the form of application, the names of researchers who would take part in the survey, the purpose and form of the study and how the output data will be used were mentioned ensuring the anonymity of participants and the confidentiality of results. This study followed all the fundamental principles of research. Specifically, all the information about the participants was completely anonymous and confidential. Commitment given that the information and the extracted data will be used solely for the purposes of this study, and hospitals will not bear the financial burden.

# 3 Results

## 3.1 Participant's Characteristics

A total of 47 questionnaires were distributed of which 44 were completed giving a response rate of approximately 94%. The sample consists of 44 perioperative nurses (9 men and 35 women) in the majority right-handed 95.5%, with a mean age of 42.7 years (SD ± 5.5 years). The characteristics of the sample are presented in Table 1.

In this study, an educational program relative to the subject of work has attended 50% but only 14% said that their education was enough to prepare them for their work.

## 3.2 Levels of Difficulty Associated with Activities at Work

The difficulty levels which relate to activities at work of perioperative nursing are presented in Table 2.

Employees rated difficulty from 0 to 10, and further the degree of difficulty was categorized into moderate problem (score of 2–7) and a big problem (8–10). The percentages indicate major problem presented in Fig. 1. What often reported problems with "To work in the same position for long periods (standing, crouching, sitting, kneeling)", "Be still working when hurt" "to carry, to lift or move heavy materials, tools or equipment," "to work in odd/awkward position" and to use tools (weight, vibration).

## 3.3 Musculoskeletal Symptoms

The proportion of workers with musculoskeletal symptoms in nine areas of the body is shown in Table 3.

The workers percentages reported having musculoskeletal problems in the last 12 months (Fig. 2) was 54.5% for lumbar spine, 47.7% for neck, 45.5–31.8% and shoulder to wrist. No musculoskeletal symptoms experienced in the last year 6.8%, while the last week 29.5%. Even a musculoskeletal symptom for the last year showed 93.2 and 74.9% of respondents had symptoms in two or more regions of their body.

**Table 1** Descriptive characteristics of the sample

| | N(%) |
|---|---|
| Sex | |
| Men | 9 (20.5) |
| Women | 35 (79.5) |
| Age, mean (SD) | 42.7 (5.5) |
| BMI, mean (SD) | 24.7 (4.3) |
| BMI | |
| Normal | 20 (48.8) |
| Overweight | 16 (39) |
| Obese | 5 (12.2) |
| Exercise at your personal time? | |
| No | 20 (45.5) |
| Yes | 24 (54.5) |
| If yes how many times a week, mean (SD) | 3.3 (1) |
| Hand | |
| Right handed | 42 (95.5) |
| Left handed | 2 (4.5) |
| Currently working as scrub nurse | |
| No | 13 (29.5) |
| Yes | 31 (70.5) |
| How many years working as scrub nurse median (int. Range) | 10 (1–20) |
| Currently working as a circulation nurse | |
| No | 17 (41.5) |
| Yes | 24 (58.5) |
| How many years working as a circulation nurse, median (int. Range) | 8 (0–20) |
| Currently working as Other operating room staff | |
| No | 29 (65.9) |
| Yes | 15 (34.1) |
| How many years working as Other operating room staff, median (int. Range) | 0 (0–3) |
| On average, how many hours of work per day, median (int. Range) | 8 (8–8) |
| Have you attended a training program on the subject of your work? | |
| No | 22 (50) |
| Yes | 22 (50) |
| If yes how many days educate, median (int. Range) | 4.5 (1–30) |
| Was your education enough to prepare us for your work? | |
| No | 37 (86) |
| Yes | 6 (14) |

**Table 2** Levels of difficulty associated with activities at work

| | Average (0–10)* | SD | No problem (0–1) N (%) | Small to moderate problem (2–7) N (%) | Big problem (8–10) N (%) |
|---|---|---|---|---|---|
| 1. Performing the same movement over and over again | 5.7 | 3.0 | 8 (18.2) | 21 (47.7) | 15 (34.1) |
| 2. To run a task very quickly for short periods of time (pulling, lifting, pulling, pushing, etc.) | 6.6 | 2.4 | 2 (4.5) | 21 (47.7) | 21 (47.7) |
| 3. Handle or make small objects (screws, etc.) | 3.8 | 3.1 | 12 (27.3) | 23 (52.3) | 9 (20.5) |
| 4. Make enough breaks during your work day | 6.5 | 3.6 | 7 (15.9) | 12 (27.3) | 25 (56.8) |
| 5. Work in odd/awkward position | 8.1 | 3.1 | 2 (4.7) | 10 (23.3) | 31 (72.1) |
| 6. Work in the same position for long periods (standing, crouching, sitting, kneeling, etc.) | 8.5 | 1.7 | 0 (0) | 6 (13.6) | 38 (86.4) |
| 7. To bend or rotate your waist in strange ways | 7.6 | 2.0 | 0 (0) | 21 (47.7) | 23 (52.3) |
| 8. Work near your physical limits (for example when you breathless and your heart beats faster) | 7.4 | 2.4 | 1 (2.3) | 19 (43.2) | 24 (54.5) |
| 9. Work at a height above the head and away from your body | 7.3 | 2.4 | 1 (2.3) | 21 (47.7) | 22 (50) |
| 10. Work in hot, cold, dry or wet (humid) conditions | 7.6 | 2.2 | 1 (2.3) | 17 (38.6) | 26 (59.1) |
| 11. To continue to work when it hurts | 8.7 | 1.7 | 0 (0) | 8 (18.2) | 36 (81.8) |
| 12. Carrying, lifting or moving house heavy materials, tools or equipment | 8.4 | 2.0 | 0 (0) | 9 (20.5) | 35 (79.5) |
| 13. Working hours (overtime, cyclical time) | 7.9 | 2.3 | 1 (2.3) | 12 (27.3) | 31 (70.5) |
| 14. Use tools (weight, vibration, etc.) | 7.5 | 2.4 | 2 (4.5) | 12 (27.3) | 30 (68.2) |

**Note*: rating activity 0 = not at all difficult to 10 = extremely difficult

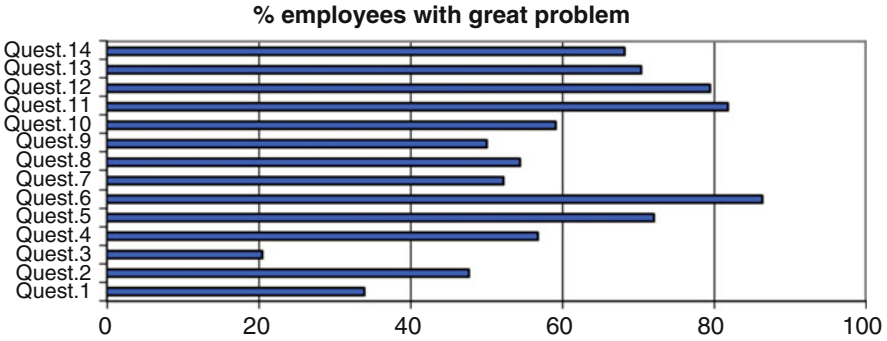


**Fig. 1** Percentage of workers who said they have a big problem with various activities at work

**Table 3** Percentage of workers with musculoskeletal symptoms

| | During the last 7 days did you feel pain or discomfort | During the past 12 months have you had any pain or discomfort | During the last 12 months are absent from work due to this situation | During the past 12 months visited a doctor, chiropractor or orthopedist because of this situation |
|---|---|---|---|---|
| | N (%) | N (%) | N (%) | N (%) |
| Neck | 13 (29.5) | 21 (47.7) | 2 (4.5) | 11 (25) |
| Shoulder blade | 14 (31.8) | 20 (45.5) | 0 (0) | 6 (13.6) |
| Upper back | 6 (13.6) | 11 (25) | 0 (0) | 0 (0) |
| Elbow | 5 (11.4) | 10 (22.7) | 0 (0) | 5 (11.4) |
| Wrist | 7 (15.9) | 14 (31.8) | 1 (2.3) | 6 (13.6) |
| Low back | 15 (34.1) | 24 (54.5) | 4 (9.1) | 6 (13.6) |
| Hip/thigh | 7 (15.9) | 12 (27.3) | 0 (0) | 3 (6.8) |
| Knee | 5 (11.4) | 11 (25) | 0 (0) | 4 (9.1) |
| Ankle | 1 (2.3) | 3 (6.8) | 0 (0) | 0 (0) |

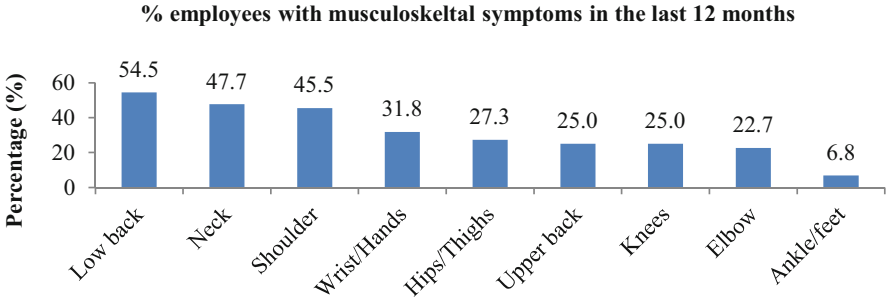


**Fig. 2** Percentage of workers who said they have musculoskeletal problems in the last 12 months in descending order

### 3.4 Duties at Work-Related Musculoskeletal Disorders

Table 4 shows the responses of preoperative nurses about when carrying out different tasks in the workplace. 34.1% said that more than 50% of working time bend the body slightly forward, with hands above the knee or push/pull loads (carts, drawers, tables).

Also, 20.5% said that more than 50% of working time turning the body (more than 45) and curving sideways or carry items weighing 4.5–13.5 kg.

The classification and rating four representative categories that can contribute to the work-related to musculoskeletal disorders is presented in Table 5.

In ranking and rating Environment and Personal preferences received the lowest ratings which means receiving the highest importance, while the tools and instruments as well as the policies and procedures of surgery received higher scores which means receiving the lower gravity.

**Table 4** Responses of employees on time performing various tasks in the workplace

| | >50% | About 50% | <50% | When |
|---|---|---|---|---|
| | N (%) | N (%) | N (%) | N (%) |
| Bending the torso slightly forward, with hands above the knee | 15 (34.1) | 13 (29.5) | 16 (36.4) | 0 (0.0) |
| Bending the torso forward slightly, hands below the knee | 2 (4.5) | 5 (11.4) | 23 (52.3) | 14 (31.8) |
| Turning the body (more than 45) and curving sideways | 9 (20.5) | 12 (27.3) | 23 (52.3) | 0 (0.0) |
| Holding large and bulky objects along hand | 5 (11.4) | 8 (18.2) | 24 (54.5) | 7 (15.9) |
| Transporting loads with one hand | 7 (15.9) | 6 (13.6) | 26 (59.1) | 5 (11.4) |
| Holding objects that are difficult to catch-unstable without handles | 2 (4.5) | 6 (13.6) | 29 (65.9) | 7 (15.9) |
| Pushing/pulling loads (carts, drawers, tables) | 15 (34.1) | 8 (18.2) | 21 (47.7) | 0 (0.0) |
| Transporting items weighing 4.5–13.5 kg | 9 (20.5) | 12 (27.3) | 22 (50.0) | 1 (2.3) |
| Transporting items weighing over 13.5 kg | 5 (11.4) | 4 (9.1) | 27 (61.4) | 8 (18.2) |
| Sit | 2 (4.5) | 1 (2.3) | 32 (72.7) | 9 (20.5) |
| Kneeling or squatting to do | 0 (0.0) | 0 (0.0) | 17 (38.6) | 27 (61.4) |
| Doing work on slippery or uneven surfaces | 2 (4.5) | 3 (6.8) | 21 (47.7) | 18 (40.9) |
| By working on overhead surfaces | 4 (9.1) | 2 (4.5) | 19 (43.2) | 19 (43.2) |

**Table 5** Ranking and rating four representative categories that can contribute to the work-related musculoskeletal disorders

| | Classification | | Score | |
|---|---|---|---|---|
| | Average (SD) | Median (Int. Range) | Average (SD) | Median (Int. Range) |
| **Environment** | 2 (1) | 2 (1–2) | 1.8 (1) | 1 (1–2) |
| Temperature | 1.9 (0.9) | 2 (1–3) | | |
| Fitting surgery | 2.2 (1) | 2 (1–3) | | |
| Teamwork | 2.1 (1) | 2 (1–3) | | |
| Administrative delay | 3.5 (0.9) | 4 (3–4) | | |
| **Personal preferences** | 2.1 (1.1) | 2 (1–3) | 1.8 (0.8) | 2 (1–2) |
| Sitting/standing | 1.5 (0.8) | 1 (1–2) | | |
| Layout and size of the operating room | 2.2 (0.8) | 2 (1.5–3) | | |
| Team members | 2.1 (0.8) | 2 (2–3) | | |
| **Tools and instruments** | 2.5 (1.1) | 3 (1.5–3) | 2.3 (1) | 2 (1–3) |
| The shape and size of the handle | 2.1 (0.8) | 2 (2–2) | | |
| Requirements for application of force | 1.4 (0.5) | 1 (1–2) | | |
| **Policies and surgical procedures** | 2.8 (1.2) | 3 (2–4) | 2.4 (1.2) | 2 (1–4) |
| Position of patient | 2 (1) | 2 (1–3) | | |
| Sitting/standing | 1.9 (0.9) | 2 (1–3) | | |
| Table height | 2.2 (0.9) | 2 (2–3) | | |

*Note*: For classification: 1 = Highest to 4 = Lowest (ranked each category from the highest to the lowest, depending on the severity) for the rating: 1 = Highest to 4 = Lowest (one or more charges could be the same score)

About setting the temperature, surgery Fitting and Teamwork received a similar score in the ranking and the Administrative delay was seen as less important. About the User preferences Sitting/standing was considered the most important. Regarding Tools and within the requirements in force application was considered as the most important, with respect to policies and procedures in surgery Sitting/standing and Patient Positioning considered as the most important.

### 3.5 Psychometric Evaluation

Table 6 shows the responses of workers in the psychometric evaluation questionnaire questions. The psychometric assessment questionnaire has four dimensions. The dimension Status of neurocognitive assessment questionnaire was found to have an average value of 2.99 (SD ± 0.51), the Administrative dimension had an average value of 2.04 (SD ± 0.40), the Pay dimension averaged equal to 1.84 (SD ± 0.32) and the Interaction dimension had an average value of 2.65 (SD ± 0.46).

Within the dimension of "interaction" 79.5% responded with positive sign in "There is good cooperation and teamwork among nurses in our department," and 97.7% agree that "The teamwork in the operating room contribute to effective delivery of necessary services," while 72.7% disagree with "there is a 'clear hierarchy' on my part. The staff rarely engages lower hierarchical levels."

In the "management" dimension 100% of all respondents were in line with the statement "The job of the surgery is demanding, complex and has anxiety." Respondents were split but the statement "The heads of nursing services generally take into account the personal view of everyday problems and procedures" where 52.3% agreed with the 47.7 state that disagrees.

## 4 Discussion

This evaluation study of the MSD-related work, and the associated risk factors among the perioperative nurses. The study found several important factors associated with MSDs among perioperative nurses which categorized and graduated. The main categories were environment, personal preferences, tools and instruments and policies and procedures. The prevalence of MSDs recorded in this study can hardly be compared directly with those found in most studies of health professionals due to its focus on the perioperative nurses and special operating room environment in which they work.

However the results are broadly in line with similar studies of the entire nursing staff, both in itself and in other European countries [3, 4, 6–14, 16, 18–22].

They emerged symptoms of musculoskeletal problems last 12 months 54.4% in the region of the lumbar spine, neck 47.7%, 45.5% in the shoulder, wrist 31.8%, 27.3% at the hip, followed by a smaller percentage knee, elbow and ankle.

Musculoskeletal problems in the area of the lumbar occupy the first position in most studies [1–4, 8, 10, 20, 21, 24] with the highest rate, followed by the shoulder and back.

In agreement comes to the study of Sheikhzadeh et al. [4] conducted in surgery American nurses and technicians in recording musculoskeletal symptoms in the last 12 months on the knee 24% and 25% respectively, while in the operating rooms of Saudi Arabia in 48.41% of workers complained about back pain [36].

**Table 6** Responses of workers to the psychometric evaluation questionnaire questions

| | Disagree/Strongly disagree | | Agree/Strongly agree | |
|---|---|---|---|---|
| | N | % | N | % |
| When working at the hospital, the time passes quickly | 12 | 27.3 | 32 | 72.7 |
| Often bored because my work is monotonous | 34 | 77.3 | 10 | 22.7 |
| There is a large gap between the hospital administration and the everyday problems of nursing services | 8 | 18.2 | 36 | 81.8 |
| Given its output medics, the fee we receive is proportional | 43 | 97.7 | 1 | 2.3 |
| It makes me proud/or talking to other people about what I do in my work | 8 | 18.2 | 36 | 81.8 |
| There is no doubt in my mind that what I do in my work is very important | 1 | 2.3 | 43 | 97.7 |
| I have several opportunities to take administrative decisions for planning and political processes to follow my department | 30 | 68.2 | 14 | 31.8 |
| An increase in fees for the nursing staff required at this hospital | 0 | 0.0 | 44 | 100.0 |
| New employees of the department not feel "like home" | 18 | 40.9 | 26 | 59.1 |
| There are many opportunities for nurses to participate in administrative decisions | 41 | 93.2 | 3 | 6.8 |
| There are many opportunities for the promotion and development of the nursing staff at the hospital | 39 | 88.6 | 5 | 11.4 |
| The rate of increase of the salaries of nurses/three is not satisfactory today | 2 | 4.5 | 42 | 95.5 |
| What I do in my work adds something important | 35 | 79.5 | 9 | 20.5 |
| The nursing staff at the hospital creates many quarrels and conflicts | 20 | 45.5 | 24 | 54.5 |
| Given the high cost of hospital care should be every effort to keep the salaries of nursing staff there that is about, or at least not increase significantly | 40 | 90.9 | 4 | 9.1 |
| Excluding myself, I have the impression that many nurses/behavior shows in this hospital are dissatisfied with their pay | 10 | 22.7 | 34 | 77.3 |
| There is good teamwork and collaboration between nurses/three in our department | 9 | 20.5 | 35 | 79.5 |
| There is no doubt that the administrative staff of the hospital care of its employees, including nurses/three | 40 | 90.9 | 4 | 9.1 |
| The nurses in my department does not hesitate to gather and help one another when the going gets tough | 7 | 15.9 | 37 | 84.1 |
| The heads of nursing services generally take into account the personal view of everyday problems and processes | 23 | 52.3 | 21 | 47.7 |
| The nurses in my department does not often act as "one big happy family" | 27 | 61.4 | 17 | 38.6 |

(continued)

**Table 6** (continued)

| | Disagree/Strongly disagree | | Agree/Strongly agree | |
|---|---|---|---|---|
| | N | % | N | % |
| There is a "clear hierarchy" on my part. The staff rarely engages lower hierarchical levels | 32 | 72.7 | 12 | 27.3 |
| The nurses in my department are not as friendly and familiar as I would like | 32 | 72.7 | 12 | 27.3 |
| Even if I could make more money working/or in another hospital nursing position, I feel more satisfied/I am here because of working conditions | 22 | 50.0 | 22 | 50.0 |
| My current salary is sufficient | 37 | 84.1 | 7 | 15.9 |
| If I had to decide again, I would choose the same kind of work satisfactory | 18 | 40.9 | 26 | 59.1 |
| From what I hear from nurses/only three other hospitals, we are paid well | 40 | 90.9 | 4 | 9.1 |
| The work in the operating room environment is demanding, complex and has anxiety | 0 | 0.0 | 44 | 100.0 |
| There is sufficient information in the decision-making result being more waiting periods | 7 | 15.9 | 37 | 84.1 |
| The atmosphere of the operating room is the appropriate | 26 | 59.1 | 18 | 40.9 |
| There are several challenges and opportunities to grow your business | 27 | 61.4 | 17 | 38.6 |
| The new ideas are not sufficiently supported | 11 | 25.0 | 33 | 75.0 |
| The natural conditions in the operating room as the temperature, lights, sound, etc. are suitable | 31 | 70.5 | 13 | 29.5 |
| Always too cold in operating room | 24 | 54.5 | 20 | 45.5 |
| He has a lot of noise in the operating room | 17 | 38.6 | 27 | 61.4 |
| There are too many people in the operating room | 16 | 36.4 | 28 | 63.6 |
| There is a constant flow of people in and out of the operating room | 9 | 20.5 | 35 | 79.5 |
| Teamwork in the operating room contribute to the efficient delivery of the services required | 1 | 2.3 | 43 | 97.7 |
| There are conflicts and poor conflict management in the operating room | 12 | 27.3 | 32 | 72.7 |
| After the surgical team members surgery, including surgeon, thank each other for help in team | 27 | 61.4 | 17 | 38.6 |
| Listening to a simple "thank you" by the surgeon after the successful surgery, make you feel full member of the group of operating room | 8 | 18.2 | 36 | 81.8 |
| There is a fair distribution of work and compliance with the rules | 30 | 68.2 | 14 | 31.8 |

The high benchmark MSDs in the neck (47.7%) of the perioperative nurses, could be explained, among other things, with the rating and ranking of environmental factors considered by participants particularly aggravating, research, ranking the temperature as the most important with mean (SD) 1.9 (0.9), arguing that very often the air conditioning was not working optimally blowing cold air onto them in conjunction with the wrong mounting the operating table below the airflow.

The operating theaters require special ventilation system for the type of air, the amount and the way it enters and circulates so as to prevent contamination of the operated patients. The air in the operating room must be filtered enters from the ceiling and its output be low near the floor [37].

For this population, the study found that the dimension of the administration 100% of respondents were in agreement with the statement "The job of the surgery is demanding, complex and has anxiety." The pressure and stress of work to keep the surgery times, in a constantly changing environment, pushes perioperative nurses to work faster and thus increase the mechanical load on the musculoskeletal system.

The large staff shortages intensify as a result of the economic crisis recruitment for a long time, not replacing health professionals have frozen retiring.

Confirms the incrimination of organizational factors such as the lack of support from the administration [5, 38], with 81.8% saying "a large gap between the hospital administration and the everyday problems of nursing services," thus reflecting the weakness of administration to identify and take preventive and protective measures for the PM. Obstacle is the minimal opportunity (6.8%) contribution of perioperative nurses in administrative decisions concerning them.

Most occupational factors may be modified by the organization of work interventions and prevention in the workplace as opposed to personal/medical [38, 39]. The increase in staffing and in-service training but could significantly reduce the risk of occurrence of PM in the operating room. Moreover, the existence of aids and equipment, improvement of environmental conditions and the ergonomic design of the site will have contributed significantly.

This study has strengths and limitations. The origin of the sample only from regional hospitals, with up to three operating rooms, rather than tertiary hospitals of the capital city, is one of the study's limitations. Moreover, the population studied did not include a significant proportion of men operating room nurses. The relatively large sample size for this particular subgroup of nurses with a response rate of 98% across the Southern Peloponnese is a strong point of the study. The results were in agreement with the respective study performed with a smaller number of participants to surgery of USA [4]. However, further inquiries are recommended in the Western world as well as between primary, secondary and tertiary hospitals.

## 5 Conclusion

In conclusion, the study showed the multi factorial origin of MSDs and highlighted a number of factors related to work. The study confirms that in addition to the reduction in engineering report, the organization of work should be an important

target for the development of strategies for the prevention of musculoskeletal disorders in perioperative nurses. Required to implement a national policy based on European directives on the protection and promotion of the health and safety of workers.

**Conflicts of Interest and Source of Funding** The authors declare no conflict of interest. This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

**Acknowledgements** The authors would like to thank the nurses for their participation in the study and acknowledge the support given by the health professionals and the administration personnel of the hospitals.

## References

1. OSHA. 2007a. *Factsheet 75. Work-Related Musculoskeletal Disorders: Back to Work*. European Agency for Safety and Health at Work.
2. OSHA. 2007b. *Factsheet 78. Work-Related Musculoskeletal Disorders: Prevention Report*. European Agency for Safety and Health at Work.
3. Caruso, C.C., and T.R. Waters. 2008. A Review of Work Schedule Issues and Musculoskeletal Disorders with an Emphasis on the Healthcare Sector. *Industrial Health* 46: 523–534.
4. Sheikhzadeh, A., C. Gore, D.J. Zuckerman, et al. 2009. Perioperating Nurses and Technicians' Perceptions of Ergonomic Risk Factors in the Surgical Environment. *Applied Ergonomics* 40: 833–839.
5. Werner, R.A. 2006. Evaluation of Work-Related Carpal Tunnel Syndrome. *Journal of Occupational Rehabilitation* 16 (2): 207–222.
6. National Institute for Occupational Safety and Health (NIOSH), Department of Health and Human Services PHS, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health. 1997. *Musculoskeletal Disorders and Workplace Factors: A Critical Review of Epidemiologic Evidence for Work-Related Musculoskeletal Disorders of the Neck, Upper Extremity, and Low Back* (DHHS [NIOSH] Publication No. 97-41). Washington, DC: US Department of Health and Human Services.
7. National Research Council (NRC), Institute of Medicine (IOM). 2001. *Musculoskeletal Disorders and the Workplace: Low Back and Upper Extremities*. Washington, DC: National Academy Press.
8. Trinkoff, A.M., J.A. Lipscomb, J. Geiger-Brown, et al. 2003. Perceived Physical Demands and Reported Musculoskeletal Problems in Registered Nurses. *American Journal of Preventive Medicine* 24 (3): 270–275.
9. Smedley, J., H. Inskip, F. Trevelyan, et al. 2003. Risk Factors for Incident Neck and Shoulder Pain in Hospital Nurses. *Occupational and Environmental Medicine* 60: 864–869.
10. Koukoulaki, T. 2014. The Impact of Lean Production on Musculoskeletal and Psychosocial Risks: An Examination of Sociotechnical Trends Over 20 Years. *Applied Ergonomics* 45: 198–212.
11. Dunn, K., and P. Goft. 2004. Epidemiology and Natural History of Low Back Pain. *Europa Medicophysica* 4: 9–13.
12. Kopec, J., E. Sayre, and J. Esdaile. 2004. Predictors of Back Pain in a General Population Cohort. *Spine* 29: 70–77.

13. Mitchell, T., P. O'Sullivan, A. Burnett, et al. 2008. Low Back Pain Characteristics to Working Nurse in Australia. *International Journal of Nursing Studies* 45 (2): 1636–1644.
14. Waters, T.R., and R.B. Dick. 2015. Evidence of Health Risks Associated with Prolonged Standing at Work and Intervention Effectiveness. *Rehabilitation Nursing* 40 (3): 148–165.
15. Fountouki, A., and D. Theofanidis. 2010. Health and Safety Risks in Nursing. *International Health Care* 2 (2): 64–72.
16. Herin, F., C. Paris, A. Levant, et al. 2011. Links Between Nurse's Organizational Work Environment and Upper Limb Musculoskeletal Symptoms: Independently of Effort-Reward Imbalance! The ORSOSA Study. *Pain* 152: 2006–2015.
17. Schall, M. Jr., B.N. Fethke, and H. Chen. 2016. Evaluation of Four Sensor Locations for Physical Activity Assessment. *Applied Ergonomics* 53: 103–109.
18. Chiou, W.K., M.K. Wong, and Y.H. Lee. 1994. Epidemiology of Low Back Pain in Chinese Nurses. *International Journal of Nursing Studies* 31: 361–368.
19. Karadag, A. 1994. *Evaluation of Ergonomic Conditions of Intensive Care Units by Nurses*. Ankara, AL: Hacettepe University Health Science Institute.
20. Mpitsios, A., A. Gioftsidou, P. Malliou, et al. 2014. Musculoskeletal Disorders and Charges in Nursing Staff Hell. *Journal of Nursing* 53 (2): 185–192.
21. Siamagka, E., A. Vassilopoulos, P. Sotiropoulos, et al. 2013. Investigation of the Education Level and Low Back Pain Appearance in Nurses and Assistants Primary Health Care Nurses Structures. *International Health Care* 5 (3): 102–108.
22. Smith, D., M.A. Choe, Y.R. Chae, et al. 2005. Epidemiology of Musculoskeletal Symptoms Among Korean Hospital Nurses. *International Journal of Occupational Safety and Ergonomics (JOSE)* 11 (4): 431–440.
23. Gerbaudo, L., and B. Violante. 2008. Relationship Between Musculoskeletal Disorders and Work-Related Awkward Postures Among a Group of Health Care Workers in a Hospital. *La Medicina del Lavoro* 99 (1): 29–39.
24. Punnett, L., and H.D. Wegman. 2004. Work-Related Musculoskeletal Disorders: The Epidemiologic Evidence and the Debate. *Journal of Electromyography and Kinesiology* 14 (1): 13–23.
25. Rajen, N.N. 2008. Occupational Use Syndromes. *Best Practice & Research Clinical Rheumatology* 22 (4): 677–691.
26. EU-OSHA. 2008a. E-Facts 44: Checklist for the Prevention of Manual Handling Risks. Available from: http://osha.europa.eu/en/publications/e-facts/efact44/view.
27. Health and Safety Executive, HSE. 2014. Manual Handling Assessment Charts (The Mac Tool). Available from: http://www.hse.gov.uk/msd/mac/.
28. EU-OSHA. 2007. E-Fact 72: Work-Related Neck and Upper Limp Disorders. Available from: http://osha.europa.eu/en/publications/factsheets/72/view.
29. EU-OSHA. 2008b. E-Fact 35: Risk Assessment for Care Workers. Available from: https://osha.europa.eu/en/publications/e-facts/efact35.
30. European Commission Occupational Health and Safety Risks in the Health Care Sector. 2010. Guide to Prevention and Good Practice. Available from: http://bookshop.europa.eu/en/occupational-health-and-safety-risks-in-the-healthcare-sector-pbKE3111047/?CatalogCategoryID=V_wKABstsBoAAAEjpJEY4e5L.
31. Linou, A. 2005. *Occupational Medicine. Epidemiology and Prevention*. Athens: Beta.
32. Greek Institute for Occupational Health and Safety (EL.IN.Y.AE.). 2014. Available from: http://www.elinyae.gr/el/index.jsp.
33. Association of Operating Room Nurses (SY.D.NO.CH.). 2014. Available from: http://www.sydnox.gr/.
34. Government Gazette. 1994. Presidential Decree PD 397/94 "Minimum safety and Health Requirements for the Manual Handling of Loads Where There is a Risk Particularly of Back Injury to Workers in Compliance with the Council 90/269/EEC." Gazette A 221/12.19.1994.
35. Velonakis, E., and P. Sourtzi. 2009. *Health and Work*. Athens: Beta.

36. Kerini, H.M. 2013. Prevelage and Risk Factors of Low Back Pain Among Nurses in Operating Rooms, Taif, Saudi Arabia. *American Journal of Research Communication* 1 (11): 45–70.
37. Karathanasi, K., P. Saraphis, M. Malliarou, et al. 2012. Investigation of Quality Criteria for Application in Surgery. *Perioperative Nursing Quarterly* 1 (2): 63–70.
38. Roquelaure, Y., C. Ha, N. Fouquet, et al. 2009. Attributable Risk of Carpal Tunnel Syndrome in the General Population: Implications for Intervention Programs in the Workplace. *Scandinavian Journal of Work Environment and Health* 35: 342–348.
39. Skov, T., V. Borg, and E. Orhede. 1996. Psychosocial and Physical Risk Factors for Musculoskeletal Disorders of the Neck, Shoulders, and Lower Back in Salespeople. *Occupational and Environmental Medicine* 53: 351–356.

# Exploring the Notion of Context in Medical Data

**Phivos Mylonas**

**Abstract** Scientific and technological knowledge and skills are becoming crucial for most data analysis activities. Two rather distinct, but at the same time collaborating, domains are the ones of computer science and medicine; the former offers significant aid towards a more efficient understanding of the latter's research trends. Still, the process of meaningfully analyzing and understanding medical information and data is a tedious one, bound to several challenges. One of them is the efficient utilization of contextual information in the process leading to optimized, context-aware data analysis results. Nowadays, researchers are provided with tools and opportunities to analytically study medical data, but at the same time significant and rather complex computational challenges are yet to be tackled, among others due to the humanistic nature and increased rate of new content and information production imposed by related hardware and applications. So, the ultimate goal of this position paper is to provide interested parties an overview of major contextual information types to be identified within the medical data processing framework.

**Keywords** Context • Metadata • Medical data analysis • Knowledge management

## 1 Introduction

Computer science and health care are two domains of great interest over the recent years. The two diverse—at first glance—disciplines have merged and researchers have been devising algorithms that search useful new patterns in data produced by medical equipment and used in medical trainings and exams. In this process it is rather true that researchers look for clinically useful correlations in the middle of huge piles of information. At the intersection of medicine and computer science, the notion of context plays a crucial role in disambiguating complex data and clarifying underlying trends. Still, the capacity of contextual information to take

P. Mylonas (✉)
Department of Informatics, Ionian University, Corfu, Greece
e-mail: fmylonas@ionio.gr



P. Vlamos (eds.), *GeNeDis 2016*, Advances in Experimental Medicine and Biology 989, DOI 10.1007/978-3-319-57348-9_4

multiple meanings is widely acknowledged, thus hindering the adoption of a single unyielding definition that covers its usage within most medical data processing efforts.

Under the broader scope of computer science, interest in contextual information is of great importance in relevant fields like artificial intelligence, information search and retrieval, as well as medical image and video analysis [1–3]. Still, effective use of available contextual information within such structures remains an open and challenging problem. After almost 50 years of informatics it is rather common knowledge that information does not occur in isolation. In particular, when dealing with human-produced or consumed information, a broader environment needs to be taken into consideration, namely the so-called *context* [4]. The notion of context is generally of great importance in the identification of the semantic meaning of data, thus by definition plays a crucial role in the medical domain. Within the latter, context is considered to be pivotal for correct diagnosis, accurate prognosis, and appropriate treatment.

In principle, contextual information may be considered as any information about the situation, circumstances and user state when a user is either producing or consuming digital content items [4, 5]. In this framework, medical data are fundamentally context-dependent, and cannot be properly interpreted outside of their specific contexts [5]. Therefore their analysis based on data mining techniques must incorporate contextual information in the process. In an early effort to identify the information needs in clinical settings, Forsythe et al. [6] conducted a related study. Still, the highly contextual nature of medical information is apparent in tasks like data mining of electronic patient records [7]. The vast amount of patients' data collected for screening, diagnosis and evaluation of treatment may and need to be viewed as resources to be exploited in related data mining tasks, as it contains valuable data and metadata. Aiming at extracting interesting information from large collections of data, data mining has been widely used as an effective decision making tool. Mining medical data datasets in the presence of context factors may improve performance and efficacy of data mining by identifying underlying unknown factors that are not easily detectable in the process of generating an expected outcome. Still, context itself appears in various forms and modifications and is not a single and uniform notion. Thus, researchers commonly emphasize distinctions between different types of context. In this paper we shall provide an overview on the definition of the basic aspects of context exploited within the medical data processing systems and applications.

The structure of the rest of this paper is as follows: in Sect. 2 we explain in more detail the motivation behind investigating context in the medical field. In Sect. 3 we provide a brief overview of an identifiable distinction of context in the medical domain, whereas Sect. 4 is devoted to context in medical data processing and related contextual approaches within the medical data analysis field. Section 5 deals with context-aware medical applications and Sect. 6 tackles briefly approaches from the electronic patient and health records domain. Section 7 discusses the utilization of context within intelligent hospital applications, whereas Sect. 8 concludes this work by briefly introducing our final comments on the topic.

## 2 The Motivating Perception of Context

A fundamental problem tackled via access to and processing of contextual information is the bridging of two fundamental gaps in the literature; the *semantic* and *sensory gap* [8]. The *semantic gap*, an issue inherent in most computerized applications, is described as the gap between high-level semantic descriptions humans ascribe to digital content like medical images and low-level features computers may automatically parse. The *sensory gap* is described as the gap between an object and the computer's ability to sense and describe this object. At this point computational systems may indeed be able to bridge both gaps under conditions, but only if incorporating contextual knowledge in the process. With the advent of all kind of new medical devices, applications and systems, new opportunities arise to infer the necessary related semantics, whereas contextual metadata are capable of playing the important role of the "semantic mediator". Information from low-level sources, such as sensors, acquired in mass quantities without any further interpretation, may be meaningless, trivial, vulnerable to small changes, or uncertain, after all [9]. As a side-effect, limitation of low-level contextual cues when modeling human interactions and behavior, risks reducing the usefulness of context-aware medical applications. On top of that and as observed early enough by Schilit et al. [10], context is considered to encompass a rich set of information, because other related things of interest are also changing at the same time or pace.

As an additional motivation to this work, it is rather common knowledge that context itself appears in various forms and modifications. Even semantically the term *context* does not have a unique definition resulting sometimes in ambiguous interpretations. The Merriam-Webster online dictionary[1] defines context as "the situation in which something happens: the group of conditions that exist where and when something happens" or "the interrelated conditions in which something exists or occurs". The Free On-line Dictionary of Computing[2] defines context as the thing that "surrounds and gives meaning to something else". Consequently, the term may be used under various different meanings. In a previous work [11] we have identified context as any information that might be used to specify the situation of an entity; the latter being a person, a place or an object that is relevant to the interaction between the user and the software system. In the medical framework this identification has to be adjusted accordingly, to tackle the nature of medical data that focus heavily on the temporal aspect of information (especially with respect to electronic medical records and biomedical information systems).

[1] http://www.merriam-webster.com/dictionary/context.

[2] http://foldoc.org/context.

## 3 A Distinction of Context in the Medical Domain

According to the so far discussion the type of knowledge required for medical data analysis is by definition thought to be context-sensitive. Consequently, to define and identify the appropriate type of context to be utilized in the process is a very important and complicated task. It is rather tempting to follow a breakdown approach whose initial task would be the definition of the suitable aspect of context at hand. As already introduced in our previous work in the multimedia domain [12], we may identify two relevant types of context in medical data analysis:

a. the *context of medical content analysis*, and
b. the *context of use*.

The first type, i.e., the *context of medical content analysis*, refers to the context exploited during preparatory medical content analysis tasks and aids the extraction of semantic metadata. These may take the form of plain low-level semantic concepts (such as the name of a patient), or composite ones (such as medical events like an ischemic stroke and/or high-level concepts like the patient herself/himself). The latter forms clearly a composite concept, since its instances are related to instances of basic nature, like name, age, or gender. In the particular framework of medical image analysis such interpretation maybe used to detect whether a picture or video sequence represents a tumor or not; an obviously crucial decision with respect to many applications.

When low-level visual features are employed to globally analyze medical multimedia content and classify it in one of a number of pre-defined categories, e.g., within a cancer staging system, we have the so-called "top-down" case of classification. Quite on the contrary, the "bottom-up" approach that focuses on local analysis to detect and recognize specific objects in limited regions of an image, without explicit knowledge of the surrounding context, e.g., recognize the presence of a growing tumor, characterizes the task of object detection/recognition. Classical attempts worth mentioning in the area include Saber et al. [13], where low-level color classification is utilized and Smith and Li [14] dealing with the context of content-based image retrieval. Still and as depicted in [15], utilizing context orientation information in generic object class detection algorithms should in principle be avoided, due to the fact that such contextual information is not always present especially in the case of medical images.

On the other hand, the *context of use* is focused on collecting and analyzing detailed information about a computational system's intended users, their tasks, as well as the technical and environmental constraints present. In the medical domain such data may be gathered using personalized interviews, site surveys, observational studies, etc. Its main goals are to ensure that all factors relating to the use of a medical application or system are identified before its design work starts and to provide a basis for future usability tests [16]. As a result all information about context of use is an essential input to the problem definition, goals, requirements,

conceptual and detailed design, as well as the planning of other usability methods to follow and is heavily exploited by search/retrieval and personalization applications [17].

## 4 Context in Medical Data Processing

In an effort to merge the two worlds of computer science and medicine a categorization of health-care related context-aware applications according to subjective criteria has been tried out almost a decade ago [3]. Among the first data-oriented approaches we may identify the context modeling survey of Bolchini et al. [18] or the classic work of Dojat and Pachet [19] defining an object-oriented context model in the medical domain. In this early pioneer work, authors described two types of contextual information, the so-called *situational* and *set-of-beliefs*. The situational context provided three aspects, namely the patient one (in terms of her/his patient's history, the type of patient's disorder and patient's response to treatment), the temporal one (in terms of the course of the patient's disorder), and the clinical one (in terms of specific clinical guidelines, expertise, and experience). The second context type provided a set of underlying assumptions made by the clinicians, e.g., excluding a specific disorder based on the absence of specific symptoms. Other early research efforts in the area include a fuzzy-based system to combine objective biomechanical data with subjective medical data [20].

In [5], authors focus on five contextual dimensions, namely goal orientation, interdependency of data, time sensitivity, source validity, and absent value semantics. They demonstrate context-dependent modeling based on examples of clinical data used for screening, diagnosis, and research of a serious respiratory disorder. Furthermore, they present a conceptual framework for representation of related contextual information. Transforming unstructured data into a readily accessible format enables many different uses for contextual information, whereas defining those use cases is critical to identifying appropriate text analytics tools [21]. In a recent study, Massey et al. [22] addressed the text analytics challenge of medical reports in a rule-based approach. Table 1 provides a detailed overview of the discussed context research efforts by categorizing them according to their task incorporated, illustrates their advantages and disadvantages and reasons on their suitability within the broader research field.

## 5 Context-Aware Medical Applications

As expected, the majority of computational health-care initiatives focus on the application domain. This remark coupled together with the fact that one of the major domains in which context currently receives growing attention is the one of mobile

**Table 1** Context in medical data processing

| Work | Task(s) | Description | Pros | Cons | Dataset |
|---|---|---|---|---|---|
| [3] | Context-aware categorization, trends | Survey, overview | Pioneer work | Outdated (2007) | – |
| [18] | Data-oriented context modeling, features | Data-oriented survey | Evaluation framework, comparison | Outdated (2007) | – |
| [19] | Medical context representation | Object-oriented context model | Pioneer study, definition of situational & set-of-beliefs context | Outdated (1995) | – |
| [20] | Contextual interpretation of biomechanical data | Fuzzy-based system | Real-life dataset, mathematical notation | Outdated (2006) | 96 fuzzy trees, 1330 rules |
| [5] | Medical context modeling | Five contextual dimensions, fuzzy approach | Conceptual context framework | Robustness of conceptual model | Several real-life datasets |
| [21] | Contextual organization of medical data | Text analytics and data management integration | Recent work (2015) | Lack of evaluation | – |
| [22] | Medical reports text analytics | Rule-based approach | Applied approach (utilizing commercial software), visualization | Evaluation size and comparison | Pathology reports |

computing, leads to interesting observations in the medical domain. But, first, let us understand the impact of aforementioned tasks and position context-aware medical applications in this framework. In principle, mobile computing involves two pylons, namely computing and mobility. In computer applications, and as depicted early enough in [23], context is acquired either explicitly by requiring the user to specify it, or implicitly by monitoring user and computer-based activity. In mobile computing on the other hand, application usage is set in different environments at different times, constituting changing contexts that lie outside the human-computer system in the environment. For acquisition of this kind of context there are two possible options:

a. to prepare a so-called "smart environment", which provides an infrastructure for obtaining context and for providing context to mobile applications.
b. to embed sensors in mobile devices to acquire context related to the physical environment.

The second option does not rely on the underlying infrastructure and is applicable to almost any type of environment. Still, a primary concern of context-awareness in mobile computing is awareness of the physical environment surrounding a user and their mobile device; early adopters go back to [24] by sensing locality of mobile users to adapt applications to people's whereabouts. In this framework only few early efforts considered context beyond location and among these are context-aware information capture and retrieval systems that use time in addition to location [25].

In principle, context awareness refers to the ability of systems to react based on their environment. Devices and computer systems may have information about the circumstances under which they are able to operate and based on rules, or an intelligent stimulus, react accordingly. A good overview of the issues in the context-awareness domain may be found in context-awareness computing surveys, like the ones conducted by Chen and Kotz [26] and Korkeaaho [27]; in addition, most of the general papers on context-awareness indicate health care as an important and promising field of research. Thus, several research and applied approaches attracted interest, such as the Vocera communication system [28], which forms a communicator badge system for mobile users. It is a wearable badge with a push-to-call button, a small text screen and versatile voice-dialing capabilities based on speech recognition, whereas it is biometrically secured with speaker verification and delivers information directly to the users. In a different approach, Munoz et al. [29], tackle the idea of empowering mobile devices to recognize the context in which hospital workers perform their tasks. In particular the authors propose an extension of instant messaging to add context awareness as part of the message. Contextual elements used include location, delivery timing, role reliance, artifacts, location and state.

A context-aware data mining framework is proposed in [30], by which contexts are automatically captured to maximize the adaptive capacity of data mining. In this process contextual information may consist of any circumstantial factors of the user and domain that may affect the data mining process. A platform for performing proper medical content adaptation based on context-awareness is also introduced in [31]. Proper coding and transmission of medical and physiological data is coupled together with sensors used to determine the status of a patient being monitored through a medical network. Additional contextual information regarding the patient's environment (e.g., location, data transmission device and underlying network conditions, etc.) are represented through an ontological knowledge base model. A similar model is followed in [32], where context is captured using an ontology formally modeling the concepts within the health-care domain, together with their relations and properties. More specifically, the authors introduce a self-learning, probabilistic, ontology-based framework, which allows context-aware applications to adapt their behavior at run-time. In [33] the authors present an image search system that allows search by a multitude of image features, metadata (demographics, patient's medical history, clinical data) and context in the form of an ontology towards efficient dementia diagnosis.

In search of applications and systems that would aid the improvement of people's quality of life, a new trend is the utilization of users' biological signals via wearable and even implantable wireless sensors that implement context-aware solutions, so

as to adapt to changes in the users' mood, mental states, biological signals and environment. A recent survey on the issue is proposed by [34] and presents an overview of context-aware solutions wrt body area networks. In a similar but more specific sense, Miao et al. [35] propose a wearable, low power context-aware ECG monitoring system integrated with built-in kinetic sensors utilizing a smartphones' processing capabilities, in order to recognize physical activity and automatically detect arrhythmias. Mitchell [36] describes the rapidly expanding capabilities of modern smartphones that enable the creation of new classes of health- and wellness-related applications by utilizing data collected from on-board sensors, web services, social media and external biosensors and combined contextual information in the sense of the context of the device, user, and environment.

On another approach, RecFit [37] takes into account contextual information and suggests physical activities to users based on the users' environmental and behavioral context (e.g., their risk tolerance, their budget, their location, or even the surrounding weather). The latter forms a rather novel approach in the sense that it augments activities with metadata of ideal performance context (namely: popularity, sociability, risk, location, expense, time, and weather).

Trying to combine two distinct trends, i.e., the Internet of Things [38] interrelated computing devices world and the computationally rich health-care sector, [39] introduce a new concept of smart health, which according to the authors forms a context-aware complement of mobile health within smart cities and provide an overview of the main fields of knowledge that are involved in the process of building this new concept. In addition, Doukas et al. [40] investigate the potential of Future Internet-based architectures for enabling context-aware content adaptation and specialized delivery of health-related information in assistive environments. Focusing on the concept of medical cyber-physical systems that enable automatic medical device coordination for patient protection, Lia et al. [41] propose to utilize contextual information to improve them and tackle their limited capabilities detecting human errors that result into late device coordination in the case patients have already developed adverse physiological reactions. Finally, following Table 2 presents the herein discussed context-aware medical applications according to their type and illustrates each one's main features.

## 6 Electronic Patient and Health Records

Electronic patient records (EPR) are considered to be the electronic upgraded version of traditional paper-based patient records [42]. They typically contain a patient's medical history, including her/his diagnoses, medications, immunizations, family medical history, etc., as well as her/his contact information. In the biomedical sub-domain, the rapid adoption of such electronic patient and health records with the parallel growth of narrative data in electronic form, along with the needs for

**Table 2** Context-aware wireless medical applications

| Work | Task(s) | Description | Pros | Cons | Dataset |
|---|---|---|---|---|---|
| [23] | Context definition | Wide notion of context, context modeling | PDA prototypes, sensor-related study | No strict medical impact | – |
| [24] | Context-awareness definition | Indoor context-aware applications | Novel sensor system | No strict medical uti-lization/impact | – |
| [25] | Context in wearable computers | 4 contextual capabilities, Contextual Information Service | Prototype application | No medical application | – |
| [26] | Context-awareness computing survey | Analysis of types and models of context | Detailed literature analysis, point of reference | Outdated (2000), no medical focus | – |
| [27] | Context-awareness computing survey | Focus on temporal and spatial context | Detailed literature analysis, point of reference | Outdated (2000), no medical focus | – |
| [28] | Mobile pervasive computing | Health care wearable context-aware application | Pioneer mobile real-life application | Outdated (2003) | – |
| [29] | Context-aware mobile communication in hospitals | Context-aware mobile system | Mobile device context exploitation | Outdated (2003) | – |
| [30] | Context-aware data mining framework | Application model | Use context to maximize data mining's adaptive capacity | Outdated (2003) | Public medical datasets |
| [31] | Medical content adaptation, semantics | Platform, ontological framework | Semantics utilization, sensors, ontological framework, SWRL rules | No evaluation | – |
| [32] | Context modeling | Self-learning, probabilistic, ontology-based framework | Ontology-based context model, rule-based context-aware algorithms | – | 5 data values, +1000 instances SIRS dataset |

(continued)

**Table 2** (continued)

| Work | Task(s) | Description | Pros | Cons | Dataset |
|---|---|---|---|---|---|
| [33] | Dementia diagnosis | Image search based on ontologies and contextual information | Context-aware medical image retrieval | Focused on dementia | Real-life imaging data |
| [34] | Context-aware applications in wireless body area networks | Survey study | Network-oriented approach | Medical and non-medical focus | – |
| [35] | ECG monitoring system | Wearable context-aware ECG monitoring system | Smartphone sensors exploitation, integrated approach | – | 1697, 2320 & 2006 physical activities samples (rest, walking, running, respectively) |
| [36] | Smartphone-related medical applications | Context and bio-aware mobile applications | Implementation | Weak evaluation | Biosensors, web services, social media, 3 devices |
| [37] | Physical activity recommendation | Environmental and behavioral context, smartphone application | Smartphone application prototype | Limited dataset | 137 physical activities database |
| [39] | Intelligent smart cities/health-care | Smart-health concept | Combination model of Internet of Things and health-care | No evaluation | – |
| [40] | Cognitive and context-aware assistive environments | Context-aware content adaptation & information delivery | Future Internet technologies utilization | Qualitative evaluation only | – |
| [41] | Medical cyber-physical systems | Contextual information utilization | Contextual information utilization, prototype system | No real-life evaluation | Emulated dataset |

improved quality of care and reduced medical errors are both strong incentives for the development of computational intelligent systems [43]. The huge potential for medical research is also depicted in [44], where authors propose a dynamic consent model based on contextual information such as time and metadata, although they ultimately focus on the social means to maintain public trust. Temporal data mining and exploitation of contextual information is also utilized in [45]. Authors claim that

the developed method can be used to extract dose-dependent adverse drug reactions information from already collected EPR data. Taking this a step further, mining of electronic health records has the potential for establishing new patient-stratification principles and for revealing unknown disease correlation as depicted in [46].

In general several methods have been employed in the biomedical literature to extract facts from free text and fill out template slots. For instance, McNaught et al. [47] describe a detailed review of information extraction techniques in the biomedical domain; however, their review does not include the clinical field. In [48] the author studies the ways contextual information in the form of linguistic ethnography may enhance the understanding of EPRs in health care settings. Another approach is pattern-matching, which exploits basic patterns over a variety of contextual information structures, like text strings, tags, semantic pairs, and even dictionary entries [49]. Its main disadvantage is its lack of generalization ability, which limits their extension and adaptation to new domain features. Last but not least, even knowledge-based approaches have been incorporated in the task, by introducing ontology-driven information extraction in order to guide free-text processing [50]. A summary of the aforementioned studies is provided in the following Table 3.

## 7 Intelligent Hospital Applications

Considering this rather standalone health-care sector, there are also several standalone intelligent hospital applications worth mentioning herein. Being an ongoing implementation field, there are currently a variety of software solutions, platforms and systems enabling smart health-care activities and assisting health-care providers diagnosing and deciding the correct course of actions. In this manner a context-aware prototype is proposed in [51], which includes a context-aware hospital bed with a built-in display that may be used by both patients (e.g., for entertainment) and clinicians (e.g., for accessing medical data). Furthermore, the bed is able to identify the nurse, the patient and the medicine tray, and displays relevant information according to this context, such as a medicine schema or patient record. In another work following a study of the needs of the Royal London Hospital, authors in [52] proposed a variety of usage scenarios (i.e., remote consultation, tracking of patients and equipment, notification of awareness and patient data) and have implemented an experimental prototype. In MobileWARD [53] a prototype is introduced to support morning procedure tasks in a hospital ward; the prototype is able to efficiently display patients lists and information.

Effective critical care administration is a very important aspect in health-care. Having the ultimate goal to improve communication capabilities in hospitals, diverse communication mechanisms are also proposed in the literature and some of them do realize the importance of context in the process, like the one introduced in [54], where authors propose a flexible, automated and asynchronous context-aware medical instant message middleware that supports message dispatching based

**Table 3** Electronic patient and health records

| Work | Task(s) | Description | Pros | Cons | Dataset |
|---|---|---|---|---|---|
| [42] | Electronic patient records definition | Electronic patient records definition | Robust term definition | No context exploitation | – |
| [43] | Electronic health record information extraction | Survey study | Review of electronic health records info extraction techniques | Outdated (2008) | – |
| [44] | Electronic patient records management | Dynamic consent model based on contextual information | Utilized dynamic consent model | Focus solely on patient trust issues | – |
| [45] | Temporal data mining of EPRs | Temporal data mining, exploitation of contextual information | Real-life evaluation, novel methodology | Focus solely on limited medical sub-domain | 3394 & 43,528 patients datasets |
| [46] | Electronic health records mining | Overview of related techniques | High-level approach | Weak evaluation | – |
| [47] | Biomedical information extraction | Review study | Detailed review, in-depth analysis | No clinical field discussion, weak context | – |
| [48] | EPRs understanding | Context utilization in the form of linguistic information | Detailed analysis and investigation of contextual aspects | Weak evaluation | Real-life dataset |
| [49] | Contextual information pattern-matching | Contextual data mining for clinical texts | Integrated system architecture | Lack of generalization ability, small dataset | 351 documents, 4 topics |
| [50] | Text mining from biomedical reports | NLP-based knowledge-based approach | Ontology-driven information extraction | Knowledge scalability issues | 5000 entries, 4000 concepts and roles, 4973 documents |

on context information, so as to improve in-hospital communications. A prototype of this contextual messaging communication system has been implemented in a real clinical setting for evaluation purposes. In an effort to apply context-aware computing using service-oriented architecture in acquiring, analyzing and assisting hospital personnel with necessary information for time-saving decision making, [55] presents an implementation of a set of web services that can be consumed

during an intensive care unit (ICU) treatment within a hospital use case scenario. Finally, in [56] a tablet-based system prototype is proposed focused on ICU based workflows that allows for ubiquitous patient monitoring and smart alert generation. Interestingly enough the aforementioned prototype is supported by open source software and hardware platforms. To the reader's convenience following Table 4 provides a brief summary and categorization of the aforementioned research works.

## 8 Conclusion and Future Work

As discussed herein researchers from the fields of computer science and health-care have developed different approaches to address the medical data processing and related analytics challenges. In this position paper we attempted to summarize briefly the ones that presented and discussed several types of contextual information; the latter being suitable for utilization, exploitation and usage within the medical data framework. Thus, we identified four distinct expressions of such context, namely context in medical data analysis, the domain of context-aware applications, contextual support to electronic patient and health records analysis, as well as context exploitation within intelligent hospital applications. We observed and analyzed why such contextual information may be extremely helpful in computational tasks relating to health-care activities, especially with respect to handling related

**Table 4** Intelligent hospital applications

| Work | Task(s) | Description | Pros | Cons |
|---|---|---|---|---|
| [51] | Context-aware hospital bed | Context-aware prototype | Functionalities, variety of users | Installation costs |
| [52] | Context aware application middleware | Context-aware experimental hospital prototype | Context-sensitive communications, integrated platform | Evaluation |
| [53] | Intelligent hospital support | Mobile context-aware electronic patient record prototype | Integrated system | Weak real-life evaluation (3 subjects) |
| [54] | Hospital middleware | Context-aware medical instant messaging middleware | Improved in-hospital communications, prototype real-life evaluation | – |
| [55] | Hospital decision making | Service-oriented architecture, context-aware computing | Context-aware ICU web-services | Evaluation aspects |
| [56] | ICU workflow optimization | Tablet-based system prototype | Ubiquitous patient monitoring, open source SW | – |

information search, retrieval and utilization problems. The main conclusion of this survey is the fact that context plays a significant role in disambiguating medical data and may be extremely helpful when processing them in the framework of EPRs and/or medical applications.

Based on the aforementioned discussion and interpretation of each analyzed context group, we hope that future useful research directions may be identified by interested fellow researchers. According to the herein presented works tackling a variety of context variations, we may identify a clear effort towards the bridging of the semantics and sensory gaps dominating both computer science and medicine. As a future plan, we intend to extend this survey work towards including a review of additional health-care domains not tackled herein, like for instance health-care big data analytics.

## References

1. Tajbakhsh, N., et al. 2016. Convolutional Neural Networks for Medical Image Analysis: Full Training or Fine Tuning? *IEEE Transactions on Medical Imaging* 35 (5): 1299–1312. doi:10.1109/TMI.2016.2535302.
2. Zakhem, E., S.V. Murphy, M.L. Davis, S. Raghavan, and M.T. Lam. 2016. Image and Video Acquisition and Processing for Clinical Applications. *Biomedical Engineering and Computational Biology* 7 (Suppl 1): 35–38. doi:10.4137/BECB.S40272.
3. Bricon-Soufa, N., and C.R. Newman. 2007. Context Awareness in Health Care: A Review. *International Journal of Medical Informatics* 76: 2–12.
4. Dey, A., and G. Abowd. 1999. Towards a Better Understanding of Context and Context-Awareness. Proceedings of the 1st International Symposium on Handheld and Ubiquitous Computing, 304–307.
5. Kwiatkowska, M., and N.T. Ayas. 2014. Context-Dependent Interpretation of Medical Data. Chapter in *Studies in Fuzziness and Soft Computing, Recent Developments and New Directions in Soft Computing*, 409–425. doi:10.1007/978-3-319-06323-2_26.
6. Forsythe, D.E., B.G. Buchanan, J.A. Osheroff, and R.A. Miller. 1992. Expanding the Concept of Medical Information: An Observational Study of Physicians' Information Needs. *Computers and Biomedical Research* 25 (2): 181–200.
7. Berg, M., and E. Goorman. 1999. The Contextual Nature of Medical Information. *International Journal of Medical Informatics* 56: 51–60.
8. Lipson, P., E. Grimson, and P. Sinha. 1997. Configuration Based Scene Classification and Image in-Dexing. IEEE International Conference on Computer Vision & Pattern Recognition.
9. Ye, J., L. Coyle, S. Dobson, and P. Nixon. 2007. Using Situation Lattices to Model and Reason About Context. 4th International Workshop on Modeling and Reasoning in Context, MRC 2007.
10. Schilit, B., N. Adams, and R. Want. 1994. Context-Aware Computing Applications. IEEE Workshop on Mobile Computing Systems and Applications, Santa Cruz, CA, USA.
11. Mylonas, P., D. Vallet, P. Castells, M. Fernandez, and Y. Avrithis. 2008. Personalized Information Retrieval Based on Context and Ontological Knowledge. *Knowledge Engineering Review* 23 (1): 1–24.
12. Mylonas, P. 2012. Understanding How Visual Context Influences Multimedia Content Analysis Problems. *Artificial Intelligence: Theories and Applications, Lecture Notes in Computer Science* 7297: 361–368.

13. Saber, E., M. Tekalp, R. Eschbach, and K. Knox. 1996. Automatic Image Annotation Using Adaptive Colour Classification. *CVGIP: Graphical Models and Image Processing* 58: 115–126.
14. Smith, J.R., and C.-S. Li. 1998. Decoding Image Semantics Using Composite Region Templates. IEEE International Workshop on Content-Based Access of Image & Video Database.
15. Vailaya, A., and A. Jain. 2000. Detecting Sky and Vegetation in Outdoor Images. SPIE, vol. 3972.
16. Context of Use Analysis, http://www.usabilitybok.org/context-of-use-analysis, last retrieved: July 5, 2016.
17. Patel, D. 2014. Usability Testing of Context-Aware Mobile Applications. Bachelor Thesis, Lancaster University, IT for Creative Industries, http://www.lancaster.ac.uk/postgrad/pateld1/Dissertation%20(Dharmendra%20Patel).pdf.
18. Bolchini, C., C. Curino, E. Quintarelli, F. Schreiber, and L.A. Tanca. 2007. A Data-Oriented Survey of Context Models. *SIGMOD Record* 36 (4): 19–26.
19. Dojat, M., and F. Pachet. 1995. Representing Medical Context Using Rule-Based Object-Oriented Programming Techniques. In *Artificial Intelligence in Medicine*, ed. P. Barahona, M. Stefanelli, and J. Wyatt, 423–424. Berlin: Springer.
20. Roux, E., A.-P. Godillon-Maquinghen, P. Caulier, S. Bouilland, and D. Bouttens. 2006. A Support Method for the Contextual Interpretation of Biomechanical Data. *IEEE Transactions on Information Technology in Biomedicine* 10 (1): 109–118.
21. Massey, J.G. 2015. In Context: Extracting Relevance from Unstructured Medical Data, December.
22. Massey, J.G., R. Myneni, M.A. Mattocks, and E.C. Brinsfield. 2014. Extracting Key Concepts from Unstructured Medical Reports Using SAS® Text Analytics and SAS® Visual Analytics. Proceedings of SAS Global Forum.
23. Schmidt, A., M. Beigl, and H.-W. Gellersen. 1999. There Is More to Context Than Location. *Computers & Graphics* 23: 893–901.
24. Ward, A., A. Jones, and A. Hopper. 1997. A New Location Technique for the Active Office. *IEEE Personal Communications* 4 (5): 42–47.
25. Pascoe, J. 1998. Adding Generic Contextual Capabilities to Wearable Computers. Proceedings of the Second International Symposium on Wearable Computing, Pittsburgh, PA, October 19–20.
26. Chen, G., and D. Kotz. 2000. A Survey of Context-Aware Mobile Computing Research, Dartmouth Computer Science Technical Report TR2000-381. Hanover.
27. Korkea-aho, M. 2000. Context-Aware Applications Survey, http://www1.ju.edu.jo/ecourse/abusufah/cpe532_Spr06/notes/Web/Context-Aware%20Applications%20Survey.htm.
28. Stanford, V. 2003. Beam Me Up, Dr. McCoy. *IEEE Personal Communications Magazine* 2 (3): 13–18.
29. Munoz, M., M. Rodriguez, J. Favela, A. Martinez-Garcia, and V. Gonzalez. 2003. Context-Aware Mobile Communication in Hospitals. *IEEE Computer* 36 (9): 38–46.
30. Vajirkar, P., S. Singh, and Y. Lee. 2003. Context-Aware Data Mining Framework for Wireless Medical Application, Database and Expert Systems Applications, Volume 2736, Lecture Notes in Computer Science, 381–391.
31. Doukas, C., I. Maglogiannis, and K. Karpouzis. 2008. Context-Aware Medical Content Adaptation Through Semantic Representation and Rules Evaluation. Third International Workshop on Semantic Media Adaptation and Personalization.
32. Ongenaea, F., M. Claeysa, T. Duponta, W. Kerckhovea, P. Verhoeveb, T. Dhaenea, and F. De Turcka. 2013. A Probabilistic Ontology-Based Platform for Self-Learning Context-Aware Healthcare Applications. *Expert Systems with Applications* 40 (18): 7629–7646.
33. Soydemir, M., and D. Unay. 2013. Context-Aware Medical Image Retrieval for Improved Dementia Diagnosis. *Intelligent Multimedia Technologies for Networking Applications: Techniques and Tools*.

34. Tobón, D.P., T.H. Falk, and M. Maier. 2013. Context Awareness in WBANs: A Survey on Medical and Non-medical Applications. *IEEE Wireless Communications* 20 (4): 30–37.
35. Miao, F., Y. Cheng, Y. He, Q. He, and Y. Li. 2015. A Wearable Context-Aware ECG Monitoring System Integrated with Built-in Kinematic Sensors of the Smartphone. *Sensors* 15 (5): 11465–11484. doi:10.3390/s150511465.
36. Mitchell, M. 2011. Context and Bio-Aware Mobile Applications. M. Sc. Thesis, Florida.
37. He, Q., E. Agu, D. Strong, and B. Tulu. 2014. RecFit: A Context-Aware System for Recommending Physical Activities. Proceedings of the 1st Workshop on Mobile Medical Applications (MMA'14), 34–39. New York, NY: ACM.
38. Atzori, L., A. Iera, and G. Morabito. 2010. The Internet of Things: A Survey. *Computer Networks* 54: 2787–2805.
39. Solanas, A., C. Patsakis, M. Conti, I.S. Vlachos, V. Ramos, F. Falcone, O. Postolache, P.A. Perez-Martinez, R. Di Pietro, D.N. Perrea, and A. Martinez-Balleste. 2014. Smart Health: A Context-Aware Health Paradigm Within Smart Cities. *IEEE Communications Magazine* 52 (8): 74–81. doi:10.1109/MCOM.2014.6871673.
40. Doukas, C., N. Fotiou, G.C. Polyzos, and I. Maglogiannis. 2014. Cognitive and Context-Aware Assistive Environments Using Future Internet Technologies. *Universal Access in the Information Society* 13 (1): 59–72. doi:10.1007/s10209-013-0299-y.
41. Lia, T., J. Caoa, J. Lianga, and J. Zhenga. 2015. Towards Context-Aware Medical Cyber-Physical Systems: Design Methodology and a Case Study. *Cyber-Physical Systems* 1 (1).
42. Kluge, E.-H.W. 2015. Electronic Patient Records. Encyclopedia of Global Bioethics, 1–10, 13 May 2015.
43. Meystre, S.M., G.K. Savova, K.C. Kipper-Schuler, and J.F. Hurdle. 2008. *Extracting Information from Textual Documents in the Electronic Health Record: A Review of Recent Research*. IMIA Yearbook of Medical Informatics.
44. Williams, H., K. Spencer, C. Sanders, D. Lund, E.A. Whitley, J. Kaye, and W.G. Dixon. 2015. Dynamic Consent: A Possible Solution to Improve Patient Confidence and Trust in How Electronic Patient Records Are Used in Medical Research. *JMIR Medical Informatics* 3 (1): e3.
45. Eriksson, R., T. Werge, L.J. Jensen, and S. Brunak. 2014. Dose-Specific Adverse Drug Reaction Identification in Electronic Patient Records: Temporal Data Mining in an Inpatient Psychiatric Population. *Drug Safety* 37 (4): 237–247. doi:10.1007/s40264-014-0145-z.
46. Jensen, P.B., L.J. Jensen, and S. Brunak. 2012. Mining Electronic Health Records: Towards Better Research Applications and Clinical Care. *Nature Reviews Genetics* 13: 395–405.
47. McNaught, J., and W.J. Black. 2006. Information Extraction: The Task. In *Text Mining for Biology and Biomedicine: Artech House Books*, ed. S. Ananiadou, and J. McNaught, 143–176.
48. Swinglehurst, D. 2015. How Linguistic Ethnography May Enhance Our Understanding of Electronic Patient Records in Health Care Settings. Linguistic Ethnography, Part of the Series Palgrave Advances in Language and Linguistics, 90–109.
49. Pakhomov, S., J. Buntrock, and P.H. Duffy. 2005. High Throughput Modularized NLP System for Clinical Text. 43rd Annual Meeting of the Association for Computational Linguistics, Ann Arbor, MI.
50. Hahn, U., M. Romacker, and S. Schulz. 2002. Creating Knowledge Repositories from Biomedical Reports: The MEDSYNDIKATE Text Mining System. *Pacific Symposium on Biocomputing*: 338–349.
51. Bardram, J. 2004. Applications of Context-Aware Computing in Hospital Work—Examples and Design Principles. Proceedings of SAC, Cyprus, March 14–17.
52. Mitchell, S., M. Spiteri, J. Bates, and G. Coulouris. 2000. Context Aware Multimedia Computing in the Intelligent Hospital. Proceedings of the Ninth ACM SIGOPS European Workshop, Denmark, September.
53. Kjeldskov, J., and M. Skov. 2004. Supporting Work Activities in Healthcare by Mobile Electronic Patient Records. Proceedings of the 6th Asia–Pacific Conference on Human–Computer Interaction, APCHI 2004, Rotorva, New Zealand.
54. Cheng, H.-X., L.-T. Min, X.-D. Lü, and H.-L. Duan. 2015. A Context-Aware Medical Instant Message Middleware. *Journal of Shanghai Jiaotong University (Science)* 20 (1): 113–117.

55. Immanuel, V.A., and P. Raj. 2015. Enabling Context-Awareness: A Service Oriented Architecture Implementation for a Hospital Use Case. 2015 International Conference on Applied and Theoretical Computing and Communication Technology (iCATccT), Davangere, 224–228.
56. Antony, J., B. Vijayan, S. Joy, G.S. Santhoshkumar, and N. Chandran. 2013. Ubiquitous Patient Monitoring and Smart Alert Generation in an Intensive Care Unit Supported by Low Cost Tablet PC Based Automation System Powered Through Open Source Software and Hardware Platforms. Global Humanitarian Technology Conference: South Asia Satellite (GHTC-SAS), 2013 IEEE, Trivandrum, 334–339.

# vhMentor: An Ontology Supported Mobile Agent System for Pervasive Health Care Monitoring

**Stella C. Christopoulou, Theodore Kotsilieris, Ioannis Anagnostopoulos, Christos-Nikolaos Anagnostopoulos, and Phivos Mylonas**

**Abstract** Healthcare provision is a set of activities that demands the collaboration of several stakeholders (e.g. physicians, nurses, managers, patients etc.) who hold distinct expertise and responsibilities. In addition, medical knowledge is diversely located and often shared under no central coordination and supervision authority, while medical data flows remain mostly passive regarding the way data is delivered to both clinicians and patients. In this paper, we propose the implementation of a virtual health Mentor (vhMentor) which stands as a dedicated ontology schema and FIPA compliant agent system. Agent technology proves to be ideal for developing healthcare applications due to its distributed operation over systems and data sources of high heterogeneity. Agents are able to perform their tasks by acting proactively in order to assist individuals to overcome limitations posed during accessing medical data and executing non-automatic error-prone processes. vhMentor further comprises the Jess rules engine in order to implement reasoning logic. Thus, on the one hand vhMentor is a prototype that fills the gap between healthcare systems and the care provision community, while on the other hand allows the blending of next generation distributed services in healthcare domain.

S.C. Christopoulou (✉)
Business Administration Department, TEI Peloponnese, Kalamata, Greece

Computer Science and Biomedical Informatics Department, University of Thessaly, Lamia, Greece
e-mail: stellachristop@gmail.com

T. Kotsilieris
Business Administration Department, TEI Peloponnese, Kalamata, Greece

I. Anagnostopoulos
Computer Science and Biomedical Informatics Department, University of Thessaly, Lamia, Greece

C.-N. Anagnostopoulos
Cultural Technology & Communication Department, University of the Aegean, Mytilene, Greece

P. Mylonas
Department of Informatics, Ionian University, Corfu, Greece



P. Vlamos (eds.), *GeNeDis 2016*, Advances in Experimental Medicine and Biology 989, DOI 10.1007/978-3-319-57348-9_5

**Keywords** Healthcare information systems • Pervasive computing • Mobile software agents • Health care monitoring • Medical knowledge management

## 1 Introduction: Related Work

Healthcare provision is a set of activities that demands the collaboration of several stakeholders (e.g. physicians, nurses, managers, patients etc.) who hold distinct expertise and responsibilities. Also, medical knowledge is diversely located and often shared under no central coordination authority to supervise.

Consequently, software modules and resources (i.e. hardware and human participants) of medical information systems are usually spatially and functionally distributed. Furthermore, data flow of medical systems across healthcare professionals, patients and other individuals (e.g. next of kin) remains quite passive, while the automation gap of administrative and assistance processes is recognized to be wide. In such an information intensive environment, we propose the vhMentor system, an agent-based and ontology-supported solution that employs software agents to process and monitor distributed medical data flows through concrete ontology-driven knowledge sources and provide them upon request to the end-users.

Accordingly, agent technology has proved to be ideal for developing healthcare applications, mainly due to its intrinsic characteristics of distributed operation over different systems and data sources of high heterogeneity. Agents are able to perform their tasks under a cooperation scheme by acting pro-actively in order to: (a) assist individuals to overcome burdens posed by complex decision-making and (b) access medical data and non-automatic error-prone processes.

In a typical healthcare services provision scenario, patients are expected to be hospitalized in several facilities that subsequently provokes the produced data to be split across several diverse and non-integrated information systems. Orgun and Vu propose a multi-agent system combined with an ontology that defines and implements the HL7 vocabulary in order to facilitate patient data flow across the resources of a healthcare organization [1]. Liu et al. introduce an alternate integration approach, introduces the idea of a Virtual Integrated Medical information System (VIMS) [2]. VIMS spins around a two layers integration scheme: (a) the data layer employs mobile agents to acquire and transmit medical data, (b) the application layer is used to process the data acquired from various sources (HISs, medical devices etc.).

Another scenario of spatially distributed patient data is described by Martin-Campillo et al. [3] where mobile agents are employed to query data from a Virtual Electronic Patient Medical Record (VEPMR) that is developed over a distributed medical database. Furthermore, on the basis of distributed e-health model, Pouyan, Ekrami, and Taban propose a multi-agent system where each human actor, device, software system and process is assigned to a mobile agent [4]. However, the proposed solution fails to completely discard the client-server architecture of the legacy information system.

Moreover, the Java Agent DEvelopment Framework—JADE [5] has attracted vast research community attention for its powerful task execution, composition and interoperability model. JADE allows for the peer to peer agent communication through an asynchronous message passing scheme while ad-hoc versions are designed to facilitate the deployment of agents on various Java-oriented devices such as Android. It is considered to be the most widespread and stable agent-oriented framework in use today. Furthermore, noteworthy research has been conducted on applying JADE framework in the field of health care. Su and Wu [6] propose MADIP, a ubiquitous electronic health monitoring distributed information infrastructure. MADIP is a multi-agent system where each agent corresponds to a human actor in the real life process that allows for the automatic detection of patient data abnormalities both from the physician's and patient's perspectives. Kim et al. in [7] describe a context-aware healthcare system for effective management and automated services. A distributed service that is named K4Care is fully developed in JADE where agents are responsible to support knowledge and data dissemination in one hand and process execution in the other hand [8]. Nguyen et al. propose an agent-based application [9], MEDIMAS, that aims to overcome the inefficiencies implied by legacy information systems (such as automation and mobility gap, manual information search, error prone processes etc.). MEDIMAS takes advantage of JADE mobile agents in order to enhance the operation of a legacy laboratory information system through an ontology that acts as a knowledge broker among the stakeholders. Mobile agents have also been applied in order to adopt medical sensors in a distributed paradigm [10] and drug safety surveillance [11].

In this work, we propose vhMentor, an ontology supported and agent-based system for healthcare data monitoring. Our objective is to propose a solution that covers the automation gap and at the same time avoids error-prone processes through a systematic and strategic approach of medical data delivery. Thus, we thoroughly study the applicability and usefulness of jointly applying the ontology framework and the mobile agent paradigm in the healthcare domain.

The rest of the paper is organized as follows. The next section introduces the main features of the vhMentor framework. In subsequent sections we outline our system's architecture and functional specifications and then we describe a use case scenario and system validation environment. The last section concludes our paper with suggested future research directions.

## 2 The vhMentor Proposed Framework

vhMentor is an agent-based framework with ontology support based on the JADE platform, the Protégé ontology tool suite and the Ontology Bean Generator middleware. Accordingly, the Jess rule engine is applied for carrying out reasoning tasks.

JADE is the multi-agent platform of choice because: (a) it is operating system independent and requires minimal resources to be executed on Java enabled devices (e.g. tablets, smartphones, etc.), (b) it supports the development of JAVA software agents according to the FIPA specification [12], (c) the ontology support of JADE allows the manipulation of information exchange between vhMentor agents as JAVA objects instead of ACL messages, and (d) it provides the functionality to perform queries against complex ontological schemas.

A typical JADE deployment consists of the runtime environment, the agent development APIs and a suite of graphical agent management tools. Every instance of the JADE runtime environment is called a Container that act as agent hosts, which is the space where one or more agents may be created and exist. In order to create a new platform, a special Container, called Main-Container that plays the role of the coordinator, must be always active so that every other typical Container may register with it. In the event that a new Main-Container is initiated, it is considered to be a different platform that may accept new containers through registration.

A middleware that binds together the JADE ontology support mechanism and the Protégé ontology development environment [13] was necessary during the implementation of the prototype. BeanGenerator was selected as it allows the transformation of an ontology that is designed and developed in Protégé into JADE compliant JAVA classes.

Another significant component of vhMentor is the Jess rules engine that allows reasoning logic to be built under three programming schemes: fully developed in Jess, entire application implementation through a dedicated JAVA API or a mixture of them. Jess is a JAVA library fully interoperable with the JADE platform. Furthermore, research efforts have been devoted on studying integration of Jess with the semantic web rule language SWRL [14] and their combined utilization in health domain applications [15].

## 3 The vhMentor Architecture and Functional Specifications

The healthcare domain is mission critical and the intrinsic complexity of medical care activities stems from their distributed and fragmented nature along with their diversity and autonomy. The purpose of the proposed vhMentor system architecture is not to compare the advantages and disadvantages of the available technologies neither to benchmark the performance the agent-based approach against other implementations. vhMentor aims at process optimization through agents which are able to act as proxies either of human actors or medical devices that lack the computational resources for reasoning and management. Data management and monitoring, decision-making, multi-source information retrieval, dynamic, asynchronous and autonomous operation and fault-tolerance are only a part of the wide range of applications in the field.

The main feature introduced by vhMentor is to “listen” on health devices and sensors and disseminate the collected information through a well-defined

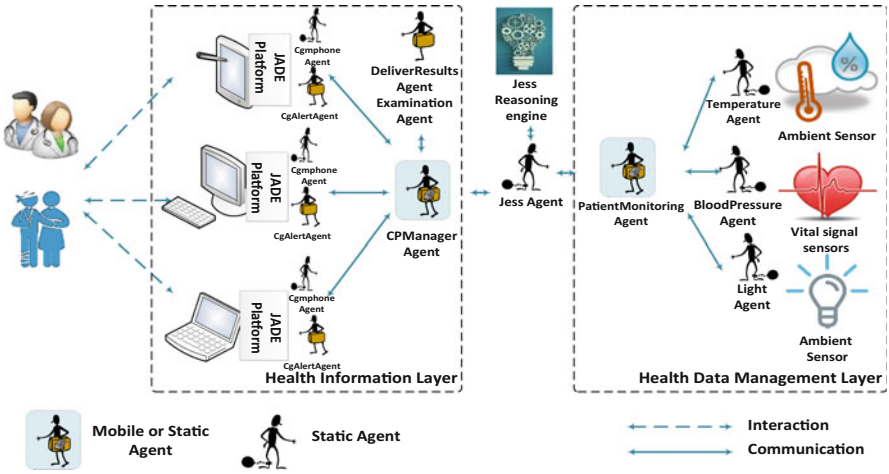


**Fig. 1** The conceptual model of vhMentor

knowledge ontology base. Patient information is managed by the Health Data Management Layer (HDML) which is responsible for collecting, storing, and broadcasting vital clinical messages to subscribers and is implemented through JADE agents. Namely, PatientMonitoringAgent and device specific agents (i.e. TemperatureAgent, BloodPerssureAgent, LightAgent) act as brokers between the sensors, the service agents layer (i.e. Health Information Layer—HIL) and the Jess Agent.

HIL is designed to cope with real-time data requests and queries from the end-users against ontological and knowledge bases. This layer performs the interpretation of health information related content to personalized medical actions (i.e. DeliverResultsAgent, ExaminationAgent, AskForResultAgent) or alarm generations (i.e. CgAlertAgent, NotificationAgent). Thus, care providers are able to review the status of the patients through the software platform. HIL provides to daily medical practice features such as dynamic interaction, continuous data update and cooperative management. Also, it allows for maximum customization, so as medical, nursing and technical staff can easily adapt by adopting a digital mode of operation in patient monitoring. Figure 1 depicts the conceptual design of the vhMentor system along with its main components and the interactions of the aforementioned functional modules.

## 4 Use Case Scenario and System Validation

Every healthcare monitoring ecosystem consists of patient bio-signals, environmental and accelerometer/gyroscope sensors. Although generated data forwarding

are either "pushed" and "pulled," within the scope of this work we study the "pull" mode of operation as it is more complicated and operates by gathering all necessary data upon request. On the contrary, the "push" mode of operation simply transmits all sensed data to the processing center. The HDML stores the information—measurement sent from each sensor's static agent (see Fig. 1). In parallel, depending on their assigned role, practitioners and family members have access to medical/health data through a delegated agent that resides on the networked device they use (i.e. CgmphoneAgent). Sensed data are forwarded to the JessAgent so as to be further processed by a reasoner engine, in order to diagnose, advise or alert for each individual patient. Upon processing the data of the HDML layer, HIL can inform practitioners or family members through their personal proxy agents (i.e. CPManagerAgent and CgmphoneAgent) about a patient's medical condition.

In order to verify the validity of the ontological model (Fig. 2) that is proposed for healthcare monitoring we translated it to JAVA classes that were embedded in agents implemented over the JADE platform. Subsequently, we developed an experimental environment that implements the scenario described above. More specifically, each

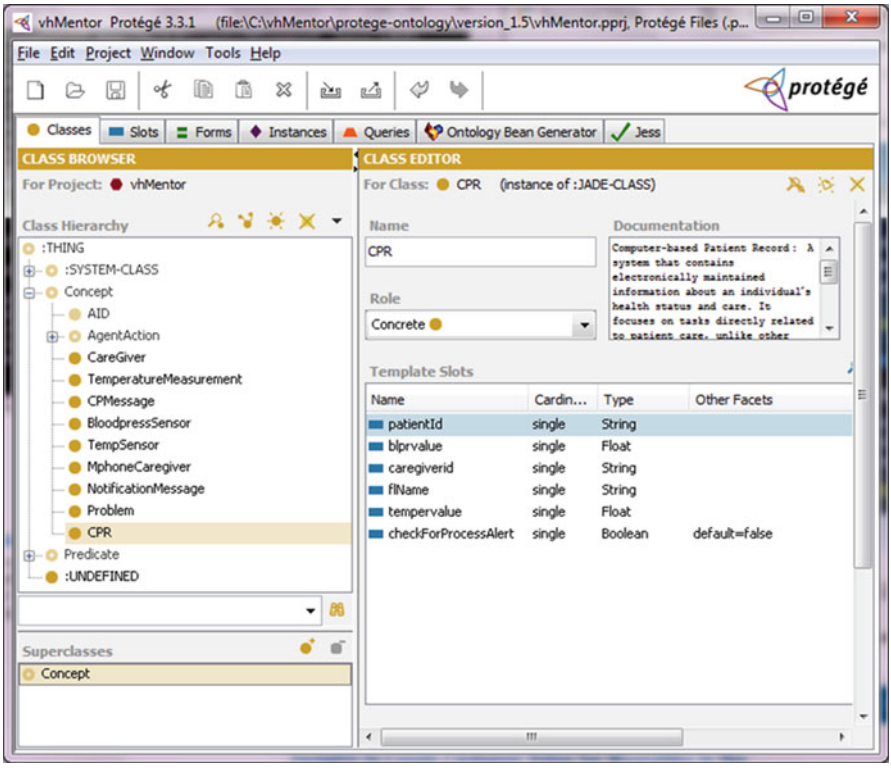


**Fig. 2** The vhMentor ontological model in Protégé tool suite

```
<<---- PATIENTS- MENU ---->>
        1. Create a new patient
        2. Make a temperature measurement
        3. Make a blood pressure measurement
        4. Get the most recent patient's values
        5. Get the list of temperature measurements
        6. Get the list of blood pressure measurements
```

**Fig. 3** The command-line main menu of the proposed system

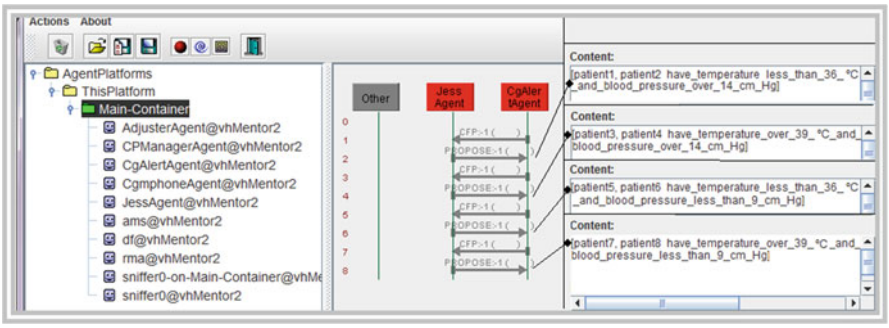


**Fig. 4** An example of the vhMentor execution and the resulting messages within the Jade Sniffer environment

sensor (i.e. ambient and vital signal) is simulated through a static JADE agent that is also dedicated to collect and transmit the sensed data whenever requested. The CPManagerAgent is the central processing module of vhMentor. At least a CPManagerAgent has to be active in a typical vhMentor deployment. Each caregiver owns a delegated agent that is named CGmphoneAgent and acts on his/her behalf. Other individuals that should participate (e.g. patients, family members etc.) are represented by CGmphoneAgent instances too.

A command line menu provides a set of six options as provided in Fig. 3. The first option creates a Computerized Patient Record (CPR) and contains a patient's personal health data. Upon its creation a unique code and a default alias is assigned. In future implementation it will also hold demographic data, such as address, phone numbers etc. By using this option we created three patients (i.e. *patient0, patient1* and *patient2*). Then, we simulate the operation of ambient and vital signal sensors and we assign to the actor agent of *patient2* sample temperature and blood pressure values through the *"Make a temperature measurement"* and *"Make a blood pressure measurement"* menu options respectively. Subsequently, the *"Get the most recent patient's values"* collects all the data that are already assigned to a specific patient CPR.

The Jess engine through the delegated actor JessAgent employs data and information provided from the HDML and HIL layers respectively along with decision-making and health advising logic that is defined in Jess rule language. An example of the vhMentor execution is depicted in Fig. 4 and exhibits its reasoning capabilities towards combining knowledge of rules and the vhMentor ontology.

## 5 Conclusion and Future Work

We proposed vhMentor, a system that employs an ontology supported and agent implemented framework for applying ubiquitous patient monitoring. vhMentor is a platform independent health-care provision framework built on top of the well-established JADE platform, the Protégé ontology tool suite, the BeanGenerator middleware and the Jess rule engine. Their respective interoperability-oriented, scalable and heterogeneity bridging libraries allow for faster, fault-tolerant and optimized implementations than "custom" ones. In parallel, we introduced the methods so as sensing technology and devices to be included in an ontology-based healthcare information system. The outcome of this framework is an efficient system that allows for the introduction of next generation services (e.g. decision making and reasoning) through autonomous and intelligent agents.

vhMentor is expected to improve the offered healthcare quality by integrating the notable evolution in sensor technologies and knowledge management. Also, healthcare providers are able to actively monitor pre-hospital, hospitalised and ambulatory patients with the help of the agents.

Our future work includes the development and implementation of a prototype for the automatic correlation of healthcare and environmental measurements with care plans through a reasoning engine.

## References

1. Orgun, B., and J. Vu. 2006. HL7 Ontology and Mobile Agents for Interoperability in Heterogeneous Medical Information Systems. *Computers in Biology and Medicine* 36: 817–836.
2. Liu, C.-H., Y.-F. Chung, T.-W. Chiang, T.-S. Chen, and S.-D. Wang. 2012. A Mobile Agent Approach for Secure Integrated Medical Information Systems. *Journal of Medical Systems* 36: 2731–2741.
3. Martin-Campillo, A., R. Marti, S. Robles, and C. Martinez-Garcia. 2009. Mobile Agents for Critical Medical Information Retrieving from the Emergency Scene. Seventh International Conference on Practical Applications of Agents and Multi-Agent Systems (PAAMS 2009), 30–39.
4. Pouyan, A.A., S. Ekrami, and M. Taban. 2011. A Distributed E-health Model Using Mobile Agents. The Seventh International Conference on Autonomic and Autonomous Systems.
5. Telecom Italia Lab. 2000. Java Agent DEvelopment Framework (JADE) [WWW Document]. URL http://jade.tilab.com/. Accessed 5.23.16.
6. Su, C.-J., and C.-Y. Wu. 2011. JADE Implemented Mobile Multi-Agent Based, Distributed Information Platform for Pervasive Health Care Monitoring. *Applied Soft Computing* 11: 315–325.
7. Kim, N.-H., Y.-S. Jeong, S.-J. Song, and D.-R. Shin. 2007. Middileware Interoperability Based Mobile Healthcare System. The 9th International Conference on Advanced Communication Technology, 209–213.
8. Isern, D., A. Moreno, D. Sánchez, Á. Hajnal, G. Pedone, and L. Varga. 2011. Agent-Based Execution of Personalised Home Care Treatments. *Applied Intelligence* 34: 155–180. doi:10.1007/s10489-009-0187.

9. Nguyen, M.T., P. Fuhrer, and J. Pasquier. 2009. Enhancing Legacy Information Systems with Agent Technology. *International Journal of Telemedicine and Applications-Special Issue on Electronic Health Archive*.
10. Vaidehi, V., M. Vardhini, H. Yogeshwaran, G. Inbasagar, R. Bhargavi, and C.S. Hemalatha. 2013. Agent Based Health Monitoring of Elderly People in Indoor Environments Using Wireless Sensor Networks. *Procedia Computer Science* 19: 64–71. doi:10.1016/j.procs.2013.06.014.
11. Ji, Yanqing, Hao Ying, M.S. Farber, J. Yen, P. Dews, R.E. Miller, and R.M. Massanari. 2010. A Distributed, Collaborative Intelligent Agent System Approach for Proactive Postmarketing Drug Safety Surveillance. *IEEE Transactions on Information Technology in Biomedicine* 14: 826–837. doi:10.1109/TITB.2009.2037007.
12. FIPA TC C. 2002. FIPA ACL Message Structure Specification [WWW Document]. URL http://www.fipa.org/specs/fipa00061/SC00061G.pdf.
13. Protégé. 2016. Protégé [WWW Document]. URL http://protege.stanford.edu/. Accessed 6.22.16.
14. O'connor, M., H. Knublauch, S. Tu, B. Grosof, M. Dean, W. Grosso, and M. Musen. 2005. Supporting Rule System Interoperability on the Semantic Web with SWRL. International Semantic Web Conference, 974–986.
15. Chen, R.C., Y.H. Huang, C.T. Bau, and S.M. Chen. 2012. A Recommendation System Based on Domain Ontology and SWRL for Anti-Diabetic Drugs Selection. *Expert Systems with Applications* 39: 3995–4006.

# Internet Addiction of Young Greek Adults: Psychological Aspects and Information Privacy

**P. Grammenos, N.A. Syrengela, E. Magkos, and A. Tsohou**

**Abstract** The main goal of this study is to examine the Internet addiction status of Greek young adults, aged from 18 to 25, using Young's Internet Addiction Test (IAT) and self-administered questionnaires. In addition this paper assesses the psychological traits of addicted persons per addiction category, using the big five factor model tool to study the user's personality and analyze the components that lead a person to become Internet addicted. Furthermore, we found an association between addicted people and the five factors from the Big Five Factor Model; i.e., extraversion, agreeableness, conscientiousness, neuroticism, openness to experience. Moreover, this paper discusses information privacy awareness issues related to Internet Addiction treatment.

**Keywords** Internet addiction • Psychological factors • Big five factor model • Information privacy

## 1 Introduction

Internet addiction (IA) defined as the inability to control Internet use [1, 2], is a behavioral addiction which nowadays is being considered as a serious mental health issue, with neurological effects, serious psychopathological symptoms, as well as difficulties at school, work, and relationships [2, 3]. And most importantly, with no standardized treatment.

Research on IA has always been controversial. While IA has been shown to be related to *disorders* such as impulse control disorder [2], attention deficit hyperactivity [4] etc., it is still under debate whether IA is a discrete disorder or it constitutes a symptom of another major disorder [5]. Second, it is still unknown whether all types of excessive Internet use, i.e., online pornography/social media/online gaming/gambling/browsing etc., constitute discrete addictions or they just share same psychological, neurophysiological and personality characteristics [6].

P. Grammenos • N.A. Syrengela • E. Magkos (✉) • A. Tsohou
Department of Informatics, Ionian University, Plateia Tsirigoti 7, 49100, Corfu, Greece
e-mail: p12gram@ionio.gr; p12syre@ionio.gr; emagos@ionio.gr; atsohou@ionio.gr



P. Vlamos (eds.), *GeNeDis 2016*, Advances in Experimental Medicine and Biology 989, DOI 10.1007/978-3-319-57348-9_6

Among common *factors* determining Internet addiction to people of late adolescent category are [7–9]: Gender/sex, family and social status, academic achievements, or even other addictions. Psychological factors also seem to play an important role in IA. Specifically, IA has been shown to share *psychological* and *psychopathological* characteristics with substance-based and other behavioral addictions such as pathological gambling [10], including depression, anxiety, obsessive symptoms [11]. IA has also be shown to be related to *personality* traits such as impulsivity [10], the feeling of loneliness, emotional instability and low self-esteem [3, 12–14]. IA has also be shown to be related to *neurological* complications (e.g., immature cognitive control) and a few works have studied the effects of IA on brain activity (i.e., cerebral blood flow [15], abnormalities in white/grey matter [16] etc). It is unknown whether all these aspects contribute positively to the development of Internet addiction for a person, or whether the addiction itself creates all these symptoms.

The IA problem is more acute in *late adolescence*, and particularly when parents do not control their children who live, most of the times, far from their hometown [7]. In this paper we focus on aspects of IA among young adults.

**Our Contribution** The main contribution of this study is first to examine the Internet addiction status of Greek young adults. Second to assess the psychological traits and symptoms of addicted persons, per addiction category, using the big five factor model tool to study the user's personality and analyze the components that may lead a person to become Internet addicted. More specifically, we performed a survey targeting people between 18 to 25 years old in Greece and we collected responses from 210 participants. Our results show a relatively large percentage of addicted users but also a large percentage of adolescents who are at a risk of become addicted. Furthermore, we found an association between addicted people and the factors from the Big Five Factor Model. Finally, this paper discusses information privacy awareness issues related to Internet Addiction treatment.

This paper is organized as follows. Section 2 presents the methodology and results of the empirical survey. Section 3 discusses the related work on the subject and in Sect. 4 we discuss security and privacy issues related to Internet Addiction.

## 2 A Study of IA Regarding Early Adults in Greece

### *2.1 Methodology*

The target group of this research were people aged from 18 to 25 years. We surveyed a total of 210 people and the valid questionnaires were 183. Our survey used self-administered questionnaires and its purpose was to find whether people from our target group are Internet addicted, which hours users prefer to be online, what they like doing when online and also the users' psychological and personality profiles. The level of addiction was investigated using the *Internet Addiction Tool* (IAT),

which contains a set of 20 questions. The users' profile was investigated with the help of the *Big Five Factor Model* which studies the psychological characteristics of users through five traits.

**Internet Addiction Tool** The tool (IAT) was created by Young [1]. We use IAT because it fully examines the user's personality in different psychological dimensions without the need to use different types of questionnaires for each dimension. Normally it contains 20 questions, but in this research we used a shorter version of this tool with 11 questions by merging some questions with the same meaning. The reason was that it contains some questions which are useless for the purpose of this research, so we adjusted them correctly to find out the hours that users stay online, the time of day that they prefer to be online, and their behaviors while they are online. IAT classifies IA with a score ranging from 0 to 100, with higher scores presenting higher levels of IA. People with score that ranges from 0 to 30 points considered to be normal Internet users. Scores that range from 31 to 49 represented mild level of addiction, from 50 to 79, a moderate level and scores from 80 to 100 a severe level of Internet addiction.

**Big Five Factor Model** The *Big Five Factor Model* [17] is a set of questions used in order to investigate the psychological characteristics of the users' personality through five traits. We used a shorter version of this model because normally this question set contains over 70 questions. We chose 2–3 of the most characteristic questions for each factor in order for our results to be valid. The five dimensions that this tool evaluates are:

*Extraversion*: It is the personality trait of seeking fulfillment from outside sources. High scorers tend to be very social while low scorers are lonely.

*Agreeableness*: The trait reflects how much individuals adjust their behavior to suit others. High scorers are typically polite and likeable people. Low scorers tend to "tell things as they are".

*Conscientiousness*: It is the personality trait of being honest and hardworking. High scorers tend to follow rules. Low scorers may cheat other people and be less honest.

*Neuroticism*: The personality trait of being emotional. People with low scores are emotionally stable. People with high scores are more anxious from the others and they have higher chances of suffering from depression in the future.

*Openness to Experience*: It is the personality trait of seeking new experiences and intellectual pursuits. High scores may dream a lot. Low scorers may be very down to earth.

## 3 Results

Our target group consisted of 87 males and 96 females. The mean score from the Internet Addiction Tool was 22.53. According to IAT categories, 27.8% (51 people) presented a normal level of Internet usage, 51.3% (94 people) a mild level

**Table 1** Gender and Internet addiction levels

| | Total people | Females | Males |
|---|---|---|---|
| Normal Users | 51 (27.8%) | 29 (30.2%) | 22 (25.3%) |
| Mild addiction | 94 (51.3%) | 50 (52%) | 44 (50.6%) |
| Moderate addiction | 37 (20.2%) | 16 (16.66%) | 21 (24.1%) |
| Severe addiction | 1 (0.7%) | 1 (1.04%) | 0 |

**Table 2** Addiction level per addiction category

| | Males | Females | Mild addiction | With addiction (moderate or severe) | Normal users | Total number of people |
|---|---|---|---|---|---|---|
| Information | 57 (65.5%) | 73 (76%) | 69 (73.4%) | 25 (65.7%) | 36 (70.5%) | 130 (71%) |
| Online gaming | 43 (49.4%) | 19 (19.7%) | 30 (31.9%) | 19 (50%) | 13 (25.4%) | 62 (33.8%) |
| Social networks | 63 (72.4%) | 83 (86.4%) | 73 (77.6%) | 31 (81.5%) | 42 (82.3%) | 146 (79.7%) |
| E-mail | 41 (47.1%) | 63 (65.6%) | 50 (53.1%) | 25 (65.7%) | 29 (56.8%) | 104 (56.8%) |
| Pornography | 27 (31%) | 2 (2%) | 15 (15.9%) | 8 (21%) | 6 (11.7%) | 29 (15.8%) |
| Gambling | 3 (3.4%) | 1 (1.04%) | 1 (1%) | 3 (7.8%) | 0 (0%) | 4 (2%) |
| Work/Education | 11 (12.6%) | 3 (3.1%) | 8 (8.5%) | 1 (2.6%) | 5 (9.8%) | 14 (7%) |
| Chat | 2 (2.2%) | 1 (1.04%) | 1 (1%) | 0 (0%) | 2 (3.9%) | 3 (1%) |
| Entertainment | 4 (4.5%) | 12 (12.5%) | 5 (5%) | 2 (5.2%) | 9 (17.6%) | 16 (8%) |
| Online purchases | 6 (6.8%) | 4 (4.1%) | 5 (5%) | 2 (5.2%) | 3 (5.8%) | 10 (5%) |

of addiction, 20.2% (37 people) a moderate level and 0.7% (1 person) a severe Internet addiction. As we can see, moderately addicted users are mostly male, although admittedly this may not constitute an important result due to the small sample (Table 1). People mostly prefer to be online at night and stay online for 5–10 h per day.

With regard to the addiction categories, we notice that social network activities, information searching and email are the top three categories associated with IA (Table 2). In addition, young female adults mostly prefer SNS while online gaming and pornography has been one of the favourite preoccupation of male users that took part in this study.

Furthermore, we found an association between addicted people and the five factors from Big Five Factor Model (Table 3). For example, normal users seem to have more extraversion and less neuroticism than mildly and moderately addicted users, and they seem to be more open to new experiences. On the other hand, addicted users seem to be more conscientious and les agreeable than normal users.

**Table 3** Association between addiction and the big five factors

| | Extraversion | Agreeableness | Conscientiousness | Neutoticism | Openness to new experiences |
|---|---|---|---|---|---|
| Normal users | 41 (80%) | 44 (86%) | 30 (59%) | 24 (47%) | 48 (94%) |
| Mild level | 54 (57%) | 81 (86%) | 74 (79%) | 61 (65%) | 83 (88%) |
| Moderate level | 21 (57%) | 26 (70%) | 25 (68%) | 23 (62%) | 28 (76%) |
| Severe | 0 | 1 | 1 | 1 | 1 |

# 4 Related Work

## *4.1 Psychological and Personality Traits per Internet Addiction Category*

Typically, addiction can be observed in one or more from the categories below:

(a) **Online social media**. The success of social media is explained by the fact that they are egocentric media, with Facebook being one of the most common occupations [7]. Addicted users typically want to be accepted by their social circle and maintain their relations [18], mostly by bringing out the positive features of his appearance and personality [19]. In fact, young people tend to connect to Facebook at least 5–10 times a day [8]. They tend to be connected to this 5–10 times per day [8]. Furthermore, men tend more to be addicted to Internet than women. [7, 8].
(b) **Online pornography**. Men being influenced by the content of these movies, become more aggressive [20], addictive and coercive [21].
(c) **Online gambling**. Online gambling players, similarly to social media (addicted) users, do not admit or try to hide how many hours they spend in their online activity [22].
(d) **Online gaming**. The biggest percentage of addicted users associated to online gaming is teen boys [23]. Their distinctive feature is that if they continue this addictive behavior, their addiction will stay or may be increased as they grow old.
(e) **Internet browsing**. Users addicted to Internet browsing are divided in other subcategories according to their habits such as Internet shopping, e-mail checking, discussing in forums/groups [7]. It has been shown that addicted people might use the Internet up to 20 times a day [8]

One of the purposes of this paper was to survey the personality features of addicted users and their psychological symptoms. To be consisted with our own survey of Sect. 2, Table 4 summarizes, per addiction category, the psychological characteristics of addicted users (underlined in the table), as well as their basic personality traits as described in the big five factor model.

**Table 4** Psychological and personality traits per Internet addiction category

| | Extraversion | | Neuroticism | | | | Openness to experience | | Agreeableness | | Conscientiousness |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Pornography | Men aggressive towards women [21] | Sexual stimulation [26] | Unsuccessful efforts for abstinence from pornography [35] | Uncontrollable sexual behaviour [36] | Solitary stimulation [26], mood regulation [26], Distraction [26] | Pathological disorder in decision-making [35], Obsessive-Compulsive Disorder (OCD) [36] | Imagination connecting unacceptable actions with acceptable. [36] | Sexual curiosity [26], Imagination becomes reality [26] | Cocktail of chemical reactions in brain causing pleasure [35] | Satisfaction of sexual fantasies [26] | No qualms due to anonymity [37] |
| Gambling | Social closeness [27] | Well being, social potency [27] | Unsuccessful efforts for abstinence from gambling [19] | Irritable when trying to reduce or stop gambling [19] | Anxiety [36], Feeling sad [19], Negative Emotionality [27], Agoraphobia [38] | Panic [36], self-supression [27], Feeling angry [36] | Betting more money in order to feel more excited [19] | | | | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Gaming | Alone-ness [37] | Impul-sivity [37] | Hyper-activity [37] | Quitting all other interests [38], Violent behavior [12] | Social stress about whether the social circle would accept them or not [37] | Emotionally stable [20], Higher tolerance for stressful situations [25, 28] | | | Getting bored easily [37], Jumping from one game to another [38] | Sense of achieved success [27], concerns for other's well-being [20] | Aversion towards delayed recognition by the social circle [37] |
| Social media | Curi-ousness [17] Sensi-tive to poten-tial threats [17] | User social-izes [37], have more friends [24], Narcis-sism [37] | Subtropical behavior (when abstain for a period) [37] | Symptoms of deprivation [37] | Mental anxiety [37], Neglecting personal life [37], Empathetic [17] | Trying to hide addictive behaviour [37] | In a mood for alternate experiences [37] | Helpful [23] | Tolerance in devoting more time on social media [13] | Have low self-esteem [37] | |
| Web browsing | | | Feeling isolated [17], Mood changes [36] | Deprivation symptoms [36], Need for more time online [1] | Social stress [35], Looking for self-esteem [17] | Stress from the familiar environment [36] | | | Internet fraud when being online [36] | Difficulty in defining his happiness [17] | |

It is evident from the table that most of the Internet addicted users are related to neurosis. In all IA categories, besides Web browsing, users seem to feel loneliness. In comparison to other categories, the social media and online gaming users seem to try hardly to be accepted from their social environment. In addition, online gaming and Web browsing users seem to be more averse to new experiences in comparison with the other categories, with Web browsing category exhibiting the fewest personality characteristics. Finally, based on their characteristics, pornography users seem to have the most dysfunctional personality features.

### *4.2 Related Internet Addiction Surveys on Young Adults*

In a recent research [29], conducted in Italy, the user habits and psychological factors of Internet addicted users, aged 19–26, where surveyed, using the Big Five Factor Model and Internet Addiction Test. In the survey, which involved 190 people (117 women and 73 men), it was indicated that 31 people ( 16%), 13 women and 18 men were addicted. As for user habits, the majority (109 persons - 58%) connected mainly in the afternoon, while the number of users at night and midday was the same. The majority of users were shown to use the Internet to meet other people or chat with friends, but also to gather information, while very few users appear to use the Internet for work or education purposes. As for psychological factors, it was observed that the factor of extraversion and agreeableness had a negative impact in the addiction problem, while the factor of openness to new experiences had a positive effect in addiction. Conscientiousness and neuroticism did not have any effect in the addiction problem [29]. Specifically no person was detected to have high scores in the Internet Addiction Test and there were not any differences between the two sexes. It was observed that the frequent Internet use can have positive impact in the problem [29].

A survey in China [30] targeted students between 20 and 30 years old. The survey focused on the psychological profile of users, such as stress, restraint and depression while trying to correlate them with the users' Internet addiction level. In the survey participated 500 people, 262 of them were women and 238 men. The results of the Internet addiction test showed a total of 85 people (17%) being addicted, (in particular, 42 women and 43 men). There were also 33 addicted people (38.8%) and 54 people (13%) without addiction that showed depression signs. It appears that people with positive relation with the problem are more likely to experience depression than others [30]. No differences were observed in relation to age or sex. It was also observed that the self-restraint is not linked to the problem of Internet addiction while the denial is positively related to it. The research also showed that the addiction is associated with stress, while persons with positive relation are more likely to have other mental diseases such as depression [30].

A survey in Chile [8] assessed the addiction levels of 384 medical students, with an average age of 21 years, on the Internet as well as the psychological factors associated with the problem. A 63.8% of surveyed students, among which 224 males

(58.3%) and 160 females (41.7%), answered that their parents live away from the town of their study. All users answered that they use e-mail, while 97.6% answered to be Facebook users and 33% Twitter users. Also 35.2% said they had a history of psychiatric diagnosis while 9.1% were in psychiatric treatment [8]. The results of the Internet addiction test showed that 33 men (14.7%) and 11 women (6.9%) were addicted.

In Greece, a survey was conducted with 534 medical students at the Aristotle University of Thessaloniki [7]. From the participants, 373 people (69.9%) were normal Internet users, 131 (24.5%) showed mild level of addiction, 29 people (5.4%) had moderate level of addiction and one person (0.2%) showed a severe dependence [7]. From the addicted people, 76 were men and 85 women. It was detected that the majority of addicted people lived alone in the town of their study (81 people). Addicts were mainly connected to the Internet from home, while Facebook usage was shown to have positive relation with the problem. Other activities of dependent users were online games, online gambling, pornography, and chatting. It was also observed that the use of email has a negative association with the problem. An observation made in the survey is that the connection of people in places other than their home is a factor that can make people develop Internet addiction [7].

The difference between own research and the survey in [7] is that we not only examine the addiction levels of young adults but also we use the big five factor model to assess the psychological profile of the addicted adults and study their personality.

## 5 Information Privacy and Internet Addiction

Several studies have investigated the factors driving online information disclosure willingness and the information privacy paradox [31]. The information privacy paradox refers to an inconsistent behavior in which although privacy is a primary concern for individuals, at the same time they are willing to reveal personal information for relatively small rewards, often just for drawing the attention of peers in an online social networks [31]. Users claim that the main benefits of information sharing that they value are self-clarification, social validation, relationship development, social control, and self-representation [32].

Therefore, in this paper we stress that in addition to all other psychological symptoms (e.g., depression) and impacts that had been associated to IA, addicted individuals may also be confronted with significant consequences regarding their information privacy following disclosure of personal information. Research in this field is in its infancy and mostly targeted around social networks. Studies associate the possession of SNS profile with high-risk taking attitudes towards information sharing. Interestingly, a survey study conducted in 2013 [33] among Facebook users and Facebook quitters concludes that people who quitted Facebook had higher IA scores and higher concerns about information privacy. The survey investigated the reasons behind Facebook quitting: the top reason reported was information privacy

concerns and the second reason was the feeling of getting addicted to Facebook. Information privacy are also reported to be the main reason leading individuals to decide what is metaphorically called 'virtual identify suicide' (a person quitting her online social life and associated digital identity) [33]. On the other hand, another study presents contradictory findings: a survey conducted also in 2013 concludes that privacy concerns of SNSs users (including unauthorized secondary use of, and improper access to, shared information) did not significantly affect their problematic SNS use, which means even if people have privacy concerns, those concerns do not necessarily prevent them from using SNS compulsively [34]. Future research is this field is imperative which will investigate the relationship among information privacy risk-taking behavior and the personality traits of Internet addicted individuals. Further, additional research in necessary to explore the association among privacy concerns and their potential contribution to IA treatments, thus IA interventions with emphasis on privacy concerns aiming to deal with IA. Further, future research should investigate information privacy in the context of other IA categories, such as email or information search, which have not been explored yet.

## References

1. Young, K.S. 1998a. Internet Addiction: The Emergence of a New Clinical Disorder. *Cyber Psychology & Behavior* 1 (3): 237–244.
2. Young, K.S., and R.C. Rogers. 1998. The Relationship Between Depression and Internet Addiction. *Cyber Psychology & Behavior* 1 (1): 25–28.
3. Young, K.S. 1998b. *Caught in the Net: How to Recognize the Signs of Internet Addiction–and a Winning Strategy for Recovery*. New York: John Wiley & Sons.
4. Yoo, H.J., S.C. Cho, J. Ha, S.K. Yune, S.J. Kim, J. Hwang, A. Chung, Y.H. Sung, and I.K. Lyoo. 2004. Attention Deficit Hyperactivity Symptoms and Internet Addiction. *Psychiatry and Clinical Neurosciences* 58 (5): 487–494.
5. Pies, R. 2009. Should DSM-V Designate "Internet Addiction" a Mental Disorder? *Psychiatry (1550–5952)* 6 (2): 31–37.
6. Griffiths, M. 2000. Internet Addiction-Time to be Taken Seriously? *Addiction Research* 8 (5): 413–418. Chicago.
7. Tsimtsiou, Z., A.B. Haidich, D. Spachos, S. Kokkali, P. Bamidis, T. Dardavesis, and M. Arvanitidou. 2015. Internet Addiction in Greek Medical Students: An Online Survey. *Academic Psychiatry* 39 (3): 300–304.
8. Berner, J.E., J. Santander, A.M. Contreras, and T. Gómez. 2014. Description of Internet Addiction Among Chilean Medical Students: A Cross-Sectional Study. *Academic Psychiatry* 38 (1): 11–14.
9. Wallace, P. 2014. Internet Addiction Disorder and Youth. *EMBO Reports* 15 (1): 12–16.
10. Lee, H.W., J.S. Choi, Y.C. Shin, J.Y. Lee, H.Y. Jung, and J.S. Kwon. 2012. Impulsivity in Internet Addiction: A Comparison with Pathological Gambling. *Cyberpsychology, Behavior, and Social Networking* 15 (7): 373–377.
11. Carli, V., T. Durkee, D. Wasserman, G. Hadlaczky, R. Despalins, E. Kramarz, C. Wasserman, et al. 2012. The Association Between Pathological Internet Use and Comorbid Psychopathology: A Systematic Review. *Psychopathology* 46 (1): 1–13.
12. M'hiri, K., A. Costanza, Y. Khazaal, R. Khan, D. Zullino, and S. Achab. 2016. Problematic Internet Use in Older Adults, A Critical Review of the Literature. *Journal of Addiction Research and Therapy* 2015.

13. Shaw, L.H., and L.M. Gant. 2002. In Defense of the Internet: The Relationship Between Internet Communication and Depression, Loneliness, Self-Esteem, and Perceived Social Support. *Cyberpsychology & Behavior* 5 (2): 157–171.
14. Caplan, S.E. 2006. Relations Among Loneliness, Social Anxiety, and Problematic Internet Use. *Cyber Psychology & Behavior* 10 (2): 234–242.
15. Feng, Q., X. Chen, J. Sun, Y. Zhou, Y. Sun, W. Ding, Y. Zhang, Z. Zhuang, J. Xu, and Y. Du. 2013. Voxel-Level Comparison of Arterial Spin-Labeled Perfusion Magnetic Resonance Imaging in Adolescents with Internet Gaming Addiction. *Behavioral and Brain Functions* 9 (1): 1.
16. Yuan, K., W. Qin, G. Wang, F. Zeng, L. Zhao, X. Yang, P. Liu, et al. 2011. Microstructure Abnormalities in Adolescents with Internet Addiction Disorder. *PloS One* 6 (6): e20708.
17. Goldberg, L.R. 1990. An Alternative "Description of Personality": The Big-Five Factor Structure. *Journal of Personality and Social Psychology* 59 (6): 1216.
18. Kuss, D.J., and M.D. Griffiths. 2011. Online Social Networking and Addiction—A Review of the Psychological Literature. *International Journal of Environmental Research and Public Health* 8 (9): 3528–3552.
19. O'Keeffe, G.S., and K. Clarke-Pearson. 2011. The Impact of Social Media on Children, Adolescents, and Families. *Pediatrics* 127 (4): 800–804. http://pediatrics.aappublications.org/content/early/2011/03/28/peds.2011-0054.
20. Mowlabocus, S., and R. Wood. 2015. Introduction: Audiences and Consumers of Porn. *Porn Studies* 2 (2–3): 118–122.
21. Dhuffar, M.K., and M.D. Griffiths. 2015. A Systematic Review of Online Sex Addiction and Clinical Treatments Using CONSORT Evaluation. *Current Addiction Reports* 2 (2): 163–174.
22. Sauvaget, A., S. Jiménez-Murcia, F. Fernandez-Aranda, A.B. Fagundo, L. Moragas, I. Wolz, M. Veciana De Las Heras, et al. 2015. Unexpected Online Gambling Disorder in Late-Life: A Case Report. *Frontiers in Psychology* 6: 655.
23. Wang, C.W., R.T. Ho, C.L. Chan, and S. Tse. 2015. Exploring Personality Characteristics of Chinese Adolescents with Internet-Related Addictive Behaviors: Trait Differences for Gaming Addiction and Social Networking Addiction. *Addictive Behaviors* 42: 32–35.
24. Tsitsika, A., E. Tzavela, F. Mavromati, T. Schoenmakers. 2014. Research on Internet Addictive Behaviours Among European Adolescents.
25. Wéry, A., and J. Billieux. 2016. Online Sexual Activities: An Exploratory Study of Problematic and Non-problematic Usage Patterns in a Sample of Men. *Computers in Human Behavior* 56: 257–266.
26. Bean, A., and G. Groth-Marnat. 2016. Video Gamers and Personality: A Five-Factor Model to Understand Game Playing Style. *Psychology of Popular Media Culture* 5 (1): 27.
27. Gainsbury, S.M. 2015. Online Gambling Addiction: The Relationship Between Internet Gambling and Disordered Gambling. *Current Addiction Reports* 2 (2): 185–193.
28. Watson, J.C. 2005. Internet Addiction Diagnosis and Assessment: Implications for Counselors. *Journal of Professional Counseling, Practice, Theory, & Research* 33 (2).
29. Servidio, R. 2014. Exploring the Effects of Demographic Factors, Internet Usage and Personality Traits on Internet Addiction in a Sample of Italian University Students. *Computers in Human Behavior* 35: 85–92.
30. Chou, W.P., C.H. Ko, E.A. Kaufman, S.E. Crowell, R.C. Hsiao, P.W. Wang, and C.F. Yen. 2015. Association of Stress Coping Strategies with Internet Addiction in College Students: The Moderating Effect of Depression. *Comprehensive Psychiatry* 62: 27–33.
31. Kokolakis, S. 2015. Privacy Attitudes and Privacy Behaviour: A Review of Current Research on the Privacy Paradox Phenomenon. *Computers & Security*. Available online 10.
32. Lee, H., H. Park, and J. Kim. 2013. Why Do People Share Their Context Information on Social Network Services? A Qualitative Study and an Experimental Study on Users Behavior of Balancing Perceived Benefit and Risk. *International Journal of Human-Computer Studies* 71 (9): 862–877.
33. Stieger, S., C. Burger, M. Bohn, and M. Voracek. 2013. Who Commits Virtual Identity Suicide? Differences in Privacy Concerns, Internet Addiction, and Personality Between Facebook Users and Quitters. *Cyberpsychology, Behavior, and Social Networking* 16 (9): 629–634.

34. Chen, H., and Y. Kim. 2013. Problematic Use of Social Network Sites: The Interactive Relationship Between Gratifications Sought and Privacy Concerns. *Cyberpsychology, Behavior and Social Networking* 16 (11): 806–812.
35. Sayre, G.M., and J.J. Dahling. 2016. Surveillance 2.0: How Personality Qualifies Reactions to Social Media Monitoring Policies. *Personality and Individual Differences* 90: 254–259.
36. Miller, J.D., J. MacKillop, E.E. Fortune, J. Maples, C.E. Lance, W.K. Campbell, and A.S. Goodie. 2013. Personality Correlates of Pathological Gambling Derived from Big Three and Big Five Personality Models. *Psychiatry Research* 206 (1): 50–55.
37. Egan, V., and R. Parmar. 2013. Dirty Habits? Online Pornography Use, Personality, Obsessionality, and Compulsivity. *Journal of Sex and Marital Therapy* 39 (5): 394–409.
38. Marshall, T.C., K. Lefringhausen, and N. Ferenczi. 2015. The Big Five, Self-Esteem, and Narcissism as Predictors of the Topics People Write About in Facebook Status Updates. *Personality and Individual Differences* 85: 35–40.

# A DICOM Based Collaborative Platform for Real-Time Medical Teleconsultation on Medical Images

**Ilias Maglogiannis, Christos Andrikos, Georgios Rassias, and Panayiotis Tsanakas**

**Abstract** The paper deals with the design of a Web-based platform for real-time medical teleconsultation on medical images. The proposed platform combines the principles of heterogeneous Workflow Management Systems (WfMSs), the peer-to-peer networking architecture and the SPA (Single-Page Application) concept, to facilitate medical collaboration among healthcare professionals geographically distributed. The presented work leverages state-of-the-art features of the web to support peer-to-peer communication using the WebRTC (Web Real Time Communication) protocol and client-side data processing for creating an integrated collaboration environment. The paper discusses the technical details of implementation and presents the operation of the platform in practice along with some initial results.

**Keywords** Online collaboration systems • Multi-disciplinary team meetings • Medical images • DICOM • WebRTC

## 1 Introduction

Medical Institutions and Hospitals are nowadays equipped with advanced medical imaging devices, often called image modalities, that produce several GigaBytes (GBs) of data per day. According to a recent study performed in the framework of a national infrastructure project operated by GR-NET for the development of a central image repository, the amount of data produced by image modalities in

I. Maglogiannis (✉)
Department of Digital Systems, University of Piraeus, Piraeus, Greece
e-mail: imaglo@unipi.gr

C. Andrikos • G. Rassias
GR-NET, Athens, Greece
e-mail: candrikos@cslab.ece.ntua.gr; grassias@cslab.ece.ntua.gr

P. Tsanakas
School of Electrical and Computer Engineering, National Technical University of Athens, Athens, Greece
e-mail: panag@cs.ntua.gr



P. Vlamos (eds.), *GeNeDis 2016*, Advances in Experimental Medicine and Biology 989, DOI 10.1007/978-3-319-57348-9_7

the Greek hospitals is above 200 PetaBytes per year. Modern Picture Archiving and Communication Systems called PACS are undertaking the burden of storing and communicating this rich medical information, in Electronic Health Records, Databases and terminal devices operating with the use of the DICOM protocol (http://dicom.nema.org/standard.html). Although the utilization of medical images is a routine in hospital clinical practice, this kind of data exchange is usually reduced at a hospital level between clinics and radiology departments. The need to integrate this processes in geographically distributed and organizationally independent health organizations and their medical personnel has arisen, so as to exploit expert medical knowledge and improve the quality of healthcare services. Furthermore, complex medical cases, requiring sophisticated decisions, have become the springboard of team-based treatment in modern healthcare practice. This trend shifts healthcare practice from a single clinician to a group of healthcare experts in different disciplines, providing unique services to the patient, with the aim of ensuring care and support. This results in the necessity for the development of MDTMs (Multi-Disciplinary Team Meetings) infrastructure.

This challenge leads the design of health information applications that combine the principles of heterogeneous Workflow Management Systems (WfMSs), the peer-to-peer networking architecture and state of the art technologies of the World Wide Web such as WebRTC (Web Real Time Communication), JavaScript and the SPA (Single-Page Application) concept, to facilitate medical information exchange among personnel geographically distributed. The goal of this research is to combine communication and computing technology in order to provide such a collaborative environment able to support physicians in team based treatment and the exchange of second opinion through the distributed communication of medical data/images. The proposed service will exploit the high-speed optical connection of major hospitals to the GRNET backbone network and the Cloud infrastructure, which is already available. The establishment of computer based collaborative medical environments is not a new idea according to the literature survey included in the next Section. However, the WWW technology for real time services and applications that satisfy the demanding physicians requirements has recently been improved enabling new potentials in this domain. The main technological innovations introduced in this project is the full exploitation of Cloud features such as elasticity and scalability for medical image storage and processing and the adoption of the state of the art WebRTC technology for real time video and data communication. This approach enables client-side computing and Web2 stacks (HTML 5, JavaScript, CSS) allowing the development of fast and platform-independent applications. Furthermore, recent developments in cloud computing and the widespread use of mobile smart devices raise the need of device interoperability and transparency, introducing the concept of BYOD (Bring Your Own Device). A SPA (Single-Page Application) is a web application or a web site that fits on a single web page with the goal of providing a more fluid user experience akin to a desktop application complying with the aforementioned principle. The users of a SPA may access the same service from their own workplace desktop as well as any other fixed of mobile device, getting the additional benefits of portability and cross-platform functionality

**Table 1** The basic requirements of the implemented online collaboration system

| Functionality | Description |
|---|---|
| User registration | All participating physicians should be registered. During the registration procedure, the necessary identification will be provided in compliance with the user lists that exist in the GRNET AAI Federation. |
| Collaborative session establishment | Upon logging into the system, each physician will declare availability to receive calls. In case that a call is accepted by a user, a secure communication channel will be initiated and the collaboration environment will be established, including the visualization of medical imaging data. The images will be kept in the cloud infrastructure while the Digital Imaging and Communications in Medicine (DICOM) standard will be utilized for data storage and transmission. |
| Audiovisual communication | Real-time audiovisual and data communication within the web browser using state of the art videoconferencing technology. |
| Image analysis tools | The collaborative environment will be enhanced by bi-directional interaction on objects in real time. The platform could support indicatively the following actions:<br>• Image editing and Annotation: Textual notes can be included on particular regions of interest (ROI) within the picture and geometrical schemes can be drawn on ROIs.<br>• Basic Image Manipulation and Processing: Physicians will be able to select different color or Spectrum channels for image viewing, Alter the contrast and the brightness level of the medical image displayed and apply filters.<br>• Image scaling (zoom-in, zoom-out): The user should be able to increase and decrease the zoom level of a picture. |
| Management and security issues | An application for the system administration is foreseen in order to manage role-based access and security. Secure Socket Layer (SSL) and digital certificates will be utilized, to achieve secure transmission. |

of the web. The basic requirements of the foreseen on-line collaboration system delivered as a SPA are summarized in Table 1.

The rest of the paper is structured as follows: In Sect. 2 we present the related work and some background information on this field, while in Sect. 3 we discuss the technical details of the proposed implementation. Section 4 describes the operation of the platform in practice and finally, Sect. 5 concludes the paper.

## 2 Related Work

As already mentioned, the development of a distributed collaborative system for medical teleconsultation is not a new idea. CREW [1] is the first example of a medical collaborative platform implemented at the University of Michigan. This

computer-based environment is able to provide multiple accesses to exported file and provide the medical community with information related to other CREW members. InterMed [2] and TeleMed [3] are similar systems aiming at the development of robust frameworks for medical collaboration, using the Internet as the basic network. Especially the project TeleMed supports both real-time and off-line sessions. The ARTEMIS project had as goal the "advanced cooperative activities of healthcare providers and the promotion of total and real-time care" [4]. In the specific project a group of developers, physicians, and healthcare researchers were using prototypes and commercial off-the-shelf technologies integrated as an open collaboration healthcare environment. This environment allowed primary care physicians to consult with remote specialists entailing computer support for X-rays, ultrasound, voice-annotations, and other multimedia information. Another project focusing on the healthcare collaboration domain is the virtual medical office ref., which was an integrated environment that encourages users to take active participation in the management of their health. This system provided access to digital medical libraries, yellow pages, and regional healthcare resources. WebOnCOLL [5] is another similar system that has been designed in the context of a regional healthcare network in Crete and employs the infrastructure of regional healthcare networks to provide integrated services for virtual workspaces, annotations, e-mail, and on-line collaboration.

A newer approach to the problem of online medical collaborative platforms is presented in [6]. Authors in this work adopt a hybrid architecture combining peer-to-peer and client-server elements. More specifically peer-to-peer exchange is used during the collaborative sessions for audio and video communication between the remote medical personnel as well for medical data exchange (medical records and DICOM image files). The described system implements client-server communication on the other hand for user management in order to resolve security issues, and for retrieving medical data from external sources (i.e. PACS or external EHRs). The VIRGO network [7] was implemented to support physicians, patients and academic institutions in the discovery and extraction of complex medical knowledge. The proposed system adopts a semantic approach to information search over DHTs (Distributed Hash Tables) and focuses mainly on data sharing between independent medical institutions. In the same context, the authors in [8] present a system that handles data integration and interoperability issues based on an ontological model. Similarly, the authors of [9] present a web based architecture for workflow management in the medical domain using an ontological model. The proposed system is applied a variety of circumstances where medical professionals of different specialties must work together. A medical procedure is treated as a subject of study and activities related to medical meetings are allocated to peer participants, according to their metadata. This strategy provides time efficiency, faster treatment and reducing the risk of loss of medical records. A central entity plays a key role in the commissioning of peers since there are no mechanisms for distributed data storage and retrieval. In [10], authors present a grid based system built for telemedicine purposes. A distributed data network is formed between hospitals, mobile clinics and regional clinics. Medical information is flown between

the entities involved and geographical criteria are used in order to route data and reduce the response time in critical medical events. Finally, authors in [11] introduce the concept of an active content collaboration platform, which supports automated event-drive collaborative procedures. The proposed system leverages the power of cloud computing to perform demanding tasks, such as three-dimensional image reconstruction. However, the specific system does not offer video conferencing capabilities or interaction with medical data in real time.

The surveyed systems have proven the value of peer-to-peer solutions for the exchange of medical data and the development of collaborative MDTMs (Multi-Disciplinary Team Meetings) for healthcare professionals. The described platforms focus on the storage and transmission of medical data presenting mostly easy to use tools for medical data transfer. What we try to accomplish in this work is more than a communication tool. It is an integrated collaboration environment that shares medical data among physicians that could work as a decision-making tool for assisting joint diagnosis. The proposed tool is limited for the moment in medical images, however this idea could be expanded in complete EHRs. The contribution of this work is the design and the implementation of the foreseen integrated collaboration environment. The goal is to offer, in addition to secure medical data sharing, the ability to create processing workflows that will assist participating doctors to reach a common diagnosis and taking a common medical decision. In this context the proposed system includes, in addition to the video and data communication facilities, modules that enable common annotation and handling of medical images, as well as libraries for filtering image data and applying complex processing workflows for better visualization of findings. To this end, state-of-the-art web technologies such as HTML5, CSS3, JavaScript and APIs such as WebRTC, Canvas are used in order to enable user friendly and interoperable on-line MDTMs capabilities. The proposed system is fully compatible with the DICOM standard, thus it can communicate with any known PACS or DICOM archive systems and can be easily integrated in a wider medical information system supporting the DICOM format (i.e. a centralized hospital information system or a Cloud EHR repository). In the next section the architectural aspects and the technical details of the implemented SPA are summarized.

## 3 Architectural Aspects and Utilized Technology

As already mentioned this work focuses on the design and implementation of a transparent and robust platform for on-line medical collaboration and MDTM services, which will be delivered as a SPA. The proposed platform introduces an indirect RPC (Remote Procedure Call) scheme that enables physicians to collaborate in real time using an image processing toolbox. The technical details of the platform are presented in [12]. The overall architecture is depicted in Fig. 1 and consists of the UAC (User Access Control) and the PAS (Participant server) subsystems.

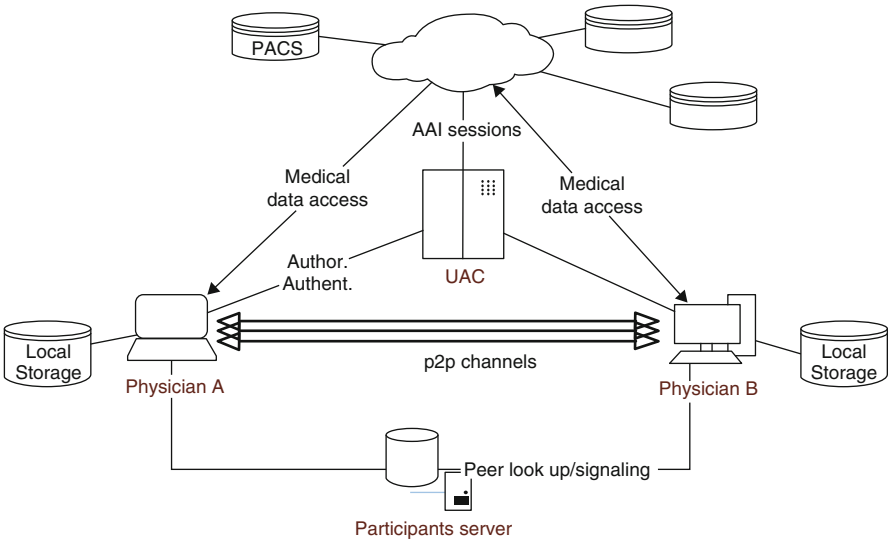


**Fig. 1** Overall architecture

UAC is responsible for user authentication and authorization, by interacting with AAI (Authentication and Authorization Infrastructure), while PAS enumerates securely the user profiles to all potential callers-participants and coordinates initial communication stages.

The communication establishment is as follows: Consider two potential users: A and B as illustrated in Fig. 1. Upon login, user (physician) A acquires an authentication token by triggering UAC to request a digital signature from a third trusted party. PAS returns to user A the manifest of all online participants matching to contact list. After user B logins, PAS updates asynchronously the contact list of physician A, while A may access the supported PACS service of his choice to retrieve and process any medical data. A conference session between the two physicians takes place after the initiator creates a new room. Initial negotiations and further signaling are propagated to participants through PAS, to result to symmetric WebRTC data channels set up.

The proposed system supports the DICOM standard and incorporates a complete DICOM file viewer. Interaction with external DICOM sources (i.e. a PACS imaging modality) is done via the WADO (Web Access DICOM Objects) protocol. The main feature, which is the real-time collaboration service, is based on multi-channel video conferencing, workspace screen and file sharing, data channels and shared annotations. The peer-to-peer interconnection scheme is selected in order to eliminate any intermediate party overheads and scalability issues. A significant innovation of the proposed platform is the utilization of the WebRTC protocol as communication mechanism. WebRTC is a state of the art open source project initiated by Google that provides browsers with secure (encryption embedded) RTC (Real-Time Communication) capability including both audiovisual and data channels.

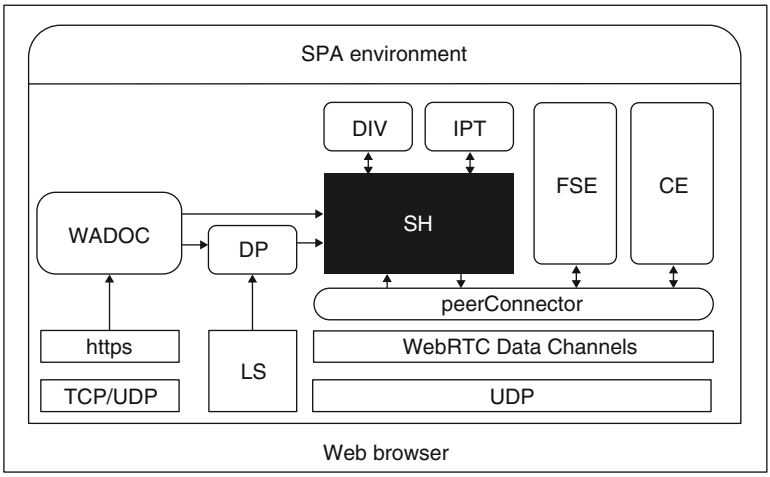


**Fig. 2** The SW modules of the single-page web application that provide rich real-time collaborative services

The implemented SPA consists of seven autonomous modules: WADOC, DP, DIV, IPT, FSE, CE and PeerConnector as illustrated in Fig. 2. WADOC (WADO Connector) is responsible for requesting and receiving DICOM persistent objects, i.e. images and medical imaging reports, from remote repositories, via a simple REST API. DP (DICOM Parser) parses DICOM files to extract medical images and corresponding medical metadata. It is designed to utilize modern multi-core architectures efficiently and reduce memory footprint. DIV (DICOM Image Viewer) is the component tasked with displaying medical images, while IPT (Image Processing Toolbox) provides key functionality for image manipulation and processing. PeerConnector leverages WebRTC APIs (i.e. MediaStream, RTCPeerConnection, RTCDataChannel) to manage the communicational requirements of the SPA, via streams and asynchronous message exchange. The conferencing and file sharing services are provided by CE (Conferencing Engine) and FSE (File Sharing Engine), respectively. Both engines interact with PeerConnector module according to producer-consumer Scheme. CE manages audio/video channels and offers PeerConnector local streams while the latter returns to CE the remote ones. In a similar way, FSE supplies PeerConnector with arbitrary data to be transmitted, and vice versa.

## 4 The System in Practice

Designing the user interface for such a complex application is not a trivial task. In our effort we have adopted basic design guidelines established by major medical imaging software such as the RadiAnt (http://www.radiantviewer.com) and the

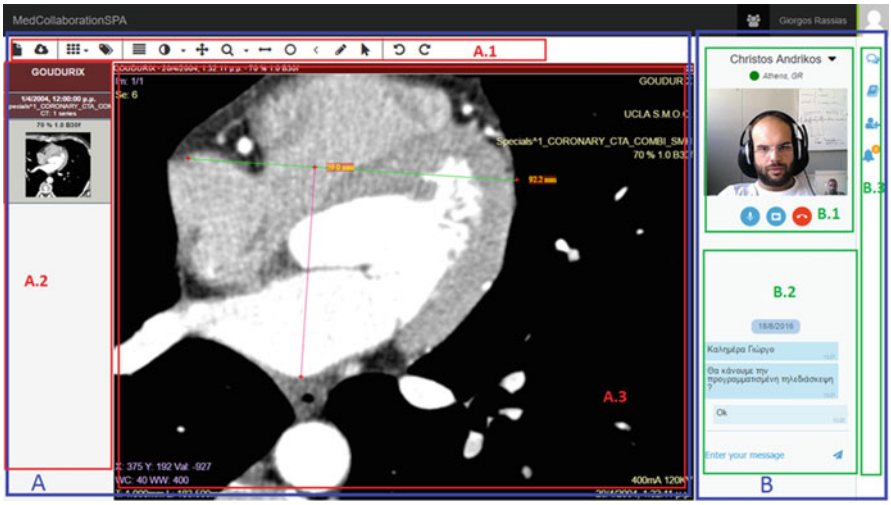


**Fig. 3** SPA screenshot during a real-time collaborative session on a CT instance between two participants

OsiriX (http://www.osirix-viewer.com) SW packages. In Fig. 3 we illustrate an indicative screenshot of the proposed SPA. The frame indicated with the letter A depicts the imaging panel, and hosts all the basic functionality related to the collaborative working on medical image studies. The upper toolbar framed as A.1 includes the incorporated DICOM commands, while the left-side column framed as A.2 depicts previews of all the opened series organized according to patient and study unique identifiers. A user can navigate to the desired series and display the corresponding images, by clicking the appropriate thumbnail view, while the actual rendering takes place in the adjacent interactive viewport framed as A.3.

Frame B in the same figure refers to the windows of the communication facilities provided by the proposed SPA. In these windows the SPA incorporates the video, chat, and contacts subpanels framed as B.1, B.2 and B.3, respectively. Video panel includes all the local and remote video streams, while the chat panel includes text and data exchange among the participants of a collaborative session. Finally, the contact panel provides users the ability to create virtual rooms, by browsing their contact lists and sending invitations to other users/physicians that they wish to collaborate with.

The proposed SPA supports single medical images compliant to the DICOM format or DICOM image series from a specific examination. The medical images could be retrieved either from a local storage device (i.e. a CD or a USB containing the DICOM image series) or a remote DICOM server using the WADO (Web Access to DICOM Objects) protocol. At the current state the implemented SPA supports interconnection with the Orthanc and the DCM4CHE DICOM ref. servers that support WADO communication using RESTful APIs. The latter functionality is illustrated in Fig. 4.

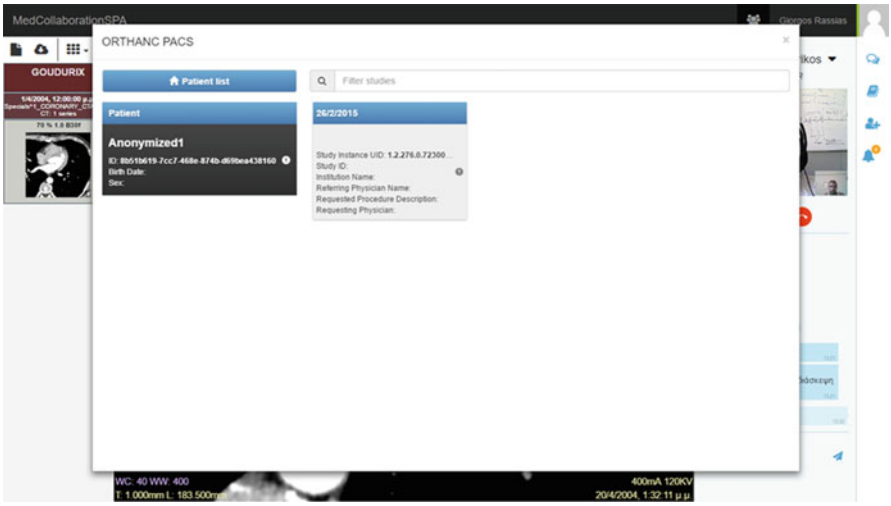


**Fig. 4** Browsing a remote PACS server (Orthanc) during a teleconference session

The implemented SPA does not imply any kind of limitation to the size of the medical image data loaded simultaneously. The limitations are related only to the memory and computing resources of the machine running the SPA. The user can navigate across the loaded images using thumbnails similarly to any commercial DICOM viewer application (see Fig. 5). The image series displayed in the main panel has a lighter grey color, while for each image series basic information is included in the thumbnail (i.e. patient name, image type, date, etc.).

Image manipulation is done using the buttons that appear in the image processing toolbar (Fig. 6). The basic supported operations are as follows:

- Image window adjustment
- Image Navigation
- Basic Processing: Brightness and Contrast Adjustment, Window Level
- Move Image
- Zoom-in and Zoom-out
- ROI (Regions of Interest) Tools: Length, Area, Angle, Path
- Change of Orientation
- View DICOM data

Figure 7 displays an example of adjusting image brightness and contrast, while Fig. 8 depicts ROI measurements. It should be noted that any action performed by a user during a collaborative session appears in real time in all-participating users. Finally, Fig. 9 displays the window containing all DICOM data.

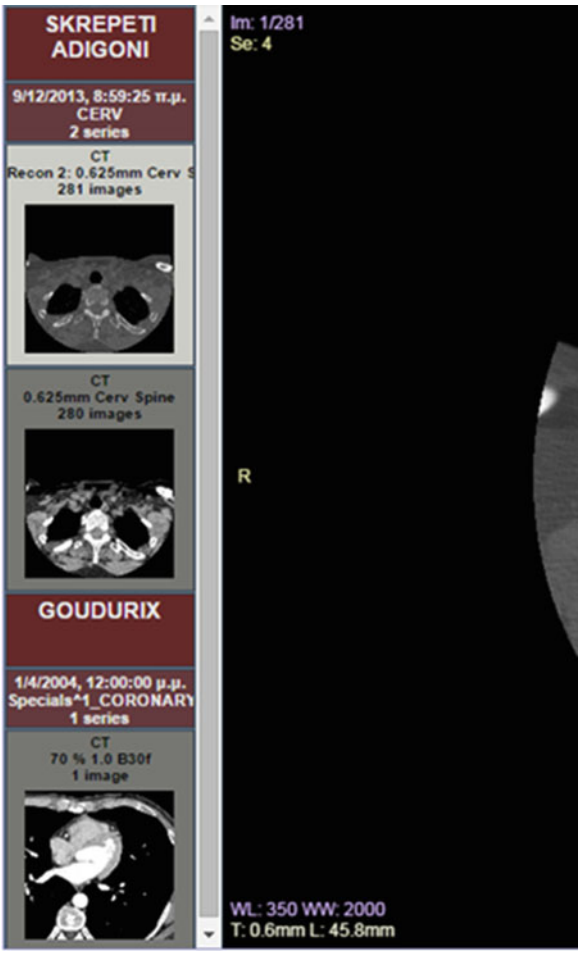


**Fig. 5** Navigation panel using thumbnails for each DICOM image or series

**Fig. 6** Image processing toolbox

## 5 Conclusion and Future Work

In this paper we presented an online collaborative platform enabling physicians located at geographically remote places to co-work on a DICOM medical image. The same concept presented here can be expanded to any type of medical data (i.e. an ECG signal or a digital pathology image). The proposed platform follows the BYOD (Bring Your Own Device) trend, since the client framework is developed on the web browser. Thus the proposed implementation does not require plug-ins or any external software. It resembles a typical web application, while the

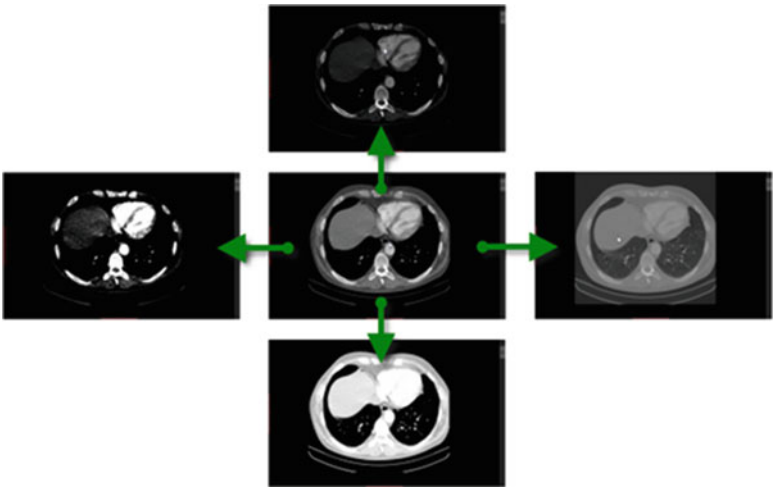

**Fig. 7** Adjusting image brightness and contrast

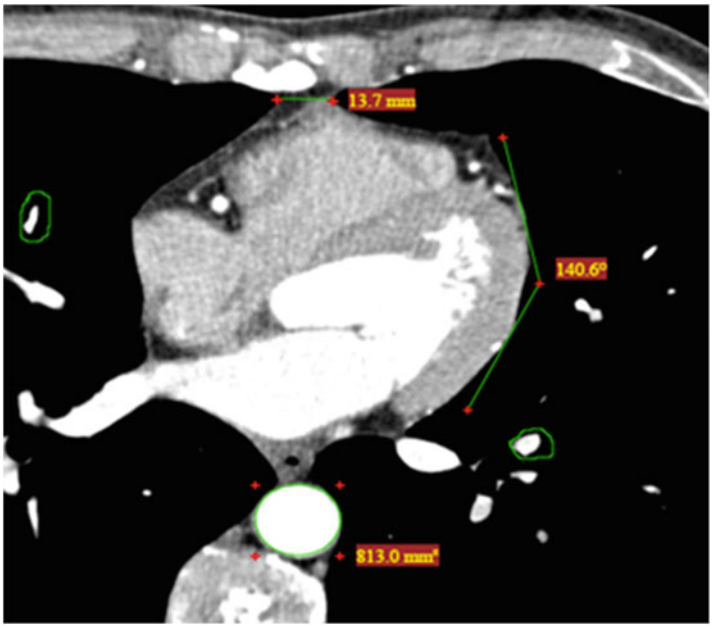


**Fig. 8** ROI measurements

main image processing takes place at the client side. This, in conjunction with the peer-to-peer mesh network configuration for interconnecting the participants, is proven a scalable and efficient solution to support remote MDTMs. As a future work we wish to include extra functionality to extend the concept of common

DICOM tags

| Tag ID | VR | Length | Description | Value |
|---|---|---|---|---|
| (0002,0001) | OB | 2 | FileMetaInformationVersion | 0 / 1 |
| (0002,0002) | UI | 26 | MediaStorageSOPClassUID | 1.2.840.10008.5.1.4.1.1.2 |
| (0002,0003) | UI | 46 | MediaStorageSOPInstanceUID | 1.3.12.2.1107.5.99.2.5562.4.0.575506410962905 |
| (0002,0010) | UI | 18 | TransferSyntaxUID | 1.2.840.10008.1.2 |
| (0002,0012) | UI | 22 | ImplementationClassUID | 1.3.6.1.4.1.19291.2.1 |
| (0002,0013) | SH | 10 | ImplementationVersionName | OSIRIX001 |
| (0002,0016) | AE | 6 | SourceApplicationEntityTitle | OSIRIX |
| (0008,0005) | CS | 10 | SpecificCharacterSet | ISO_IR 100 |
| (0008,0008) | CS | 34 | ImageType | ORIGINAL / PRIMARY / AXIAL / CT_SOM5 SPI |
| (0008,0016) | UI | 26 | SOPClassUID | 1.2.840.10008.5.1.4.1.1.2 |
| (0008,0018) | UI | 46 | SOPInstanceUID | 1.3.12.2.1107.5.99.2.5562.4.0.575506410962905 |
| (0008,0020) | DA | 8 | StudyDate | 20040401 |
| (0008,0021) | DA | 8 | SeriesDate | 20040401 |
| (0008,0022) | DA | 8 | AcquisitionDate | 20040420 |
| (0008,0023) | DA | 8 | ImageDate | 20040420 |
| (0008,0030) | TM | 14 | StudyTime | 120000.000000 |
| (0008,0031) | TM | 14 | SeriesTime | 120000.000000 |
| (0008,0032) | TM | 14 | AcquisitionTime | 133211.784922 |
| (0008,0033) | TM | 14 | ImageTime | 133211.784922 |
| (0008,0060) | CS | 2 | Modality | CT |
| (0008,0070) | LO | 8 | Manufacturer | SIEMENS |

**Fig. 9** Window displaying the DICOM tags of the highlighted image

assisted diagnosis. Additional image processing and ROI analysis tools are foreseen to perform image classification through a machine learning cloud portal. Linking selected ROIs to semantically organized taxonomies should enhance the discovery of novel knowledge through generation of new hypotheses. In addition, to reduce image processing and rendering time we consider using the WebGL alternative to native HTML5 Canvas API, which should afford the 3D virtual reconstruction of DICOM files.

**Acknowledgement** Research supported by the GSRT under the grant "Medical Collaborative Environment over GRNET Cloud Infrastructure".

## References

1. Arbor, A. Collaboratory for Research on Electronic Work, [Online]. Available: http://www.crew.umich.edu/CREW.home.html.
2. Stiefel, S.C., F.J. Huyse, W. Söllner, J. Slaets, J. Lyons, C. Latour, N. van der Wal, and P. De Jonge. 2006. Operationalizing Integrated Care on a Clinical Level: The INTERMED Project. *Medical Clinics of North America* 90 (4): 713–758.
3. Kilman, D., and D. Forslund. 1997. An International Collaboratory Based on Virtual Patient Records. *Communications of the ACM* 40 (8): 111–117.

4. Jagannathan, V., Y.V. Reddy, K. Srinivas, R. Karinthi, R. Shank, S. Reddy, G. Almasi, T. Davis, R. Raman, S. Qiu, S. Friedman, B. Merkin and M. Kilkenny. 1995. An Overview of the CERC ARTEMIS Project. Proceedings of the Annual Symposium on Computer Application in Medical Care.
5. Chronaki, C., D. Katehakis, X. Zabulis, M. Tsiknakis, and S. Orphanoudakis. 1997. WebOnCOLL: Medical Collaboration in Regional Healthcare Networks. *IEEE Transactions on Information Technology in Biomedicine* 1 (4): 257–269.
6. Maglogiannis, I., C. Delakouridis, and L. Kazatzopoulos. 2006. Enabling Collaborative Medical Diagnosis Over the Internet via Peer-to-Peer Distribution of Electronic Health Records. *Journal of Medical Systems* 30 (2): 107–116.
7. Huang, L. 2009. Semantic P2P Network for Healthcare. Fifth International Joint Conference on INC, IMS and IDC, 2009. NCM '09.
8. Barhamgi, M., P.-A. C. Champin, D. Benslimane and A.M. Ouksel. 2007. Composing Data-Providing Web Services in P2P-Based Collaboration Environments. In *Advanced Information Systems Engineering*, 531–545. Berlin Heidelberg: Springer.
9. Fakas, G.J., and B. Karakostas. 2004. A Peer to Peer (P2P) Architecture for Dynamic Workflow Management. *Information and Software Technology* 46 (6): 423–431.
10. Kailasam, S., S. Kumar, and J. Dharanipragada. 2010. Arogyasree: An Enhanced Grid-Based Approach to Mobile Telemedicine. *International Journal of Telemedicine and Applications* 2010 (1687–6415): 2:1–2:11.
11. John, H.B., J. In-Yong, K. Ki-Hyun, L. Do-kwang, S. Rho, and C.-S. Jeong. 2013. Cloud-Based Active Content Collaboration Platform Using Multimedia Processing. *EURASIP Journal on Wireless Communications and Networking* 2013 (1): 1–13.
12. Andrikos, C., G. Rassias, I. Maglogiannis and P. Tsanakas. 2015. Real-time medical collaboration services over the web. in *IEEE EMBC 2015*, Milan.

# Exploring Amyloidogenicity of Clusterin: A Structural and Bioinformatics Analysis

**Paraskevi L. Tsiolaki, Katerina C. Nastou, Nikolaos N. Louros, Stavros J. Hamodrakas, and Vassiliki A. Iconomidou**

**Abstract** Clusterin, a multitasking glycoprotein, is a protein highly conserved amongst mammals. In humans, Clusterin is mainly a secreted protein, described as an extracellular chaperone with the capability of interacting with a broad spectrum of molecules. In neurodegenerative diseases, such as Alzheimer's disease, it is an amyloid associated protein, co-localized with fibrillar deposits in amyloid plaques in systemic or localized amyloidoses. An 'aggregation-prone' segment (*NFHAMFQ*) was located within the Clusterin α-chain sequence using AMYLPRED, a consensus method for the prediction of amyloid propensity, developed in our lab. This peptide was synthesized and was found to self-assemble into amyloid-like fibrils in vitro, as electron microscopy, X-ray fiber diffraction, Attenuated Total Reflectance Fourier-Transform Spectroscopy and Congo red staining studies reveal. All experimental results verify that this human Clusterin peptide-analogue, possesses high aggregation potency. Additional computational analysis highlighted novel and at the same time, unexplored features of human Clusterin.

**Keywords** Consensus algorithm • Aggregation-prediction algorithm • Clusterin • "Aggregation-prone" peptides • Alzheimer's disease • Neurodegenerative disease • Protein network

## 1 Introduction

A great number of proteins with divergent functions and different sequences and structures have been identified as causative agents of important neurodegenerative diseases such as Alzheimer's disease, Parkinson's disease and Amyotrophiclateral

P.L. Tsiolaki • K.C. Nastou • N.N. Louros • S.J. Hamodrakas • V.A. Iconomidou (✉)
Section of Cell Biology and Biophysics, Department of Biology, National and Kapodistrian University of Athens, Panepistimiopolis, Athens, 15701, Greece
e-mail: etsiolaki@biol.uoa.gr; katnastou@biol.uoa.gr; nlouros@biol.uoa.gr; shamodr@biol.uoa.gr; veconom@biol.uoa.gr



P. Vlamos (eds.), *GeNeDis 2016*, Advances in Experimental Medicine and Biology 989, DOI 10.1007/978-3-319-57348-9_8

sclerosis (ALS). Amyloid fibrils, found in association with these medical disorders, are formed by normally soluble proteins, which accumulate to form closely packed and highly ordered insoluble aggregates. Emerging data suggest that several peptides and proteins, which had not previously been associated with "conformational diseases" have been proven to form amyloid-like fibrils in vitro, indicating that under appropriate conditions ordered self-aggregation may be an inherent property of proteins [1, 2].

Clusterin (Apolipoprotein J or ApoJ), a heterodimeric protein, is a highly conserved extracellular chaperon, expressed in almost all mammalian tissues. The precursor polypeptide, consists of 449 amino acids and after the proteolytical cleavage of the signal peptide, it is subsequently cleaved between residues 227 and 228 to generate α- and β-chains (Fig. 1a, dark red and blue respectively) [3]. In its predominant form mature Clusterin is a protein of ∼80 kDa, which is highly glycozylated (Fig. 1a, red rectangles) and is covalently stabilized by five (5) interchain disulfide bonds (Fig. 1a, yellow dashed lines) [4]. Literature concerning Clusterin function is constantly enriched [5]. As a chaperon, Clusterin binds a large number of diverse ligands, including apolipoproteins, lipids and amyloid-forming proteins [6, 7]. Noteworthy, chaperone-like activity of Clusterin is similar to that of small heat shock proteins [8].

An increase in Clusterin expression is observed in numerous neurodegenerative conditions as a result of abnormal cell death or proliferation [9]. Complete cerebral ischemia, for example, could lead to the accumulation of Clusterin in neuronal cells and in onset of extracellular deposits close to microvessels [10]. Despite the fact that Clusterin has also been found co-localized with fibrillar deposits in amyloid plaques [11–13], there are no experimental data to verify that Clusterin itself self-aggregates into amyloid fibrils. However, contradictory studies point out another perspective, suggesting that co-localization with amyloid deposits may reveal protective properties of Clusterin [14].

AMYLPRED [15, 16] is a consensus prediction algorithm for amyloid fibril favoring regions, the so-called "aggregation-prone" peptides, which was developed in our lab. Testing the Clusterin sequence by AMYLPRED, 12 stretches were predicted as possible "aggregation-prone" peptides. Seven (7) oligopeptides with high aggregation propensity were predicted for Clusterin β-chain (Fig. 1b), whereas five oligopeptides were predicted for Clusterin α-chain (Fig. 1c). As a first step toward studying Clusterin amyloidogenicity, we focused on the *NFHAMFQ* peptide. This Clusterin heptapeptide is located at the edge of the α-chain (Fig. 1a, b, orange colour), a critical interaction site between α and β chains [8, 17], which deserves attention from a structural perspective (see Sect. 4). In this work, we report on the self-assembly properties of the crucial Clusterin heptapeptide *NFHAMFQ* and discuss the implications of the findings.

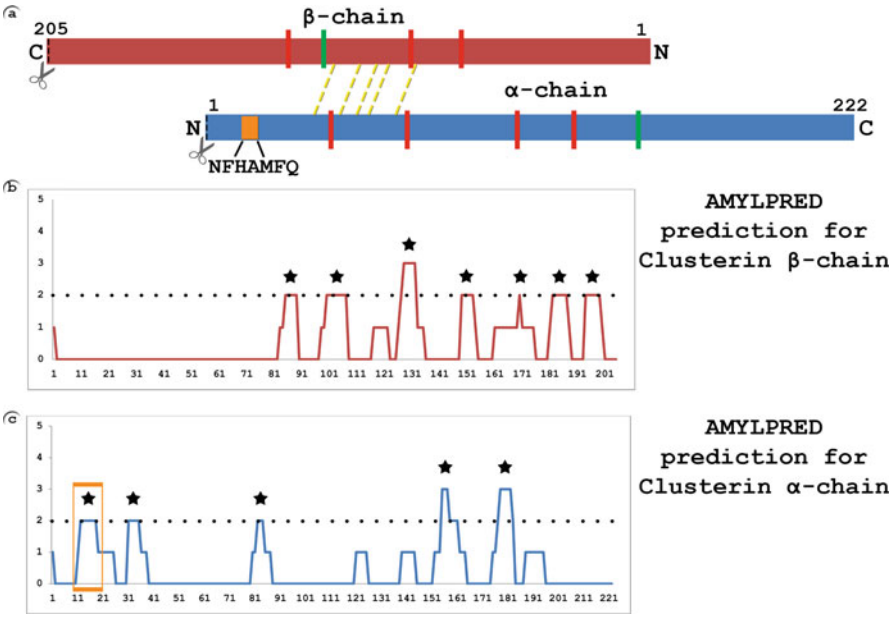


**Fig. 1** (**a**) Schematic representation of mature human Clusterin (α-chain *blue*, β-chain *dark red*) depicts post translational modifications and annotations derived from UniprotKB (UniprotKB AC P10909) [18, 19]. Glycozylation sites are shown in *red*, phosphoserines are shown in *green* and disulfide bridges are marked with *yellow dashed lines*. Scissors represent the proteolytic cleavage sites in both α-chain and β-chain. The *NFHAMFQ* "aggregation prone" peptide, shown in *orange*, is located at the N-terminal of Clusterin α-chain (**b**), (**c**) "Amyloid propensity" prediction histograms of human Clusterin by AMYLPRED [15]. Five (5) and seven (7) peptides with aggregation propensity were predicted for α-chain (**c**) and β-chain (**b**) respectively, both chains present, though, a low overall amyloidogenic profile. "Aggregation-prone" regions are marked with a star and the default AMYLPRED threshold is shown with a *dotted line*. An *orange box* indicates the position of the *NFHAMFQ* peptide

## 2 Materials and Methods

### *2.1 Prediction of Potential "Aggregation-Prone" Peptides in Human Clusterin*

AMYLPRED [15], as well as AMYLPRED2 [16], both consensus algorithms developed in our lab, were used to identify "aggregation-prone" segments in the amino acid sequence of human Clusterin (Uniprot AC: P10909). Our tools are publicly available for academic users in our website: http://biophysics.biol.uoa.gr/.

## 2.2 Peptide Synthesis and Preparation of Amyloid-Like Fibrils

The 7 amino acid Clusterin peptide-analogue (*NFHAMFQ*) (Fig. 1, red box) was synthesized by GeneCust© Europe, Luxembourg. The purity of the synthesized peptide was >98% (free N- and C-terminals). The synthesized peptide was dissolved in distilled water (pH 5.5), at a concentration of 10 mg $ml^{-1}$. After 1 week incubation at ambient (room) temperatures, *NFHAMFQ* peptide forms amyloid-like fibril-containing gels. Oriented fibers, suitable for X-ray diffraction, were obtained from suspensions of the peptide mature amyloid fibrils, as described below.

## 2.3 X-ray Diffraction

A droplet (∼10 μl) of mature fibril suspension was placed between two quartz capillaries covered with wax, spaced ∼1.5 mm apart and mounted horizontally on a glass substrate, as collinearly as possible, to obtain an oriented fiber. The X-ray diffraction pattern from this fiber was collected, using a SuperNova-Agilent Technologies X-ray generator, equipped with a 135-mm ATLAS CCD detector and a 4-circle kappa goniometer, at the Institute of Biology, Medicinal Chemistry and Biotechnology, National Hellenic Research Foundation ($CuK_\alpha$ high intensity X-ray micro-focus source, $\lambda = 1.5418$ Å), operated at 50 kV, 0.8 mA. The specimen-to-film distance was set at 52 mm and the exposure time was set to 200 s. The X-ray patterns initially were viewed using the program CrysAlisPro and consequently measured with the aid of the program iMosFLM.

## 2.4 Negative Staining and Transmission Electron Microscopy

For negative staining, droplets (∼3–5 μl) of the *NFHAMFQ* peptide mature fibril suspensions were applied to glow- discharged 400-mesh carbon-coated copper grids for 60 s. The grids were stained with a droplet (5 μl) of 2% (w/v) aqueous uranyl acetate for 60 s. Excess stain was removed by blotting with a filter paper. The grids were air-dried. The fibril-containing grids were examined with a Morgagni™ 268 transmission electron microscope, operated at 80 kV. Digital acquisitions were performed with an 11 Mpixel side-mounted Morada CCD camera (Soft Imaging System, Muenster, Germany).

## 2.5 Attenuated Total Reflectance Fourier-Transform Infrared Spectroscopy (ATR FT-IR)

A 10-μl droplet of *NFHAMFQ* peptide mature fibril suspension was cast on a front-coated Au mirror and left to dry slowly at ambient conditions to form a thin film. Infrared spectra were obtained from these films at a resolution of 4 $cm^{-1}$, utilizing

an IR microscope (IRScope II by Bruker Optics) equipped with a Ge attenuated total reflectance (ATR) objective lens (20×) and attached to a Fourier-transform infrared (FTIR) spectrometer (Equinox 55, by Bruker Optics).

### *2.6 Congo Red Staining and Polarized Light Microscopy*

The *NFHAMFQ* peptide mature fibril suspensions were applied to glass slides and stained with a 10 mM Congo Red (Sigma) solution in PBS (phosphate-buffered saline, pH 7.4) for approximately 30 min. Then, they were washed several times with 90% ethanol and were left to dry approximately for 10 min. The samples were observed under bright field illumination and between crossed polars, using a Leica MZ75 polarizing stereomicroscope, equipped with a JVC GC-X3E camera.

### *2.7 Protein–Protein Interaction Network*

Interactors of Clusterin and their interactions were identified using BioGRID [20], a public database that archives and disseminates genetic and protein interaction data from model organisms and humans. BioGRID currently contains the most comprehensive, and at the same time, well-annotated list of interactions for Clusterin. The interaction network created from this dataset was visualized using Cytoscape [21]. The network was further studied with functional and graph theory based analyses, using BinGO [22] and NetworkAnalyzer [23], two applications exclusively developed for Cytoscape. BinGO was used to detect overrepresented Gene Ontology terms in Biological Networks, while NetworkAnalyzer was used to evaluate topological simple and complex network parameters.

## 3 Results

After incubation for 1 week, the *NFHAMFQ* peptide self-assembles into amyloid-like fibrils, forming dense gels (upper right quarter of Fig. 2a). Electron micrographs (Fig. 2a) display the amyloid-like fibrils to be straight and unbranched with an indefinite length (several microns long) and a diameter of approximately 40–50 Å (Fig. 2a). Frequently, the fibrils wound around each other, forming supercoils (Fig. 2a, black arrows). This apparent morphological polymorphism has previously been established as a common characteristic of amyloid fibrils formed by several aggregation-prone peptides and proteins [24].

Amyloid deposits prepared as described above (see Sect. 2) bind Congo red, as it is clear under bright field illumination (Fig. 2b, upper) and exhibit a characteristic for amyloid fibrils yellow/green birefringence, when viewed under crossed polars (Fig. 2b, lower). The X-ray diffraction patterns of oriented fibres produced from the amyloid-like fibril suspensions of the *NFHAMFQ* peptide indicate a “cross-β”

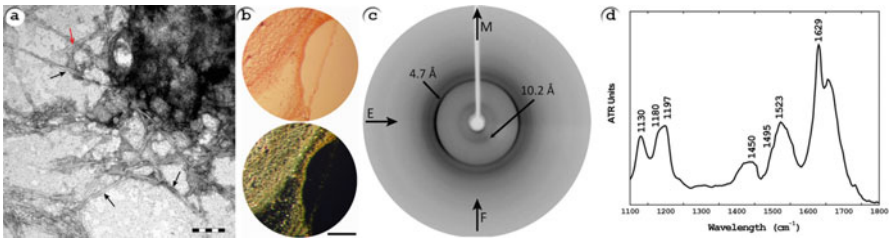


**Fig. 2** Experimental results of the *NFHAMFQ* peptide self-aggregation (**a**) An electron micrograph of amyloid-like fibrils derived by self-assembly, from a 10 mg $ml^{-1}$ solution of the Clusterin peptide-analogue in distilled water. Amyloid-like fibrils appear straight, unbranched and of indefinite length with a diameter of each protofilament ca. 40–50 Å (*red arrow*). Protofilaments wound around each other, forming supercoils (*black arrows*). Scale bar 200 nm (**b**) Photomicrographs of an amyloid fibril containing gel, derived from *NFHAMFQ* peptide self-assembly, stained with Congo red. The Congo red dye is bound, as seen under bright field illumination (*upper photomicrograph*) and the apple-green birefringence that amyloids typically exhibit is clearly seen under crossed polars (*lower photomicrograph*). Bar 100 μm (**c**) X-ray diffraction pattern from an 'oriented' fiber of the Clusterin peptide-analogue amyloid-like fibrils. The fiber axis (F) is vertical (meridian, M), whereas the equator is horizontal (E). The "cross-β" structure is evident; a 4.7 Å reflection is due to the distance between successive hydrogen bonded β-strands and a 10.2 Å reflection is derived from the spacing between packed β-sheets (**d**) ATR FT-IR (1100–1800 $cm^{-1}$) spectrum is indicative of the preponderance of β-sheet secondary structure (see Table 1)

**Table 1** Bands observed in the ATR FT-IR (1100–1800 $cm^{-1}$) spectrum produced from a hydrated film of the amyloidogenic *NFHAMFQ* peptide after self-assembly, and their tentative assignments (Fig. 2)

| Band ($cm^{-1}$) | Assignment |
|---|---|
| 1130 | TFA |
| 1180 | TFA |
| 1197 | TFA |
| 1450 | $CH_2$ deformation |
| 1495 | Phe (F) |
| 1523 | Amide II (β-sheet) |
| 1629 | Amide I (β-sheet) |

conformation, observed for most amyloids (Fig. 2c). The intense reflection on the equator (perpendicular to the fiber axis) corresponds to a periodicity of 4.7 Å. This periodicity refers to the distance between consecutive hydrogen bonded β-strands. The reflection on the meridian, corresponding to a repeat of 10.2 Å, is attributed to the packing distance between successive packed β-sheets, parallel to the fiber axis.

The ATR FT-IR spectrum from thin films produced by the Clusterin peptide fibril-containing solutions (Fig. 2d and Table 1) shows a prominent band at 1629 $cm^{-1}$ in the amide I region and a band at 1523 $cm^{-1}$ in the amide II, which are definitely due to β-sheet conformation [25]. Thus, the results from ATR FT-IR spectroscopy strongly support the evidence from X-ray diffraction experiments.

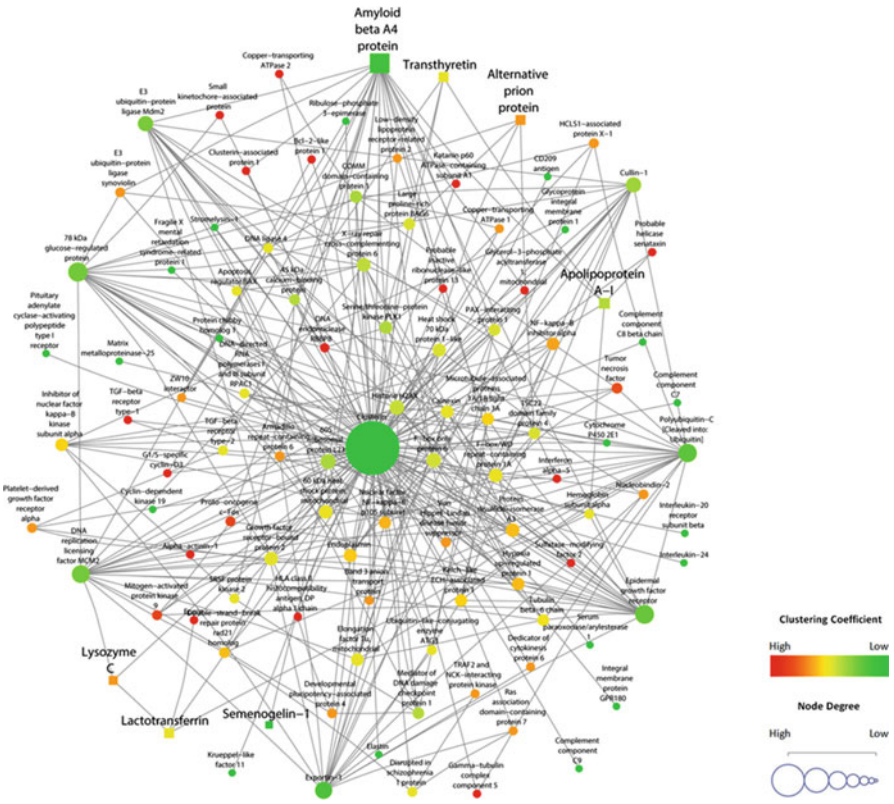


**Fig. 3** The interaction network of human Clusterin. Interaction data for the creation of this network were gathered from the publicly available database BioGRID [20] and Cytoscape [21] was used as a visualization tool. The network consists of 103 nodes and 324 edges. The color gradient is visualized based on the clustering coefficient of each node and the size gradient based on the node degree. In darker colors are the "bottlenecks" of the network, while larger nodes correspond to "hubs". Amyloidogenic proteins, depicted as *rectangles* are also present in the network (see also Table 2)

Moreover a computational analysis performed on the network of Clusterin and its interactors highlight the key role of Clusterin. The network includes 103 nodes (proteins, Fig. 3 coloured rectangles and circles) and 324 edges (interactions, Fig. 3 grey lines) and has a node degree distribution that decays as a power law and accentuates the scale-free properties of the network. The color gradient, shown in Fig. 3 is visualized based on the clustering coefficient of each node. In darker colours (red) are the nodes with the higher clustering coefficients, which are "bottleneck" proteins. These proteins are extremely important for the transduction of information across the entire network and thus its normal function, meaning that their removal would destroy many links between the currently connected proteins. Nodes with high degree are central nodes or "hubs", which are also extremely important,

since they interact with many proteins in the network. "Attacks" on these proteins could have devastating effects on the network, due to the loss of many important interactions, leading to its impending failure (Fig. 3).

For a deeper understanding of the network's functions, graph theory based analysis was performed, in order to detect the network's topology and to investigate the contribution of certain nodes to the network stability. The network has a scale-free topology consistent with the relevant "network biology theory" [26]. This shows that this network has a few protein hubs and the majority of the protein nodes have a small number of interactions. As shown in Fig. 3 most of the amyloidogenic proteins in the network (rectangle nodes) act as hubs. Moreover, a functional analysis that was performed highlight that Clusterin and its interactors are linked to functions as response to stress, immune response and chaperone binding.

## 4 Discussion

Utilizing our consensus prediction algorithm, AMYLPRED [15, 16], 12 oligopeptides of human Clusterin were predicted as "aggregation-prone" segments (Fig. 1). In this work, we attempted to shed light on the *NFHAMFQ* peptide aggregation propensity and find out whether it intrinsically exhibits amyloidogenicity. Our experimental work clearly shows that fibrils formed from this Clusterin heptapeptide fulfills all basic structural and tinctorial criteria of amyloid fibrils [27].

Recent studies suggest that amyloidogenicity is due to short protein segments, whereas one of the first articles to report on short "aggregation-prone" peptides was published back in 2005 [28]. Much time and effort have been spent in tracing short "aggregation-prone" segments and, thus, a great number of algorithms during the last decade or so, attempted to predict such hotspot stretches in protein sequences. Extensive work has been dedicated towards the in vitro studies of short peptides that are sufficient to drive a native protein to the amyloid state [29–37].

Clusterin, a multitasking protein, is involved not only in physiological but also in pathological conditions. Although currently there aren't Clusterin crystal structures available, several bioinformatics approaches elucidate intriguing structural properties. Previous sequence analysis predicted three amphipathic α-helical regions, along with long natively disordered regions for human Clusterin, reasonable secondary structures for a protein that mediates interactions with several hydrophobic molecules [4, 38, 39]. Surprisingly, the *NFHAMFQ* peptide, which according to our results self-aggregates forming characteristic amyloid structures, is located in the second putative amphipathic region, implying distinctive features of a possible chameleon sequence for this Clusterin heptapeptide.

Trying to identify and locate all functional epitopes of Clusterin, Lakins et al. thoroughly studied several cleavage products of Clusterin. Surprisingly, secreted Clusterin has three (3) distinct epitopes one of which interacts with unstressed ligands, such as Aβ the peptide. Thus, experimental evidence, along with computational analysis demonstrated that these binding sites may involve the amphipathic

helices located at the C-terminal of the β-chain and the N-terminal of the α-chain [8] (Fig. 1a). This interaction should be carefully taken into account, since *NFHAMFQ* peptide, with remarkable aggregation properties, is located exactly at the N-terminal of the Clusterin α-chain (Fig. 1a, orange rectangle).

Noteworthy, an increase in either mRNA or Clusterin protein expression is referenced in several neurodegenerative diseases, such as Alzheimer's Disease [11], HCHWA-Dutch type [40] and familial British dementia [41]. A detailed catalogue of such pathological conditions is reviewed by Calero et al. [10]. Along with the co-localization with high density lipoproteins [42], Clusterin was found to participate as a key component in senile plaques in subjects with Alzheimer's Disease [43]. However, in general the principal role of proteins found co-localized in amyloid deposits remains unclear and remains to be examined whether co-deposits transition to the amyloid state.

To obtain crucial information on Clusterin interactions with proteins related to ageing and neurodegenerative diseases, we further analyzed a novel protein network (Fig. 3). The most well-known array of proteins that were listed as Clusterin partners are gathered together in recent excellent review articles [5, 6, 8, 44]. Our results are in accordance with data obtained from the literature, since all the known interactors of Clusterin are present in the network. Among other proteins, amyloidogenic proteins, as well as, amyloid associated proteins play a crucial role in the network's integrity (Table 2). "Amyloid beta A4", for example, is evidently an important node since it acts as a hub and interacts with many proteins in the network.

Contradictory theories on whether Clusterin is guilty or innocent in neurodegenerative diseases complicate the research process. Given the limitations of current therapies on neurodegenerative diseases, Thambisetty described the potential for developing treatments based on modulating peripheral levels of extracellular chaperones [14], suggesting another intriguing perspective on Clusterin. Novel aggregation characteristics of the *NFHAMFQ* heptapeptide together with its implications as a possible interacting epitope of Aβ peptide, should be carefully examined. Since protein-based products are rapidly entering the pharmaceutical industry as successful drugs, remedies/drugs designed to prevent aggregation of targeted Clusterin "aggregation-prone" peptides, such as *NFHAMFQ*, may prove to be of paramount importance in future work, following the example of recent studies on transthyretin amyloidosis [45].

**Acknowledgments** We thank the University of Athens for support. This project was financially supported by the Greek State Scholarships Foundation, through the Siemens Program: "IKY Fellowships of Excellence for Postgraduate Studies in Greece—Siemens Programme (2015–2017)". We thank Associate Professor Ioannis Trougakos for pointing out to us the role of Clusterin in neurodegenerative diseases. We thank our collaborator Dr. Evangelia D. Chrysina for excellent assistance with the X-ray experiments and the Institute of Biology, Medicinal Chemistry and Biotechnology at the National Hellenic Research Foundation for hospitality. Finally, we thank Dr. Georgios E. Baltatzis and Prof. Efstratios S. Patsouris for excellent assistance with Transmission Electron Microscopy experiments in the Department of Pathology, at the Medical School of the University of Athens.

**Table 2** Proteins in the interaction network of Clusterin, with their respective UniProtKB ACs

| Protein name | UniProtKB AC |
|---|---|
| HCLS1-associated protein X-1 | O00165 |
| Hypoxia up-regulated protein 1 | Q9Y4L1 |
| Interleukin-24 | Q13007 |
| Katanin p60 ATPase-containing subunit A1 | O75449 |
| ZW10 interactor | O95229 |
| Inhibitor of nuclear factor kappa-B kinase subunit alpha | O15111 |
| **Gamma-tubulin complex component 5** | **Q96RT8** |
| Glycoprotein integral membrane protein 1 | Q9NU53 |
| Pituitary adenylate cyclase-activating polypeptide type I receptor | P41586 |
| Clusterin | P10909 |
| COMM domain-containing protein 1 | Q8N668 |
| Cytochrome P450 2E1 | P05181 |
| Integral membrane protein GPR180 | Q86V85 |
| Epidermal growth factor receptor | P00533 |
| Elastin | P15502 |
| PAX-interacting protein 1 | Q6ZW49 |
| TRAF2 and NCK-interacting protein kinase | Q9UKE5 |
| Clusterin-associated protein 1 | Q96AJ1 |
| Probable helicase senataxin | Q7Z333 |
| Cyclin-dependent kinase 19 | Q9BWU1 |
| Proto-oncogene c-Fos | P01100 |
| X-ray repair cross-complementing protein 6 | P12956 |
| Protein chibby homolog 1 | Q9Y3M2 |
| Sulfatase-modifying factor 2 | Q8NBJ7 |
| F-box only protein 6 | Q9NRD1 |
| Disrupted in schizophrenia 1 protein | Q9NRI5 |
| Growth factor receptor-bound protein 2 | P62993 |
| Protein disulfide-isomerase A3 | P30101 |
| Histone H2AX | P16104 |
| Hemoglobin subunit alpha | P69905 |
| CD209 antigen | Q9NNX6 |
| HLA class II histocompatibility antigen, DP alpha 1 chain | P20036 |
| Heat shock 70 kDa protein 1-like | P34931 |
| Low-density lipoprotein receptor-related protein 2 | P98164 |
| **Lactotransferrin** | **P02788** |
| **Lysozyme C** | **P61626** |
| DNA replication licensing factor MCM2 | P49736 |
| E3 ubiquitin-protein ligase Mdm2 | Q00987 |
| Stromelysin-1 | P08254 |
| Probable inactive ribonuclease-like protein 13 | Q5GAN3 |
| Nuclear factor NF-kappa-B p105 subunit | P19838 |

(continued)

**Table 2** (continued)

| Protein name | UniProtKB AC |
|---|---|
| NF-kappa-B inhibitor alpha | P25963 |
| Nucleobindin-2 | P80303 |
| 45 kDa calcium-binding protein | Q9BRK5 |
| Matrix metalloproteinase-25 | Q9NPA2 |
| Serine/threonine-protein kinase PLK1 | P53350 |
| Copper-transporting ATPase 1 | Q04656 |
| Interleukin-20 receptor subunit beta | Q6UXL0 |
| Copper-transporting ATPase 2 | P35670 |
| Serum paraoxonase/arylesterase 1 | P27169 |
| Developmental pluripotency-associated protein 4 | Q7L190 |
| Mitogen-activated protein kinase 9 | P45984 |
| **Transthyretin** | **P02766** |
| Elongation factor Tu, mitochondrial | P49411 |
| Complement component C7 | P10643 |
| Polyubiquitin-C [Cleaved into: Ubiquitin] | P0CG48 |
| Complement component C8 beta chain | P07358 |
| Von Hippel-Lindau disease tumor suppressor | P40337 |
| Complement component C9 | P02748 |
| Exportin-1 | O14980 |
| Fragile X mental retardation syndrome-related protein 1 | P51114 |
| Large proline-rich protein BAG6 | P46379 |
| Ras association domain-containing protein 7 | Q02833 |
| TSC22 domain family protein 4 | Q9Y3Q8 |
| Calnexin | P27824 |
| E3 ubiquitin-protein ligase synoviolin | Q86TM6 |
| Cullin-1 | Q13616 |
| Tubulin beta-6 chain | Q9BUF5 |
| Microtubule-associated proteins 1A/1B light chain 3A | Q9H492 |
| Krueppel-like factor 11 | O14901 |
| Alpha-actinin-1 | P12814 |
| F-box/WD repeat-containing protein 1A | Q9Y297 |
| G1/S-specific cyclin-D3 | P30281 |
| DNA-directed RNA polymerases I and III subunit RPAC1 | O15160 |
| Armadillo repeat-containing protein 6 | Q6NXE6 |
| 60S ribosomal protein L23 | P62829 |
| Small kinetochore-associated protein | Q9Y448 |
| **Amyloid beta A4 protein** | **P05067** |
| Kelch-like ECH-associated protein 1 | Q14145 |
| 78 kDa glucose-regulated protein | P11021 |
| 60 kDa heat shock protein, mitochondrial | P10809 |

(continued)

**Table 2** (continued)

| Protein name | UniProtKB AC |
|---|---|
| **Apolipoprotein A-I** | **P02647** |
| Interferon alpha-5 | P01569 |
| Mediator of DNA damage checkpoint protein 1 | Q14676 |
| DNA ligase 4 | P49917 |
| Double-strand-break repair protein rad21 homolog | O60216 |
| Apoptosis regulator BAX | Q07812 |
| DNA endonuclease RBBP8 | Q99708 |
| Bcl-2-like protein 1 | Q07817 |
| Ribulose-phosphate 3-epimerase | Q96AT9 |
| **Semenogelin-1** | **P04279** |
| Platelet-derived growth factor receptor alpha | P16234 |
| Ubiquitin-like-conjugating enzyme ATG3 | Q9NT62 |
| Band 3 anion transport protein | P02730 |
| SRSF protein kinase 2 | P78362 |
| TGF-beta receptor type-1 | P36897 |
| TGF-beta receptor type-2 | P37173 |
| Tumor necrosis factor | P01375 |
| Endoplasmin | P14625 |
| **Alternative prion protein** | **F7VJQ1** |
| Eppin | O95925 |
| Dedicator of cytokinesis protein 6 | Q96HP0 |
| Glycerol-3-phosphate acyltransferase 1, mitochondrial | Q9HCL2 |

*Amyloidogenic proteins are highlighted in bold

## References


1. Chiti, F., and C.M. Dobson. 2006. Protein Misfolding, Functional Amyloid, and Human Disease. *Annual Review of Biochemistry* 75: 333–366. doi:10.1146/annurev.biochem.75.101304.123901.
2. Uversky, V.N., and A.L. Fink. 2004. Conformational Constraints for Amyloid Fibrillation: The Importance of Being Unfolded. *Biochimica et Biophysica Acta* 1698 (2): 131–153. doi:10.1016/j.bbapap.2003.12.008.
3. Fink, T.M., M. Zimmer, J. Tschopp, J. Etienne, D.E. Jenne, and P. Lichter. 1993. Human Clusterin (CLI) Maps to 8p21 in Proximity to the Lipoprotein Lipase (LPL) Gene. *Genomics* 16 (2): 526–528. doi:10.1006/geno.1993.1222.
4. de Silva, H.V., J.A. Harmony, W.D. Stuart, C.M. Gil, and J. Robbins. 1990. Apolipoprotein J: Structure and Tissue Distribution. *Biochemistry* 29 (22): 5380–5389.
5. Trougakos, I.P., and E.S. Gonos. 2009. Chapter 9: Oxidative Stress in Malignant Progression: The Role of Clusterin, a Sensitive Cellular Biosensor of Free Radicals. *Advances in Cancer Research* 104: 171–210. doi:10.1016/S0065-230X(09)04009-3.
6. Trougakos, I.P., and E.S. Gonos. 2002. Clusterin/Apolipoprotein J in Human Aging and Cancer. *The International Journal of Biochemistry & Cell Biology* 34 (11): 1430–1448.
7. Calero, M., A. Rostagno, B. Frangione, and J. Ghiso. 2005. Clusterin and Alzheimer's Disease. *Sub-Cellular Biochemistry* 38: 273–298.

8. Lakins, J.N., S. Poon, S.B. Easterbrook-Smith, J.A. Carver, M.P. Tenniswood, and M.R. Wilson. 2002. Evidence That Clusterin Has Discrete Chaperone and Ligand Binding Sites. *Biochemistry* 41 (1): 282–291.
9. Choi-Miura, N.H., and T. Oda. 1996. Relationship Between Multifunctional Protein "Clusterin" and Alzheimer Disease. *Neurobiology of Aging* 17 (5): 717–722.
10. Calero, M., A. Rostagno, E. Matsubara, B. Zlokovic, B. Frangione, and J. Ghiso. 2000. Apolipoprotein J (Clusterin) and Alzheimer's Disease. *Microscopy Research and Technique* 50 (4): 305–315. doi:10.1002/1097-0029(20000815)50:4<305::AID-JEMT10>3.0.CO;2-L.
11. Choi-Miura, N.H., Y. Takahashi, Y. Nakano, T. Tobe, and M. Tomita. 1992. Identification of the Disulfide Bonds in Human Plasma Protein SP-40,40 (Apolipoprotein-J). *Journal of Biochemistry* 112 (4): 557–561.
12. Choi-Miura, N.H., Y. Ihara, K. Fukuchi, M. Takeda, Y. Nakano, T. Tobe, and M. Tomita. 1992. SP-40,40 is a Constituent of Alzheimer's Amyloid. *Acta Neuropathologica* 83 (3): 260–264.
13. Nuutinen, T., T. Suuronen, A. Kauppinen, and A. Salminen. 2009. Clusterin: A Forgotten Player in Alzheimer's Disease. *Brain Research Reviews* 61 (2): 89–104. doi:10.1016/j.brainresrev.2009.05.007.
14. Thambisetty, M. 2010. Do Extracellular Chaperone Proteins in Plasma Have Potential as Alzheimer's Disease Biomarkers? *Biomarkers in Medicine* 4 (6): 831–834. doi:10.2217/bmm.10.108.
15. Frousios, K.K., V.A. Iconomidou, C.M. Karletidi, and S.J. Hamodrakas. 2009. Amyloidogenic Determinants Are Usually Not Buried. *BMC Structural Biology* 9: 44. doi:10.1186/1472-6807-9-44.
16. Tsolis, A.C., N.C. Papandreou, V.A. Iconomidou, and S.J. Hamodrakas. 2013. A Consensus Method for the Prediction of 'Aggregation-Prone' Peptides in Globular Proteins. *PloS One* 8 (1): e54175. doi:10.1371/journal.pone.0054175.
17. Bailey, R.W., A.K. Dunker, C.J. Brown, E.C. Garner, and M.D. Griswold. 2001. Clusterin, a Binding Protein with a Molten Globule-Like Region. *Biochemistry* 40 (39): 11828–11840.
18. UniProt Consortium 2014. Activities at the Universal Protein Resource (UniProt). *Nucleic Acids Research* 42: D191–D198. doi:10.1093/nar/gkt1140.
19. UniProt Consortium 2015. UniProt: A Hub for Protein Information. *Nucleic Acids Research* 43: D204–D212. doi:10.1093/nar/gku989.
20. Chatr-Aryamontri, A., B.J. Breitkreutz, R. Oughtred, L. Boucher, S. Heinicke, D. Chen, C. Stark, A. Breitkreutz, N. Kolas, L. O'Donnell, T. Reguly, J. Nixon, L. Ramage, A. Winter, A. Sellam, C. Chang, J. Hirschman, C. Theesfeld, J. Rust, M.S. Livstone, K. Dolinski, and M. Tyers. 2015. The BioGRID Interaction Database: 2015 Update. *Nucleic Acids Research* 43: D470–D478. doi:10.1093/nar/gku1204.
21. Shannon, P., A. Markiel, O. Ozier, N.S. Baliga, J.T. Wang, D. Ramage, N. Amin, B. Schwikowski, and T. Ideker. 2003. Cytoscape: A Software Environment for Integrated Models of Biomolecular Interaction Networks. *Genome Research* 13 (11): 2498–2504. doi:10.1101/gr.1239303.
22. Maere, S., K. Heymans, and M. Kuiper. 2005. BiNGO: A Cytoscape Plugin to Assess Overrepresentation of Gene Ontology Categories in Biological Networks. *Bioinformatics* 21 (16): 3448–3449. doi:10.1093/bioinformatics/bti551.
23. Assenov, Y., F. Ramirez, S.E. Schelhorn, T. Lengauer, and M. Albrecht. 2008. Computing Topological Parameters of Biological Networks. *Bioinformatics* 24 (2): 282–284. doi:10.1093/bioinformatics/btm554.
24. Kreplak, L., and U. Aebi. 2006. From the Polymorphism of Amyloid Fibrils to Their Assembly Mechanism and Cytotoxicity. *Advances in Protein Chemistry* 73: 217–233. doi:10.1016/S0065-3233(06)73007-8.
25. Surewicz, W.K., H.H. Mantsch, and D. Chapman. 1993. Determination of Protein Secondary Structure by Fourier Transform Infrared Spectroscopy: A Critical Assessment. *Biochemistry* 32 (2): 389–394.
26. Barabasi, A.L., and Z.N. Oltvai. 2004. Network Biology: Understanding the Cell's Functional Organization. *Nature Reviews Genetics* 5 (2): 101–113. doi:10.1038/nrg1272.

27. Sunde, M., and C.C. Blake. 1998. From the Globular to the Fibrous State: Protein Structure and Structural Conversion in Amyloid Formation. *Quarterly Reviews of Biophysics* 31 (1): 1–39.
28. Esteras-Chopo, A., L. Serran, and M. Lopez de la Paz. 2005. The Amyloid Stretch Hypothesis: Recruiting Proteins Toward the Dark Side. *Proceedings of the National Academy of Sciences of the United States of America* 102 (46): 16672–16677. doi:10.1073/pnas.0505905102.
29. Tenidis, K., M. Waldner, J. Bernhagen, W. Fischle, M. Bergmann, M. Weber, M.L. Merkle, W. Voelter, H. Brunner, and A. Kapurniotu. 2000. Identification of a Penta- and Hexapeptide of Islet Amyloid Polypeptide (IAPP) with Amyloidogenic and Cytotoxic Properties. *Journal of Molecular Biology* 295 (4): 1055–1071. doi:10.1006/jmbi.1999.3422.
30. Teng, P.K., and D. Eisenberg. 2009. Short Protein Segments Can Drive a Non-fibrillizing Protein into the Amyloid State. *Protein Engineering Design & Selection* 22 (8): 531–536. doi:10.1093/protein/gzp037.
31. Iconomidou, V.A., D. Pheida, E.S. Hamodraka, C. Antony, A. Hoenger, and S.J. Hamodrakas. 2012. An Amyloidogenic Determinant in N-terminal Pro-Brain Natriuretic Peptide (nt-Probnp): Implications for Cardiac Amyloidoses. *Biopolymers* 98 (1): 67–75. doi:10.1002/bip.21698.
32. Iconomidou, V.A., A. Leontis, A. Hoenger, and S.J. Hamodrakas. 2013. Identification of a Novel 'Aggregation-Prone'/'Amyloidogenic Determinant' Peptide in the Sequence of the Highly Amyloidogenic Human Calcitonin. *FEBS Letters* 587 (6): 569–574. doi:10.1016/j.febslet.2013.01.031.
33. Louros, N.N., V.A. Iconomidou, P.L. Tsiolaki, E.D. Chrysina, G.E. Baltatzis, E.S. Patsouris, and S.J. Hamodrakas. 2014. An N-terminal Pro-Atrial Natriuretic Peptide (NT-proANP) 'Aggregation-Prone' Segment Involved in Isolated Atrial Amyloidosis. *FEBS Letters* 588 (1): 52–57. doi:10.1016/j.febslet.2013.10.049.
34. Tsiolaki, P.L., S.J. Hamodrakas, and V.A. Iconomidou. 2015. The Pentapeptide LQVVR Plays a Pivotal Role in Human Cystatin C Fibrillization. *FEBS Letters* 589 (1): 159–164. doi:10.1016/j.febslet.2014.11.041.
35. Tsiolaki, P.L., N.N. Louros, S.J. Hamodrakas, and V.A. Iconomidou. 2015. Exploring the 'Aggregation-Prone' Core of Human Cystatin C: A Structural Study. *Journal of Structural Biology* 191 (3): 272–280. doi:10.1016/j.jsb.2015.07.013.
36. Louros, N.N., P.L. Tsiolaki, M.D. Griffin, G.J. Howlett, S.J. Hamodrakas, and V.A. Iconomidou. 2015. Chameleon 'Aggregation-Prone' Segments of apoA-I: A Model of Amyloid Fibrils Formed in apoA-I Amyloidosis. *International Journal of Biological Macromolecules* 79: 711–718. doi:10.1016/j.ijbiomac.2015.05.032.
37. Louros, N.N., P.L. Tsiolaki, A.A. Zompra, E.V. Pappa, V. Magafa, G. Pairas, P. Cordopatis, C. Cheimonidou, I.P. Trougakos, V.A. Iconomidou, and S.J. Hamodrakas. 2015. Structural Studies and Cytotoxicity Assays of "Aggregation-Prone" IAPP(8-16) and its Non-amyloidogenic Variants Suggest Its Important Role in Fibrillogenesis and Cytotoxicity of Human Amylin. *Biopolymers* 104 (3): 196–205. doi:10.1002/bip.22650.
38. Humphreys, D.T., J.A. Carver, S.B. Easterbrook-Smith, and M.R. Wilson. 1999. Clusterin Has Chaperone-Like Activity Similar to That of Small Heat Shock Proteins. *The Journal of Biological Chemistry* 274 (11): 6875–6881.
39. de Silva, H.V., W.D. Stuart, Y.B. Park, S.J. Mao, C.M. Gil, J.R. Wetterau, S.J. Busch, and J.A. Harmony. 1990. Purification and Characterization of Apolipoprotein. *Journal of Biological Chemistry* 265 (24): 14292–14297.
40. Maat-Schieman, M.L., S.G. van Duinen, M. Bornebroek, J. Haan, and R.A. Roos. 1996. Hereditary Cerebral Hemorrhage with Amyloidosis-Dutch Type (HCHWA-D): II—A Review of Histopathological Aspects. *Brain Pathology* 6 (2): 115–120.
41. Matsubara, E., B. Frangione, and J. Ghiso. 1995. Characterization of Apolipoprotein J-Alzheimer's A Beta Interaction. *The Journal of Biological Chemistry* 270 (13): 7563–7567.
42. LaDu, M.J., S.M. Gilligan, J.R. Lukens, V.G. Cabana, C.A. Reardon, L.J. Van Eldik, and D.M. Holtzman. 1998. Nascent Astrocyte Particles Differ from Lipoproteins in CSF. *Journal of Neurochemistry* 70 (5): 2070–2081.

43. Kida, E., N.H. Choi-Miura, and K.E. Wisniewski. 1995. Deposition of Apolipoproteins E and J in Senile Plaques is Topographically Determined in Both Alzheimer's Disease and Down's Syndrome Brain. *Brain Research* 685 (1–2): 211–216.
44. Poon, S., S.B. Easterbrook-Smith, M.S. Rybchyn, J.A. Carver, and M.R. Wilson. 2000. Clusterin is an ATP-Independent Chaperone with Very Broad Substrate Specificity That Stabilizes Stressed Proteins in a Folding-Competent State. *Biochemistry* 39 (51): 15953–15960.
45. Janin, J. 1997. Specific Versus Non-specific Contacts in Protein Crystals. *Nature Structural Biology* 4 (12): 973–974.

# Applications for Electrical Impedance Tomography (EIT) and Electrical Properties of the Human Body

**Georgios Lymperopoulos, Panagiotis Lymperopoulos, Victoria Alikari, Chrisoula Dafogianni, Sofia Zyga, and Nikoletta Margari**

**Abstract** Electrical Impedance Tomography (EIT) is a promising application that displays changes in conductivity within a body. The basic principle of the method is the repeated measurement of surface voltages of a body, which are a result of rolling injection of known and small-volume sinusoidal AC current to the body through the electrodes attached to its surface. This method finds application in biomedicine, biology and geology. The objective of this paper is to present the applications of Electrical Impedance Tomography, along with the method's capabilities and limitations due to the electrical properties of the human body. For this purpose, investigation of existing literature has been conducted, using electronic databases, PubMed, Google Scholar and IEEE Xplore. In addition, there was a secondary research phase, using paper citations found during the first research phase. It should be noted that Electrical Impedance Tomography finds use in a plethora of medical applications, as the different tissues of the body have different conductivities and dielectric constants. Main applications of EIT include imaging of lung function, diagnosis of pulmonary embolism, detection of tumors in the

G. Lymperopoulos (✉)
Department of Electrical Engineering, School of Engineering, University of Southern California, Los Angeles, CA, USA
e-mail: geo.lympero@gmail.com

P. Lymperopoulos
Department of Mechanical and Aeronautical Engineering, School of Engineering, University of Patras, Patras, Greece

V. Alikari (✉)
Laboratory of Nursing Research and Practice, Department of Nursing, Faculty of Human Movement and Quality of Life Sciences, University of Peloponnese, Tripoli, Greece
e-mail: vicalikari@gmail.com

C. Dafogianni • N. Margari (✉)
Department of Nursing, Technological Educational Institute of Athens, Athens, Greece
e-mail: nmargari@teiath.gr

S. Zyga
Department of Nursing, Faculty of Human Movement and Quality of Life Sciences, University of Peloponnese, Tripoli, Greece



P. Vlamos (eds.), *GeNeDis 2016*, Advances in Experimental Medicine and Biology 989, DOI 10.1007/978-3-319-57348-9_9

chest area and diagnosis and distinction of ischemic and hemorrhagic stroke. EIT advantages include portability, low cost and safety, which the method provide, since it is a noninvasive imaging method that does not cause damage to the body. The main disadvantage of the method, which blocks its wider spread, appears in the image composition from the voltage measurements, which are conducted by electrodes placed on the periphery of the body, because the injected currents are affected nonlinearly by the general distribution of the electrical properties of the body. Furthermore, the complex impedance of the skin-electrode interface can be modelled by using a capacitor and two resistor, as a result of skin properties. In conclusion, Electrical Impedance Tomography is a promising method for the development of noninvasive diagnostic medicine, since it is able to provide imaging of the interior of the human body in real time without causing harm or putting the human body in risk.

**Keywords** Electrical impedance tomography • Skin resistance • Medical applications • Conductivity • Tumor

## 1 Introduction

Electrical impedance tomography (EIT) illustrates changes in conductivity in the interior of a body by measuring the voltage between electrodes positioned at specific locations on the body surface, as a specific number of currents run through the body. It is a promising application for imaging and description of body cavities such as the thoracic cavity, which contains various organs that undergo major changes in their conductivity while functioning [1]. This method was developed in the early 1980s by Barber and Brown in the Department of Medical Physics and Clinical Engineering in Sheffield in UK, who used 16 electrodes and applied current injection between adjacent electrodes and then utilized a back-projection method for image reconstruction along the isopotentials [2].

Since then, an intensive development of this non-invasive imaging method and its application in the health sector has started. Generally, electrical impedance tomography generates cross-sectional images of the distribution of complex resistance in electrically conductive objects.

The basic principle of this method is the repeated measurement of surface voltages in a body, as a result of rolling injection of known and small-volume sinusoidal AC current to the body through the electrodes attached to its surface [3].

Applications span over a wide range of fields, including biomedicine, industry and geology. Furthermore, many other possible applications of the method have been developed and studied for medical or industrial procedures [4].

## 2 Typical Applications of EIT

As mentioned above, electrical impedance tomography can be used in a variety of medical applications. There is a large number of medical problems, in which it would be extremely useful to know the time-varying distribution of electrical properties within the body. Electrical conductivity and dielectric constant are referred as the electrical properties of interest. Electrical conductivity is a measure of the ease with which a material conducts electricity, while the dielectric constant reflects how easily electric charges are separated in a material when it is inside an electrical field. Materials with high conductivity allow the flow of both continuous and alternating currents, while the materials with a high-value dielectric constant allow the flow of only alternating currents. Both these features are very useful in medical applications, since different tissues have different conductivities and dielectric constants. The electrical impedance tomography (EIT) is a new technology that gives us imaging of lung function near the patient's bed. The ventilator setting to avoid alveolar derecruitment, loss of aeration, is crucial both in anesthesia and intensive care units. EIT may revolutionize the mechanical aerismo [5].

A medical problem in which knowledge of these properties would be useful, is the detection of pulmonary embolism or blood clots in the lungs. Pulmonary embolism is a common and serious complication that occurs after surgery. Until now, the diagnosis procedure involves insertion of radioactive substances into the body, in order to make the regions of the lungs with normal flow of air as well as the bloodstream visible. The images from the bloodstream and the air in the lungs are compared and the areas where there is air flow, but not perfusion are identified. These areas indicate areas where there is pulmonary embolism. It is this exact process that electrical impedance tomography could contribute to. As blood, human tissue and air have different conductivity and dielectric constant, while they also differ at different times, a time-varying display of these properties can show which areas have a normal air flow, without, however, being perfused properly. In this way, the use of radioactive substances or X-rays, which are harmful for the human body, is avoided. In addition, EIT may also be used for non-invasive quantification of pulmonary edema by assessing the changes observed by the extravasation of fluids during the patient's rotation to lateral position [5–7].

Additionally, the ability of displaying the air flow in the lungs facilitates other medical procedures, too. For example, in case of acute lung injury or acute respiratory distress syndrome, mechanical ventilation is vital for severely ill patients. Unfortunately, it has been shown that placing the mechanical ventilation is accompanied by deterioration of pulmonary lesions and, consequently, increased likelihood of death. Using the method that is described in this paper, the ability of displaying extensibility or destruction of lung tissue due to artificial ventilation in patients with the aforementioned problems [8].

Furthermore, with the electrical impedance tomography method, malignant tumors in the breast area can also be detected. The electrical conductivity of a malignant tumor can be significantly different from the electrical conductivity of

the healthy tissue surrounding it. Therefore, through this method, it can detected effectively, economically, safely and accurately [3].

Another very important application of EIT is the diagnosis between ischemic and hemorrhagic stroke, which will allow early diagnosis and thrombolysis in ischemic stroke and improve the outcome of the disease. Despite the fact that EIT cannot directly compete with CT in terms of image quality, because of EIT's low cost and portability, scanners could be available not only in emergency departments, but also in ambulances. Application of EIT in brain imaging is complicated, because the skull has extremely high resistance, restricting the current that flows in the center of the head. This results in a low signal to noise ratio, since the areas with the highest current density contribute more to measurements. Research is conducted on applying the fraction reconstruction method using spectral constraints to a numerical head phantom with realistic conductivities. Further work is needed in improving the image quality in the presence of modeling errors [9, 10].

## 3 Advantages and Disadvantages of Method

The electrical impedance tomography method offers many advantages compared to other tomography techniques. Firstly, it is characterized by portability, since there is the possibility to transfer the necessary components, so that the test body can be displayed. Indeed, one of the main purposes of this paper is to present a system with minimized size to further facilitate the transfer of components. Moreover, this method is extremely safe, as the use of toxic gases, x-rays and administration of radioactive substances in the body, which is necessary for displaying in other tomographic methods, are avoided. Additionally, according to several studies that have been conducted, the current that is 456 injected into the body is not a health hazard.

Furthermore, this method is low-cost compared to the rest, as the equipment required is not particularly expensive, and requires virtually no consumables. However, its most important feature is probably the fact that it is a non-invasive imaging and diagnostic method, thus not causing damage to the body, while, at the same time, it is a straightforward process that offers image display directly, but offers also the ability to produce time-varying image, to illustrate the change of body properties in time. For example, as the air has different conductivity and dielectric constant, it is possible to show breathing through recording differences in the electrical properties of the body during inhalation and exhalation.

Of course, this method has some drawbacks which reduce its capabilities and prevent its wider spread. The main problem appears in the composition of the image from voltages measurements made by the electrodes that are arranged on the periphery of the body. This happens because the inverse problem of reconstructing the image from the recovered signals is nonlinear and generally ill-defined, since there is instability and errors in measurements and approximations in modeling [3]. More specifically, the injected currents are affected nonlinearly by the general

distribution of the electrical properties of the body. When current is injected peripherally of the body, the changes taking place in the internal current flows affect variable peripheral voltages. Such changes, however, do not significantly affect voltages measured at points away from the current injection points. Therefore, the inverse problem of electrical impedance tomography has some ill-defined features, and therefore it is difficult to reconstruct the precise static image with high resolution in real environment, where errors in measurements are inevitable.

Furthermore, until now, most implementations of the method have a limited number of electrodes for taking measurements, thereby obtaining a limited amount of information from the peripheral measurements. This means that for higher quality data, a greater number of electrodes is required. The difficulties here are several, both in design and programming as well as technical, as it becomes more difficult to place a larger number of electrodes, while error margin increases [11].

## 4 Impedance of the Human Body

### *4.1 Skin-Electrode Interface Impedance*

The complex impedance of the skin-electrode interface can be modeled using a capacitor and two resistors. Specifically, the capacitor C is considered connected in parallel with one resistor R, while the other $R_S$ resistor is connected in series with the parallel connection of the capacitor and resistor, as shown in Fig. 1.

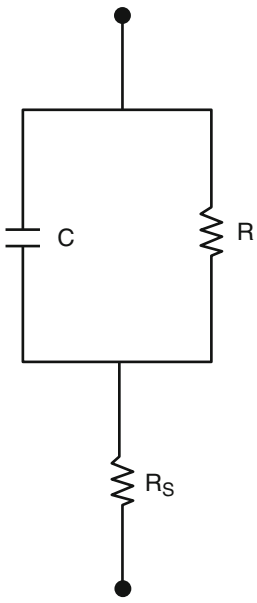


**Fig. 1** Schematic representation of a complex skin-electrode interface impedance

The above modeling arises as a result of skin properties. The skin and the immediately adjacent tissues consist of three layers: (1) the epidermis, (2) the dermis and (3) the subcutaneous layer, which is located over the muscles and bones. The epidermis, in particular, comprises several layers with stratum corneum being the outer layer, which consists of a number of dead cells. Stratum corneum is, however, a relatively poor conductor. Thus, by placing a metal object on the skin surface a capacitor is formed with the keratin layer playing the role of the dielectric, and the two electrodes being the metal object and the conductive tissues and fluids beneath the epidermis. The magnitude of this capacity C depends proportionally on the contact area and inversely proportionally on the thickness of the stratum corneum, i.e. the insulator. The magnitude of the resistance R depends inversely proportionally on the contact area and the skin moisture due to the sweat glands. At this point, it is worth mentioning that resistance R is reduced, if the metal object remains on the skin surface for a long time because of sweat accumulation. The $R_S$ resistance represents the resistance of rest of the underlying subject.

At low frequencies, the current flowing through the capacitor is small enough. However, at higher frequencies, the current flowing through the capacitor is increased. A voltage change, like connecting a voltage source, takes some time. For electronic systems, this period usually lasts less than 1 μs. The main concern in this process is the appearance of voltage peaks during the transition state, which corresponds to the mechanical connection of circuits [12].

The values of the total interface impedance range from 100,000 Ω m for current frequencies close to 0, and decrease as frequency increases. For frequencies approximately 1 MHz, the value of the total impedance is approximately 1000 Ω m, whereas for frequencies approximately 1 GHz, the value of the total impedance is approximately 100 Ω m [13, 14].

## *4.2 Circuitry Approach of Current Injection into the Human Body*

For current injection into the human body at least two contact points are needed, so that a closed circuit can be created. This current flow through many parallel paths, which consist of different kinds of tissues, such as muscles, the nervous system or bones, and the amount of current in each path is inversely proportional to the impedance of the respective tissue. The final generated circuit is illustrated in Fig. 2.

As shown in the figure below, resistances $R_1$ and $R_3$ correspond to the resistances formed by the skin-electrode interface. On the contrary, $R_3$ corresponds to the total resistance of the interior of the body. This resistance has very low values, approximately 300 Ω when there is direct current, as opposed to the resistance of the skin which usually ranges from 1000 Ω to 100,000 Ω, depending on humidity, skin condition and size of the contact area. This very high resistance makes skin the most important protective factor of the body against electric current [13].

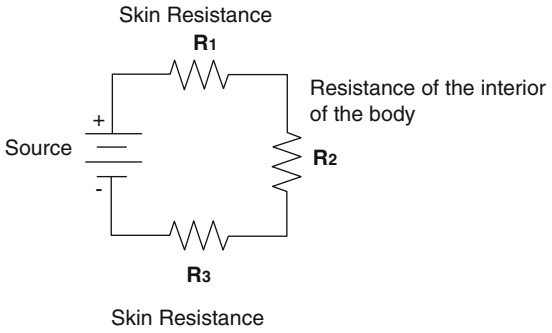


**Fig. 2** Circuitry equivalent of the body

**Table 1** Resistance values of human tissues

| | dc | 10 Hz | 100 kHz | 1 MHz | 10 MHz |
|---|---|---|---|---|---|
| Bones | | | 20 | 16.66667 | 14.28571 |
| Muscles | 2.45 | 2.857 | 1.25 | 1.11 | 1.11 |
| Skin | | 2000 | 12.5 | 2 | 1.43 |
| Lungs | | 33.33 | 10 | 6.67 | 3.33 |
| Fat | | 40 | 40 | 40 | 40 |
| Blood | | 1.6 | 1.6 | 1.426 | 0.91 |
| Total (in Ω m) | 27.45 | 2056.187 | 43.75 | 29.78 | 25.87 |
| | For electrodes distance 1 cm and with electrode surface 1 cm × 1 cm, according to the relation R = ρ × (l/A): | | | | |
| Ω | | 616856.1 | 19125 | 13934 | 12046.71 |
| kΩ | | 616.8561 | 19.125 | 13.934 | 12.047 |
| Limit i(mA)*With a small area of contact* | 1 mA | | 30 mA | 30 mA | 30 mA |
| Limit i(mA)*With large area of contact* | 5 mA | | 100–150 mA | 100–150 mA | 100–150 mA |
| Impedance phase at 50 kHz | 7–8° in normal tissue | | | | |
| | 4–12° normal range | | | | |
| Frame rate | | | 20 Hz Usually | 182.7 Hz at high frequencies (over 1 MHz) | |

## *4.3 Resistance Values and Resistivity of Various Tissues*

A table of indicative values of resistivity for various tissues, which compose the human body, in various frequencies of injected current is presented above [14–18] (Table 1).

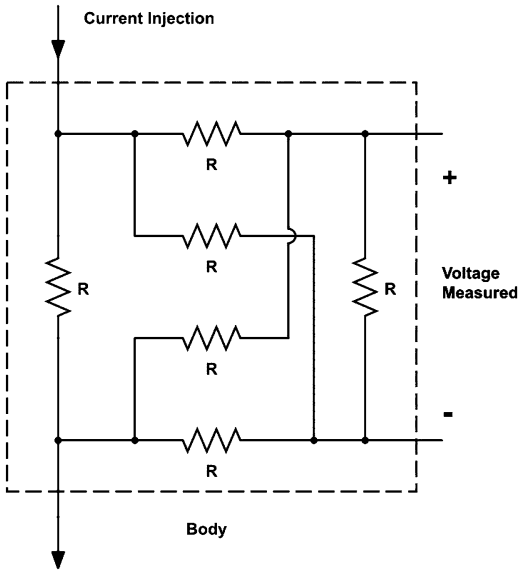


**Fig. 3** Equivalent resistance circuit during voltage measurement

### *4.4 Arising Limitations*

The adjacent measurement reception strategy is selected to be used. This strategy shows that by positioning the current source between two electrodes and by measuring voltage between two other electrodes, an equivalent shape of "cross" resistances comes as a result, while the resistors corresponding to other electrodes, that are not being used, are being ignored. Therefore, this results in a circuit, as Fig. 3.

Solving the circuit above using the Norton theorem and for the indicative resistance values of the table above, the resulting voltage is in the order of 15 V. Therefore, as the measured voltages will pass through a multiplexer system, it is necessary that the respective integrated circuits will operate in the same voltage levels, so that there is no cut-off of signals because of saturation [14, 16].

## 5 Results

The human body has tolerance for specific values and frequencies of electric current, while at the same measuring instruments perform better for certain types and values of received signals. Due to this reason, the optimum values and frequencies of the applied currents have to be calculated, so that the efficiency of the system is maximized. The electrical impedance tomography is a promising method for the development of non-invasive diagnostic medicine, as it is able to provide imaging of the interior of the human body in real time and without causing harm or putting the human body at risk. With the development of EIT systems, the opportunity

of spreading and expanding the method is given, since implementation of EIT is facilitated and cost is being reduced. In the twenty-first century, technological progress is essential, so that diagnosis and treatment have more effective and painless methods.

## References


1. Adler, A., J.H. Arnold, R. Bayford, et al. 2009. GREIT: A Unified Approach to 2D Linear EIT Reconstruction of Lung Images. *Physiological Measurement* 30: S35–S55.
2. Barber, D.C., B.H. Brown, and I.L. Freeston. 1983. Imaging Spatial Distributions of Resistivity Using Applied Potential Tomography. *Electronics Letters* 19: 93–95.
3. Frerichs, I. 2000. Electrical Impedance Tomography (EIT) in Applications Related to Lung and Ventilation: A Review of Experimental and Clinical Activities. *Physiological Measurement* 21: R1–21.
4. Wang, Q., H. Wang, Z. Cui, et al. 2012. Reconstruction of Electrical Impedance Tomography (EIT) Images Based on the Expectation Maximum (EM) Method. *ISA Transactions* 51: 808–820.
5. Constantin, J.M., S. Perbet, J. Delmas, et al. 2014. Electrical Impedance Tomography: So Close to Touching the Holy Grail. *Critical Care* 18: 164.
6. Cheney, M., D. Isaacson, and J.C. Newell. 1999. Electrical Impedance Tomography. *SIAM Review* 41: 85–101.
7. Trepte, J.C., R.C. Phillips, J. Solà, et al. 2016. Electrical Impedance Tomography (EIT) for Quantification of Pulmonary Edema in Acute Lung Injury. *Critical Care* 20: 18.
8. Gómez-Laberge, C., J.H. Arnold, and G.K. Wolf. 2012. A Unified Approach for EIT Imaging of Regional Overdistension and Atelectasis in Acute Lung Injury. *IEEE Transactions on Medical Imaging* 31: 834–842.
9. Jehl, M., A. Dedner, T. Betcke, et al. 2015. A Fast Parallel Solver for the Forward Problem in Electrical Impedance Tomography. *IEEE Transactions on Biomedical Engineering* 62: 126–137.
10. Malone, E., M. Jehl, and S. Arridge. 2014. Stroke Type Differentiation Using Spectrally Constrained Multifrequency EIT: Evaluation of Feasibility in a Realistic Head Model. *Physiological Measurement* 35: 1051–1066.
11. Bayford, R.H. 2006. Bioimpedancel Tomography (Electrical Impedance Tomography). *Annual Review of Biomedical Engineering* 8: 63–91.
12. Fish, R.M., and L.A. Geddes. 2008. Electrophysiology of Connection Current Spikes. *Cardiovascular Engineering* 8: 219–224.
13. ———. 2009. Conduction of Electrical Current to and Through the Human Body: A Review. *Eplasty* 9: e44.
14. Gabriel, S., R.W. Lau, and C. Gabriel. 1966. The Dielectric Properties of Biological Tissues: II. Measurement in the Frequency Range 10 Hz to GHz. *Physics in Medicine and Biology* 41: 2251–2269.
15. Faes, T.J., H.A. van der Meij, J.C. de Munck, et al. 1999. The Electric Resistivity of Human Tissues (100 Hz-10 MHz): A Meta-Analysis of Review Studies. *Physiological Measurement* 20: R1–10.
16. Gabriel, C., S. Gabriel, and E. Corthout. 1996. The Dielectric Properties of Biological Tissues: I. Literature Survey. *Physics in Medicine and Biology* 41: 2231–2249.
17. Geddes, L.A., and L.E. Baker. 1967. The Specific Resistance of Biological Engineer and Physiologist. *Medical & Biological Engineering* 5: 271–293.
18. Kumar, S., A. Dutt, and S. Hemraj. 2012. Phase Angle Measurement in Healthy Human Subjects Through Bio-Impedance Analysis. *Iranian Journal of Basic Medical Sciences* 15: 1180–1184.

# Application of Theranostics in Oncology

**Georgios Lymperopoulos, Panagiotis Lymperopoulos, Victoria Alikari, Chrisoula Dafogianni, Sofia Zyga, and Nikoletta Margari**

**Abstract** In recent years, due to the development of nanotechnology new horizons in treatment and diagnosis of cancer open up. Development of nano-systems for simultaneous transfer of active substances and imaging of tumor regions gathers an important amount of scientific interest. This new category of nano-systems is called Theranostics. Theranostics methods can provide multiple benefits by inserting nanoparticles into the patient and using photodynamic therapy and pave the way for personalized medicine. The objective of this paper is to study the use and application of Theranostics in the diagnosis and treatment of cancer, in order to achieve personalized anticancer treatment. For this purpose, investigation of existing literature has been conducted using electronic databases, PubMed, Google Scholar and IEEE Xplore. In addition, there was a secondary research phase, using paper citations found during the first research phase. It has to be pointed out that nanoparticles are the basis of Theranostics, since, due to their properties, they provide the ability to display accurate imaging and provide diagnosis along with simultaneous treatment of diseases. Theranostics methods may be applied in treatment of esophageal cancer, prostate cancer, breast cancer, in treatment of actinic keratosis, actinic cheilitis and Bowen's disease and in treatment of basal cell

G. Lymperopoulos (✉)
Department of Electrical Engineering, School of Engineering, University of Southern California, Los Angeles, CA, USA
e-mail: geo.lympero@gmail.com

P. Lymperopoulos
Department of Mechanical and Aeronautical Engineering, School of Engineering, University of Patras, Patras, Greece

V. Alikari (✉)
Laboratory of Nursing Research and Practice, Department of Nursing, Faculty of Human Movement and Quality of Life Sciences, University of Peloponnese, Tripoli, Greece
e-mail: vicalikari@gmail.com

C. Dafogianni • N. Margari (✉)
Department of Nursing, Technological Educational Institute of Athens, Athens, Greece
e-mail: nmargari@teiath.gr

S. Zyga
Department of Nursing, Faculty of Human Movement and Quality of Life Sciences, University of Peloponnese, Tripoli, Greece



P. Vlamos (eds.), *GeNeDis 2016*, Advances in Experimental Medicine and Biology 989, DOI 10.1007/978-3-319-57348-9_10

epithelioma and macular degeneration. As a result, application of Theranostics can provide multiple benefits by inserting nanoparticles into the patient. This method is currently encountering many challenges, but continuation of research on the field is necessary not only for the improvement of the medical field and the healthcare techniques, but also for the creation of new treatment methods for patients with diseases that are incurable until now.

**Keywords** Theranostics • Nanotechnology • Cancer • Photodynamic therapy • Personalized medicine

## 1 Introduction

Cancer is one of the major diseases responsible for deaths of millions of people during the twentieth century and remains one of the main causes of morbidity and/or mortality with more than 10 million new cases every year. It is a malignant disease characterized by uncontrolled growth and spread (metastasis) of abnormal cells which, if not controlled, can cause death [1]. Modern methods of cancer treatment include surgery, radiotherapy, chemotherapy, hyperthermia, immunotherapy, hormonal therapy, stem cell therapy, and combinations thereof. More particularly, chemotherapy is the most common method of treating cancer tumors. Except for destruction and prevention of proliferation of tumor cells, chemotherapy also affects healthy cells and causes many side effects [2–4].

In recent years with the development of nanotechnology new horizons are opened up in treatment and diagnosis of cancer. Application of nanotechnology to develop methods and means of targeted transport of anticancer drugs and reduction of side effects has been extensively studied the last decade [5]. Develop of systems for the simultaneous transfer of active substances and imaging of cancerous areas has also garnered significant research interest. This new nanosystems category is called ***Theranostics*** [6, 7].

In a slightly wider aspect, theranostics has been described as the use of appropriate screening methods for customization of therapeutic interventions [8]. Theranostics methods can offer multiple benefits by inserting nanoparticles into the patient and using photodynamic therapy. Nanoparticles consist the basis of Theranostics, as, due to their properties, they have enabled precise imaging and diagnostic capability with simultaneous treatment of diseases. The first use of photosensitizers in the treatment of cancer is backed in the early twentieth century in Munich, Germany. There, the group of von Tappeiner used eosin dye with fluorine base for the treatment of skin carcinomas. However, the first clinically acceptable photosensitizer was approved in 1993 by the Canadian Medical Association and was Photofrin, for the treatment of bladder cancer and other types of tumors. Unfortunately, this substance causes light sensitivity to patients, and also had weak radiation absorption (630 nm). However, it was found that the use of

photosensitizers enabled both diagnosis and treatment, combined resulting in the creation of a new term and field: *Theranostics*. For these reasons, there has been promotion of single factors that give the advantage of local detection and drug intake during the process, while avoiding increase of toxicity in the body [9].

Theranostics pave the way for personalized medicine. This involves the use of molecular assays to determine optimal drug dose to the right person at the right time. Although there has been considerable interest for individualized medicine, its true potential has not been discovered yet. Factors such as cost and regulatory timelines are major obstacles that must be addressed at this time.

Most of the Theranostics companies have focused on strengthening a particular step in the R & D process of a pharmaceutical company. In such a scenario, the company develops a diagnostic test by playing the role of an expert in this particular therapeutic field and the pharmaceutical company fulfills its part of the contract. This model has benefited pharmaceutical companies, particularly in reducing R&D costs and reducing drug failure rates in clinical trials.

The main techniques used to develop a Theranostic assay are:

- In-situ hybridization (ISH) to detect shifts and multiplications
- PCR, DNA sequencing of the PCR product
- Immunohistochemistry for targeting protein expression
- Gel electrophoresis and HPLC (high performance liquid chromatography)
- Oligonucleotide Ligation and technology of microarray [8,10,11].

One of the main objectives of future theranostics is to help with the treatment of cancers, especially breast cancer, in an efficient and ethical manner. A principal investigator of theranostics, Jelena M. Janjic, believes that soon there will come a time when patients with breast cancer will be able to travel to a clinic and receive a transdermal patch that will be filled with therapeutic nanoparticles. The patch will be applied to the skin of the patients and nanoparticles will be inserted from there.

When the breast tumor would be sufficiently close to the surface, near-infrared imaging could be used, which is a tissue-invasive optical technique in order to monitor the particles. If the tumor is deeper in the skin, the magnetic resonance imaging (MRI) will be the method used. After capturing images, physicians would be able to assess whether the drug actually reached the tumor in a given concentration. From these data, monthly doses can be determined. If the drug level should be changed, the dose may be increased, while monitoring the progress of the treatment. Theranostics capabilities, especially when dealing with breast cancer, can really offer better treatment [12].

Photodynamic therapy (PDT) belongs to photomedicine field. It is a method of treating cancer tumors and other non-malignant tumors and diseases which comprises three main component: a photosensitizer, light and oxygen content in the tissue. Important advantages of PDT are selectivity, the fact that it is a non-invasive form of therapy (absence of scarring), as well as speed and possibility of repeatability. It is affordable and safe treatment for the patient and medical

staff. In any case, the fact that many human organs are not directly accessible via roads (vascular) and the limited penetration depth of optical radiation in the tissues severely limits its scope [13–15].

## 2 Esophageal Cancer Therapy Via Photodynamic Therapy

Photodynamic method is the most effective treatment. In the oral cavity, the resection of early carcinomas e.g. with CO2 laser is not satisfactory. Conventional treatments (chemotherapy, surgery, radiation therapy) applied independently or in combination to primary or secondary tumors result in poor postoperative course and mortality of patients. Photodynamic process is a mild treatment for this type of surface tumors both at the esophagus and at the larynx. To achieve optimum results parameters such as photoresist dose, irradiation time, selectivity of the photosensitizer, excitation wavelength and toxicity of the substance should be accurately determined.

In photodynamic therapy of esophagus, unsatisfactory retention of the photosensitizer by the cancer cells results in the damage of healthy tissues and the development of secondary conditions such as stenosis. This phenomenon may be limited by the precise light dosimetry to the tissue. Light dosimetry is a complex problem, because the dispersion of radiation energy in the tissue is difficult to be predicted. The developed models operate under strict experimental conditions, but their results are not always as expected. Moreover, optical parameters of the tissue site of interest are difficult to be defined.

Necrosis depth in relation to the normalized irradiation on cancer tumor 1 mm thick and healthy esophagus tissue is the minimum irradiation to achieve tissue necrosis in the tumor surface. In case of early esophageal carcinomas, most significant complication in photodynamic therapy is tissue perforation. We assume that a tissue contains a tumor, and that the concentration of the photosensitizer in the tumor is greater than that in the healthy tissue. This selectivity translates into a difference in the minimum energy density to be irradiated to have necrosis. Additionally, considering same optical properties of unhealthy and healthy tissue, the thickness of the tumor that can be healed without harming surrounding healthy tissue can be calculated, for a specific selectivity.

In conclusion, based on the measurements of Stringer, Kelty, Ackroyd and Brown, we can say that photophysical properties and photo bleaching kinetics of porphyrin depend on the molecular environment. Measurements were made using radiation with two different wavelengths (705 and 635 nm) and it was found that the photo bleaching effect was the same, but not the fluorescence emission peaks. However, the treatment was effective in eliminating esophageal cancer [16–18].

## 3 Prostate Cancer Therapy Via Photodynamic Therapy

The prostate is a small gland of male mammals, including men, which is located under the bladder and surrounds the urethra. Prostate contains some smooth muscles that help in the expulsion of sperm during ejaculation, while its role is to provide a portion of the necessary liquid.

A prostate disease is generally treated at an early stage with medication. In cases where the condition cannot be treated in this way, the patient should go for surgery, where the tissue that causes swelling of the prostate is removed.

All light sources and detectors are inserted into the prostate through transparent plastic catheters (e.g. Flexi-needle®, Best Medical International, Springfield, VA). Catheters are aligned with the prostate using a guide connected to the TRUS unit (TransRectal UltraSound). The guide provides a network of possible positions of the catheter, separated by 0.5 cm in lateral and vertical direction. The TRUS unit is calibrated so as to lie above these positions when the ultrasound images are obtained. Then, a treatment plan is created in order to determine the positions and active lengths of light sources. As light sources, cylindrical diffuser fibers (CDF) with active lengths of 1–5 cm are commonly used. CDF sources are parallel, spaced 1 cm and light power per length unit is less than or equal to 150 mW/cm for each CDF. The length of CDF at a specific location within the prostate is selected so as to cover the entire length of the prostate. For some purposes, however, clinical application often requires prostate division into four quadrants. So they used four isotropic probes, each of which is placed in the center of a quadrant. A fifth isotropic probe is placed on a bladder catheter to control light flow to the urethra.

Patients receive anesthesia in the operating room in order to minimize their movement during the procedure. Before the light output, biopsies are receipted by transrectal ultrasound guidance for measuring MLu. The ultrasound unit is used as a guidance for positioning of the needle in the operating room. Four scanning probes (one for each quadrant) are inserted into the prostate. These probes are left in this position throughout the course of photodynamic therapy. Then, four more premeditated therapy catheters for light sources (shaded circles) are imported 0.5 or 0.7 cm away from the detection probe catheters. These source probes are used for the light output and for measuring optical properties. A diode is used as the source of the 732 nm light.

Modern art PDT protocols for prostate base administering light flow in direct in vivo measurements with isotropic probes. We observe that the relationship between the flow rate of the light and power of the point (or linear) source is linear, even though the relationship between the flow rate of the light and the distance from the radiation source is non-linear. Early results show that it is possible to cover the prostate gland while PDT dose is reduced to critical organs in the homogeneous prostate. Further studies aim at optimizing PDT dose in inhomogeneous material.

In conclusion, we can say that we have to take into account basic dosimetric parameters such as flow rate of light, optical properties of tissue and concentration of the photosensitizer. In suitable models, local oxygenation of tissue should be taken into account. Additionally, dosimetric indicators of the effect of PDT, such as fluorescence, photobleaching or blood flow may prove valuable. A comprehensive approach of PDT method would be supported [19, 20].

## 4 Breast Cancer Therapy Via Photodynamic Therapy

Breast cancer is a disease in which malignant (cancer) cells proliferate uncontrollably in breast tissues. Breast cancer is observed in both men in women, although the male breast cancer is much rarer.

The most common type of breast cancer is vascular carcinoma, starting in vascular cells. Other types of cancer are lobed carcinoma that starts in the lobes and lobules and is what usually occurs in both breasts and inflammatory cancer, an unusual type, in which breast is presented hot, red and swollen.

Currently there are several treatments for the different types of breast cancer and photodynamic therapy (PDT) is one of them, commonly used in tumors that have not been treated completely with the use of chemotherapy or surgery (mastectomy) or reappear after some time, especially in the thoracic breast walls region.

Thoracic breast walls cancer affects 5% of patients with breast cancer and is a major source of pain. Treatment options are limited or are not useful to be offered in these patients. Photodynamic therapy using a photosensitizer in small portions provides an excellent clinical response with minimal morbidity. The photosensitizer provides improved selectivity, prolonged retention in tumors, and quick elimination from the healthy tissue. Furthermore, the increased absorbance in a small wavelength range allows greater light penetration to the tumor. To confirm this, there have been many experiments, with results including the following.

Photodynamic therapy led to treatment of tumor in all patients, regardless of the substance dose. Recovery time depended mainly on the irradiation surface area and not by irradiation energy, ranging between 8 and 10 weeks. Pain was observed 1 day after PDT and lasted for about 10 days [21, 22].

## 5 Actinic Keratoses and Actinic Cheilitis

Actinic keratoses are erythematosquamous plaques that occur mainly in the skin areas exposed to the sun for a long time. It is a very common reason for patients to visit the dermatologist. Any actinic hyperkeratosis damage has significant probability (about 8%) to develop into squamous cell carcinoma, which is a form of dermal cancer capable of tissue infiltration beyond the skin. Therefore actinic keratoses

should be treated. Many clinical studies have shown efficiency of photodynamic treatment with ALA (aminolevulinic acid) or MAL (methylated derivative of ALA) for actinic keratoses. The probability of elimination of a damage ranges from 69% to 92%. These results are comparable to those of cryotherapy or 5-fluorouracil application, which are the other methods that are traditionally used for actinic hyperkeratosis treatment.

The advantage of photodynamic therapy is that it can treat many damages simultaneously, with quick healing time. Furthermore, if erythema and edema are observed after treatment, the aesthetic result is rather better than that obtained with cryotherapy, since the probability of appearance of scars or discoloration is much better.

Actinic cheilitis is a type of actinic keratoses on the lips. It also occurs after long-term exposure to the sun. Small studies show that one or two sessions of photodynamic therapy (using pulsed dye laser light source) treat actinic cheilitis by a percentage from 47% to 68% of patients. Review in 13, 14 and 22 months in 3 of the treated patients showed that remained damage free [23, 24].

## 6 Bowen's Disease

Bowen's disease (squamous cell carcinoma in situ) resembles red or pinkish scaly patches appearing mainly on photo exposed skin. Studies suggest that one or two of sessions of photodynamic therapy eliminate damage in an percentage from 82 to 93%.

Thus, photodynamic therapy has results comparable to cryotherapy or topical 5-fluorouracil application. It also has fewer side effects and better cosmetic results.

It is a treatment choice for damages that occur in areas with poor healing (shins, for example), in large or multiple damages, or damages appearing in areas where aesthetic appearance is of main interest [25].

## 7 Basal Cell Epithelioma

The basal cell epithelioma is the most common form of skin cancer. It arises from the basal layer cells and occurs mainly in photo-exposed regions. In the vast majority of cases it does not give metastases. The depth of the lesion is a critical factor that is important for the response to photodynamic therapy. If the damage does not exceed 2–3 mm in depth, it can be eliminated successfully with photodynamic therapy. Indeed, superficial basal cell epitheliomas respond excellently to photodynamic treatment with ALA or MAL. Complete disappearance ranges from 60 to 100%, while relapses range from 5 to 52%. Again in this case the results of the method are comparable to those of cryotherapy, with fewer side effects, faster healing and

a better final aesthetic result. The nodular basal epitheliomas that have significant vertical development and bigger depth do not respond equally well in photodynamic therapy due to limited penetration [26].

## 8 Macular Degeneration

Macular degeneration is a disease of the eye associated with age. It is often referred as Age Related Macular Degeneration (ARMD or AMD). The exact etiology of the disease remains unknown to date, whereas it is estimated that approximately 25 million people suffer worldwide. The final phase of the disease is associated with loss of central vision and is the leading cause of legal blindness in the western world in people over the age of 60.

In the early stages of AMD, depositions of substances are generated under the retina. These depositions are called Drusen and are usually visible to the ophthalmologist during the eye fundus examination. In most cases Drusen do not lead to severe vision impairment. However, in advanced stages of AMD, a decrease in vision is large, and in the final phase of the disease it can lead to legal blindness (visual acuity less than 01/10). AMD rarely leads to total blindness, because the patient retains peripheral vision.

Several clinical trials in the United States and in European countries have reported the benefits of photodynamic therapy in the case of macular degeneration. Photodynamic therapy (PDT) with verteporfin (Visudyne, the Novartis Pharmaceutical Corporation, East Hanover, NJ, USA) has been approved in more than 75 countries [27, 28]. Guidelines for the use of verteporfin in Japan have indicated that visual acuity has been maintained effectively in all types of lesions for at least 12 months [29].

## 9 Conclusion

Theranostics methods can provide multiple benefits by introducing nanoparticles into the patient and with the use of photodynamic therapy.

It is increasingly clear that the development of new technologies, both genetic and non-genetic, offers new opportunities for better understanding of the mechanisms of each disease. These developments will facilitate the development of new classes of pharmaceuticals, and sensitive and specific diagnostic exams. Continuation of research for new Theranostics applications will revolutionize the delivery of drugs and treatment. It will ensure that all patients receive the right dose of medication, which will be tailored to the needs of each patient, while it will be possible to verify that these drugs act on the targeted area and that they actually produce the desired results.

| Condition | Results of photodynamic therapy |
|---|---|
| Breast cancer (tumors that are not completely treated with chemotherapy or surgery, or reappear after some time) | Excellent response with minimal morbidity |
| Surface tumors of the esophagus and the larynx | Effective treatment. Side-effects: stenosis, tissue perforation |
| Prostate cancer | Dosimetric indicators of the effect of PDT, such as fluorescence, photobleaching or blood flow may prove valuable |
| Actinic keratoses that occur mainly in the skin areas exposed to the sun for a long time Actinic cheilitis | PDT can treat many damages simultaneously, with quick healing time |
| Bowen's disease | Fewer side effects and better cosmetic results |
| Basal cell epithelioma | Excellent results in surface lesions |
| Macular degeneration | Retention of visual acuity |

## References


1. Siegel, R., J. Ma, Z. Zou, et al. 2014. Cancer Statistics. *CA: A Cancer Journal for Clinicians* 64: 9–29.
2. Giordano, K.F., and A. Jatoi. 2005. The Cancer Anorexia/Weight Loss Syndrome: Therapeutic Challenges. *Current Oncology Reports* 7: 271–276.
3. Magge, R.S., and L.M. DeAngelis. 2015. The Double-Edged Sword: Neurotoxicity of Chemotherapy. *Blood Reviews* 29: 93–100.
4. Mihelic, R.A. 2005. Cytotoxic Drugs Used in Chemotherapy Affect Normal Cells in Addition to the Destruction and Prevention of Proliferation of Cancer Cells. *Seminars in Oncology Nursing* 21: 29–35.
5. Douziech-Eyrolles, L., H. Marchais, K. Hervé, et al. 2007. Nanovectors for Anticancer Agents Based on Superparamagnetic Iron Oxide Nanoparticles. *International Journal of Nanomedicine* 2: 541–550.
6. Janib, S.M., A.S. Moses, and J.A. MacKay. 2010. Imaging and Drug Delivery Using Theranostic Nanoparticles. *Advanced Drug Delivery Reviews* 62: 1052–1063.
7. Xie, J., S. Lee, and X. Chen. 2010. Nanoparticle-Based Theranostic Agents. *Advanced Drug Delivery Reviews* 62: 1064–1079.
8. Pene, F., E. Courtine, A. Cariou, et al. 2009. Toward Theragnostics. *Critical Care Medicine* 37: S50–SS8.
9. Josefsen, L.B., and R.W. Boyle. 2012. Unique Diagnostic and Therapeutical Roles of Porphyrins and Phtalocyanines in Photodynamic Therpay, Imaging and Theranostics. *Theranostics* 2: 916–966.
10. Blanchet, K.D. 2010. Redefining Personalized Medicine in the Postgenomic Era: Developing Bladder Cancer Therapeutics with Proteomics. *BJU International* 105: i–iii.
11. Ramachandran, G. 2009. *Theranostics: An Evolving Field Catering to the Unmet Needs of the Medical World*. Frost & Sullivan.
12. Kelkar, S.S., and T.M. Reineke. 2011. Theranostics: Combing Imaging and Therapy. *Bioconjugate Chemistry* 22: 1879–1903.
13. Allison, R.R., G.H. Downie, R. Cuenca, et al. 2004. Photosensitizers in Clinical PDT. *Photodiagnosis and Photodynamic Therapy* 1: 27–42.
14. Huang, Z. 2005. Review of Progress in Clinical Photodynamic Therapy. *Technology in Cancer Research & Treatment* 4: 283–293.

15. Wilson, B.C., and M.S. Patterson. 1986. The Physics of Photodynamic Therapy. *Physics in Medicine and Biology* 3: 327–360.
16. Stringer, M.R., C.J. Kelty, R. Ackroyd, et al. 2006. Light Dosimetry Measurements During ALA-PDT of Barrett's Oesophagus. *Photodiagnosis and Photodynamic Therapy* 3: 19–26.
17. Yi, E., C.K. Yang, C. Leem, et al. 2014. Clinical Outcome of Photodynamic Therapy in Esophageal Squamous Cell Carcinoma. *Journal of Photochemistry and Photobiology. B* 141: 20–25.
18. Yoon, H.Y., Y.K. Cheon, H.J. Choi, et al. 2012. Role of Photodynamic Therapy in the Palliation of Obstructing Esophageal Cancer. *The Korean Journal of Internal Medicine* 27: 278–284.
19. Moore, C.M., D. Pendse, and M. Emberton. 2009. Photodynamic Therapy for Prostate Cancer—A Review of Current Status and Future Promise. *Nature Clinical Practice Urology* 6: 18–30.
20. Timothy, C.Z., and C.F. Jarod. 2006. Prostate PDT Dosimetry. *Photodiagnosis and Photodynamic Therapy* 3: 234–246.
21. Hilvo, M., C. Denkert, L. Lehtinen, et al. 2011. Novel Theranostic Opportunities Offered by Characterization of Altered Membrane Lipid Metabolism in Breast Cancer Progression. *Cancer Research* 71: 3236–3245.
22. Ramakrishnan, S., M. Serricchio, B. Striepen, et al. 2013. Lipid Synthesis in Protozoan Parasites: A Comparison Between Kinetoplastids and Apicomplexans. *Progress in Lipid Research* 52: 488–512.
23. Fargnoli, M.C., D. Kostaki, A. Piccioni, et al. 2015. Photodynamic Therapy for the Treatment of Microinvasive Squamous Cell Carcinoma of the Lower Lip: A Case Report. *Giornale Italiano di Dermatologia e Venereologia* 150: 331–335.
24. Kodama, M., D. Watanabe, and Y. Akita. 2007. Photodynamic Therapy for the Treatment of Actinic Cheilitis. *Photodermatology Photoimmunology & Photomedicine* 23: 209–210.
25. Cai, H., Y.X. Wang, and J.C. Zheng. 2015. Photodynamic Therapy in Combination with CO2 Laser for the Treatment of Bowen's Disease. *Lasers in Medical Science* 30: 1505–1510.
26. Marrelli, M., G. Menichini, E. Provenzano, et al. 2014. Applications of Natural Compounds in the Photodynamic Therapy of Skin Cancer. *Current Medicinal Chemistry* 21: 1371–1390.
27. Arnold, J.I., K.J. Blinder, N.M. Bressler, et al. 2004. Treatment of Age-Related Macular Degeneration with Photodynamic Therapy Study Group; Verteporfin in Photodynamic Therapy Study Group. Acute Severe Visual Acuity Decrease After Photodynamic Therapy with Verteporfin: Case Reports from Randomized Clinical Trials-TAP and VIP Report No 3. *American Journal of Ophthalmology* 137: 683–696.
28. Japanese Age-Related Macular Degeneration Trials (JAT) Study Group. 2003. Japanese Age-Related Macular Degeneration Trial: 1-Year Results of Photodynamic Therapy with Verteporfin in Japanese Patients with Subfoveal Choroidal Neovascularization Secondary to Age-Related Macular Degeneration. *American Journal of Ophthalmology* 135: 1049–1061.
29. Tano, Y. 2008. Ophthalmic PDT Study Group. Guidelines for PDT in Japan. *Ophthalmology* 115 (3): 585–585.e6.

# Sport Participation and Ageing: Evidence from Marathon Events

**Konstantinos Koronios, Marina Mavromati, Athanasios Kriemadis, Eleni Leivaditi, Petros Kolovos, and Andreas Papadopoulos**

**Abstract** The purpose of this research is to study expectations regarding ageing (ERA) among individuals who participate in running events as well as to explore personality and demographic features as potential variables that influence ERA values. A quantitative questionnaire was selected as the predominant means of collecting the data and 196 successfully completed questionnaires were analyzed by means of the SPSS. Results indicate a positive correlation between ERA values and Change Seeker Index in our sample. Moreover gender and frequency of exercise found to have no significant effect on ERA score. Finally, ERA was examined among three generational cohorts and differences were noticed to physical subscale.

**Keywords** Sport participation • Ageing • Motives

## 1 Introduction

For a number of years there was the perception that growing older is associated closely to physical and functional decrease [1]. This negative viewpoint about the aging process is demonstrated not only from older but also from younger age sets [2]. However, in the last two centuries, emphasis has been given on optimal aging constructs [1] especially due to the increase of population over 65 years old. Indeed it is important for elder people not only to maintain their mental and physical condition [3] but also to have a positive view about their own ageing [2].

The beneficial outcomes of regular exercise for physical and mental health are documented in detail and exercising has been promoted internationally via

K. Koronios (✉) • A. Kriemadis • E. Leivaditi • A. Papadopoulos
Faculty of Human Movement and Quality of Life Sciences, Department of Sports Organization and Management, University of Peloponnese, Sparti, Greece
e-mail: konskoron@hotmail.com

M. Mavromati
Department of Business Administration, University of Macedonia, Thessaloniki, Greece

P. Kolovos
Faculty of Human Movement and Quality of Life Sciences, Department of Nursing, University of Peloponnese, Sparti, Greece



P. Vlamos (eds.), *GeNeDis 2016*, Advances in Experimental Medicine and Biology 989, DOI 10.1007/978-3-319-57348-9_11

considerable provision of sport and recreation infrastructures. The enormous publicity of physical activity followed the acknowledgment of numerous benefits of sport participation, such as physiological, psychological and social benefits. Physiologically, sport participation is associated with a reduction in cardio-vascular risk, prevention/delay of diabetes and prevention of obesity. Psychologically, exercising is correlated with a decrease in anxiety and stress. Furthermore, sport participation heightens self-esteem and offers an apparatus for social interaction [4]. These benefits are correlated with a decline in medical care expenses, as well as with higher job efficiency [5].

The physical and psychological advantages of systematic training especially for elder individuals have been analyzed in detail [6]. Regrettably, sedentary lifestyle of contemporary individuals illustrates not the exception but the norm, with nearly 66% of individuals above 65 years old, avoiding engaging in any type of systematic training. On the contrary, in case of participating in systematic training programs in the context of community sports (e.g. marathon running events), the adherence percentage of older individuals has been noted to be higher than those noted for other age sections [6].

Nowadays, given the growing life expectancy and low fecundity rates, the percentage of the older individuals is speedily growing in Western societies, including Greece. The elderly (over 65 years) population in Greece is expected to grow during the following years. As they age, middle-aged Greek people will comprise a large percentage of the total population over the next two decades. Nevertheless, it has been proven that only 20% of older individuals undertake adequate exercising to augment health advantages [7, 8].

A main stream of research has shown that the majority of older individuals in the developed world is knowledgeable about the necessity of being active and has an eagerness to be more active [9]. One of the prevalent types of systematic exercise between older adults since the 1970s is road running [10] with marathon running to demonstrate a significant increase over the last decade. Although formerly thought of as purely a professional sport, marathon running has become commonplace worldwide among amateur individuals. The typical marathon range is 42.2 km and many athletes take part each year worldwide. Marathon running is a recreational activity which has experienced an exceptional development over the last years, as an increasing number of older adults consider it an appropriate alternative for recreationally based physical activity [11]. Marathons can be organized on or off-road and they are usually arranged to encompass a particular distance or cover a ceiling distance within a specific timetable. These types of marathons are largely segregated by harsh trail circumstances, such as rugged ground, altitude differences, and nasty weather. Moreover, the amount of effort needed to participate in these types of marathons is certainly a long way off the training required to obtain elemental health benefits, which may cause tiredness and injury. Regardless of the great sacrifices correlated with training time and exertion, growing numbers of older individuals are deliberately taking part in marathons systematically [12]. This contradiction makes one wonder about their expectations regarding ageing and their motivation in participating in such running events.

Several studies have investigated the motives of individuals for sport participation, but limited empirical support has been assigned to the motives of older marathoners, individuals who despite their age, train for very long periods and often in undesirable conditions. Many of the previous studies about marathoners have examined alterations of mood, stress and/or emotions, but have not straightforwardly assessed motivation to run. Furthermore, a contemporary review of the personality attributes of marathoners proved that there is a scarcity of knowledge concerning their motivation [13]. The increasing popularity of marathon running has led researchers to ascertain the multifarious factors that entice older individuals to take part in the sport. Various researches investigating the requirements, motives and behavioral attributes underlying marathon runners have been recognized [14, 15], and have been found to be imbricating, with notions used correspondently, such as cognitive, emotional and physiological needs and motives.

The aim of this research is to single out the perception of marathon runners regarding their expectation about ageing as well as to examine potential association to personality constructs. Moreover generational cohorts, gender and frequency of exercise will be explored as potential differentiation factors.

## 2 Theoretical Background

Despite the plethora of studies that has investigated the motives of older runners [16], inadequate consideration has been assigned to the expectations that these individuals have about their own health and cognitive function while ageing.

Elder individuals are less likely than younger ones to achieve public health objectives for continuous exercise training [17]. Moreover, they may presume that health promotion campaigns about training target youthful individuals or that moderate levels of physical performance obstruct them from attempting to increase exercise performance. Hence, motivating inactive elder individuals to start and maintain physical activity behavior may face substantial challenges. The philosophy and opinions of elder individuals about the costs and benefits of training in aging humans can increase their level of exertion. Misapprehensions about the ageing procedure between elder individuals may lead to exercise limitation [18]. A stream of research has shown that many elder individuals consider training as unrelated to their own way of living, although they regard it as beneficial to others [19]. Elder individuals may be also uninformed about the advantages of training in the elderly or ignore the importance of physical activity in their life [20]. A significant percentage of older individuals underestimate their true physical ability and their potential in regular exercising as they confuse exercising with extreme physical exertion.

Despite the prevailing impression that growing age is correlated with a deterioration of physical and functional health status, geriatric medicine and gerontology introduced the idea of focusing on more forward-looking variables, like positive ageing and successful ageing [6]. The long-term health consequences, for middle-aged and elder adults, are prognosticated by objective and subjective

measures of health and ageing. Among the prevalent subjective measures is the "expectations regarding ageing – (ERA)" [21]. The conception of Expectations Regarding Ageing, can be described as anticipating accomplishments and preservation of high levels of physical and mental functioning with ageing, which denotes the anticipation of "healthy ageing", not only for the individual but also for the others. Individuals with more forward-looking/optimistic anticipations about ageing are more prone to maintain higher levels of physical activity and posit greater significance on seeking healthcare for age-related conditions. According to previous studies it may be feasible to enhance elder individuals' anticipations about ageing, in order to meliorate their health [6].

Up to the present time, mainly evaluated amid elder individuals in Western societies, anticipations concerning ageing have been correlated with physical activity and healthcare seeking comportment. Previous studies propose that it may be attainable to increase the interferences that develop positive expectations about ageing [21]. Evaluation of expectations about ageing amid present middle-aged generation will facilitate interferences about the creation of positive ageing anticipations and by extension their physical activity commitment. Nevertheless, there is a scarcity of research on determining ageing expectations amidst middle-aged individuals, who have not yet reached, but will soon enter the "youngest old" age group. Comprehending their anticipations about ageing could help policymakers to deploy strategies and improve performance of future social and health services, assist the present middle-aged generation to attain positive expectations, and age.

Moreover Davis et al. [1] have mentioned change as a key part of successful ageing. The capability to support lifestyle alteration may be meliorated by utilizing behaviour change strategies based on the variety-seeking tendency of the individuals. Previous studies support that interferences utilizing behavioural or cognitive–behavioural strategies were more persuasive than health education and exercise instructions [22, 23]. Further researches have exposed the significance of addressing individuals' confidence, attitudes and assumptions as well as the affective dimensions in order to increase the efficacy of training events [24]. The majority of physical activity interventions addressing elder individuals accentuating the significance of executing behavioural strategies in encouraging exercising [25]. Variety-seeking tendency is based mostly on the necessity for a switch in an effort to work out the boredom correlated with a given way of life [26]. The above variable has accumulated extensive research consideration in individuals' training behavior. Variety-seeking tendency has been recognized as a crucial exercising inspiration factor and an effective determinant in training participation encouragement. Moreover it has been correlated with sensation-based decision making and hedonic motivations [27].

One notable determinant, which also may differentiate the probability of participating in physical activities, is gender. Previous studies have in general limited evidence about gender differences in leisure time physical activities and have shown ambiguous results regarding the effect of gender on physical activities participation. One of the most persistent results in the sport and exercise literature regards the deprived status of women [28]. According to this stream of research, women's

lower exercise levels, particularly in late youthfulness and preadulthood, distend beyond various sports and types of physical activities, with differences between the two genders being greater in arduous sport activities ant types of exercise. More specifically, women were found to have lower overall leisure time physical activity in daily frequency as well as in weekly hours [29]. Furthermore, as Kilpatrick et al. [30] stated, participation motives vary between the two genders, with men having more ego oriented motives than women. On the contrary, no significant evidence was found about gender differences in levels of overall intense physical activities [29]. Additionally, as Koronios et al. [31] support, there is no significant evidence of linkage between gender and the intention to participate in exercising events. Hence, further research is required to identify the role of gender as a factor influencing participation in exercising.

## 3 Methodology

The objective of this research is to investigate the perceptions of individuals who participate in running events about their expectations on ageing as well as potential differences among generational cohorts. Moreover demographic and personality characteristics are studied. More specifically, elements were obtained from two running events, following a similar procedure. Both events have taken place in Southern Greece. A quantitative questionnaire was selected as the predominant means of collecting the data. The questionnaire developed for this study was based on previous research of similar subjects and populations [2, 6]. Items were assessed on interval scales and the time needed to complete the survey was 10–12 min.

To elaborate, a team of five researchers was responsible for distributing the questionnaires to the athletes and each one of them was randomly selected by the research team and politely asked to take part in the survey. The questionnaires were distributed at the end of the award ceremony to each participant by the above-mentioned team of researchers and were completed in the presence of the surveyors, with 196 questionnaires to be successfully completed. Particular circumstances on the field, such as the constant flow of athletes especially on coming to the award ceremony favors the selected operation by the researchers. The total number of questionnaires analyzed by means of the SPSS.

### *3.1 Demographics*

The demographic part of our questionnaire urged correspondents to present with information on their age, education, marital status, income, the age they started participating in running events as well as exercising frequency per week.

### 3.2 Expectations Regarding Ageing

The expectations of individuals regarding ageing were measured with the ERA-12 instrument (Expectations Regarding Ageing) [6, 32]. As Roters et al. [2], p. 68 mention a high score is a sign of "expected achievement and maintenance of mental and physical functioning while aging". On the other hand a lower rating suggests a presumed diminish in these features. A 5-point Likert scale was used. According to Davis et al. [1], the particular instrument can be divided in three subscales, each of which consists of four items. The first subscale is referred to expectation regarding physical health, the second one to metal health and the last one to cognitive function.

### 3.3 Change/Variety Seeker

Variety seeking was measured with the shortened version of Change Seeker Index which was developed by Steenkamp and Baumgartner [33]. The first version of the instrument included 95 items, while the shortened version only 7. The instrument gives a total CSI score [34] for each participant. Finally, a 5-point Likert scale was used in our study.

### 3.4 Statistical Analysis

Differences among generational cohorts and gender were examined by non-parametric tests. Comparing the means among three or more datasets, ANOVA test is usually performed. However, as our data do not follow the normal distribution, the Kruskal-Wallis test was used instead of ANOVA [35]. Moreover in order to examine the differences in variables between genders, a Mann-Whitney U test was conducted. This test is a non-parametric one and is similar to t test for normally distributed data, ascertaining the significance of deviation between the two categories [36].

## 4 Results

### 4.1 Demographics

Our sample consists of 196 respondents; 27.6% were female and 72.4% were male. Concerning the age of the participants, the mean age is 38.46 and the starting age of running in a marathon is 31.06. Moreover, trying to examine potential differences between generational cohorts, our sample was divided in 3 groups. The variables

were transformed according to the age; Baby Boomers includes those that were born from 1946 to 1964 [37], which means that in 2015 when the research was conducted, the participants of this generation were 51–69 years old. Similarly, Generation X was born between 1965 and 1977 and consequently this generation group consists of participants from 50 to 38 years old. Yet, Generation Y incorporates the rest of the runners. 12.2% of our sample are Baby Boomers, 43.4% are GenXers and 43.9% are in Generation Y. One of the respondents was 80 years old and as a result did not belong to any of these three cohorts.

In terms of their educational level, the majority of our sample had a university degree (38.3%) and 22.4% had also completed post-graduate studies. Moreover asking about their marital status, 41.3% of the respondents were single and 49.5% were married. The rest of our sample was divorced. 35.2% of our sample were private employees, 20.9% were freelancers and 19.4% were public employees. The greater number of the participants (34.2%) earned 1001–2000€ per month, 27.6% earned 601–1000€ and 21.4% received less than 600€ as their monthly income.

## *4.2 Descriptive Statistics and Correlations*

In Table 1, the descriptive statistics of the ERA along with its subscales are presented. Our sample displays 2.88 as an average value of ERA score with SD = 0.47, 3.3 as a mean score of physical subscale (SD = 0.58), 2.48 mean of mental subscale (SD = 0.76) and 2.83 is the average value of the cognitive subscale (SD = 0.56).

In the next table (Table 2) the descriptive statistics of the rest variables are presented. The minimum, maximum, mean and standard deviation scores are displayed. The mean number of exercise per week is 4.5 (SD = 1.65), signifying that it is more than 4 times in a week. Additionally, variety seeking index varies from 2 to 4.57 with mean value 3.31 (SD = 0.37).

**Table 1** Descriptive statistics (ERA-12)

| | N | Minimum | Maximum | Mean | Std. deviation |
|---|---|---|---|---|---|
| ERA_Total | 196 | 1.67 | 5.00 | 2.8818 | 0.47874 |
| ERA_Physical | 196 | 2.00 | 5.00 | 3.3291 | 0.58243 |
| ERA_Mental | 196 | 1.00 | 5.00 | 2.4834 | 0.76589 |
| ERA_Cognitive | 196 | 1.00 | 5.00 | 2.8329 | 0.56485 |
| Valid N (listwise) | 196 | | | | |

**Table 2** Descriptive statistics

| | N | Minimum | Maximum | Mean | Std. deviation |
|---|---|---|---|---|---|
| Ex_per_Week | 196 | 1.00 | 7.00 | 4.5561 | 1.65852 |
| Variety_Seeking_Total | 196 | 2.00 | 4.57 | 3.3090 | 0.37151 |
| Valid N (listwise) | 196 | | | | |

The correlations among other features are displayed using the Pearson test. As it is noticed from Table 3, the value Expectations Regarding Aging (Total Score) is significantly correlated (0.185) to Variety Seeking Index and the frequency of exercise per week (–0.158). On the other hand, Variety Seeking Value is correlated significantly also to age (–0.179) and to the subscale of physical value (0.248). Finally the frequency of exercise per week was also associated to the age of the respondents (0.266).

Moreover, searching for disparities among generations, the data were tested based on the generation that the respondents belong. However, using Kruskal Wallis test differences were noticed only to physical subscale (sig = 0.037). Finally, examining potential differences between genders, no statistically significant differences were found.

## 5 Discussion

The aim of this research was to study expectations regarding ageing among individuals who participate in running events as well as to study potential association with personality features and specifically with change characteristic. An interesting result is that compared to previous studies [3] the mean score of ERA in our sample is respectively high especially in physical subscale. Differences in the samples regarding the age, exercising habits as well as personality traits of the respondents could be potential explanations for these differences. In our study, the frequency of exercising per week was negatively correlated to participant's responses about ageing. However, Roters et al. [2] studying expectations regarding ageing between athletes and non-athletes found that both of them were relatively equal to ERA results which might indicate that exercising habits are not associated to expectations about ageing. Moreover, the ERA score was significantly correlated to Change Seeker Index which is in accordance to Davis et al. [1], p. 863 perception that "Change is a part of aging; understanding and coping with how much, how quickly, and how fast is likely a key to successful aging". Considering differences between gender in ERA and Variety Seeking Index, no significant disparities were found. However as the sample of the research is consisted more of men than women, attention should be given in terms of the generalizability of the results in accordance to previous studies [3]. Finally, ERA was examined among the three generational cohorts and differences were noticed to physical subscale. Further research is proposed about expectations regarding age in different samples as well as with different personality traits. Particularly some examination on people being involved in sports generally or on those who lead a sedentary lifestyle is strongly encouraged.

**Table 3** Correlations

| | | Starting_Age | Age | ERA Total | Variety Seeking | Ex/Week | ERA Physical | ERA Mental | ERA Cognitive |
|---|---|---|---|---|---|---|---|---|---|
| Starting Age | Pearson | 1 | | | | | | | |
| | Sig. (2-tailed) | | | | | | | | |
| | N | 196 | | | | | | | |
| Age | Pearson | 0.564** | 1 | | | | | | |
| | Sig. (2-tailed) | 0.000 | | | | | | | |
| | N | 196 | 196 | | | | | | |
| ERA Total | Pearson | −0.041 | −0.119 | 1 | | | | | |
| | Sig. (2-tailed) | 0.566 | 0.096 | | | | | | |
| | N | 196 | 196 | 196 | | | | | |
| Variety Seeking | Pearson | −0.083 | −0.179* | 0.185** | 1 | | | | |
| | Sig. (2-tailed) | 0.250 | 0.012 | 0.010 | | | | | |
| | N | 196 | 196 | 196 | 196 | | | | |
| Ex/Week | Pearson | 0.119 | 0.266** | −0.158* | 0.003 | 1 | | | |
| | Sig. (2-tailed) | 0.096 | 0.000 | 0.027 | 0.971 | | | | |
| | N | 196 | 196 | 196 | 196 | 196 | | | |
| ERA Physical | Pearson | −0.088 | −0.160* | 0.612** | 0.248** | −0.125 | 1 | | |
| | Sig. (2-tailed) | 0.221 | 0.025 | 0.000 | 0.000 | 0.080 | | | |
| | N | 196 | 196 | 196 | 196 | 196 | 196 | | |
| ERA Mental | Pearson | −0.035 | −0.050 | 0.826** | 0.075 | −0.098 | 0.193** | 1 | |
| | Sig. (2-tailed) | 0.625 | 0.483 | 0.000 | 0.298 | 0.173 | 0.007 | | |
| | N | 196 | 196 | 196 | 196 | 196 | 196 | 196 | |
| ERA Cognitive | Pearson | 0.033 | −0.070 | 0.791** | 0.113 | −0.140 | 0.263** | 0.546** | 1 |
| | Sig. (2-tailed) | 0.643 | 0.332 | 0.000 | 0.115 | 0.051 | 0.000 | 0.000 | |
| | N | 196 | 196 | 196 | 196 | 196 | 196 | 196 | 196 |

**Correlation is significant at the 0.01 level (2-tailed)
*Correlation is significant at the 0.05 level (2-tailed)

## References


1. Davis, M.M., L.A. Bond, A. Howard, and C.A. Sarkisian. 2011. Primary Care Clinician Expectations Regarding Aging. *The Gerontologist 51* (6): 856–866.
2. Roters, J., A.J. Logan, B.A. Meisner, and J. Baker. 2010. A Preliminary Study of Perceptions of Aging in Athletes and Non-Athletes. *Psychology of Sport and Exercise 11* (1): 67–70.
3. Kim, S.H. 2009. Older People's Expectations Regarding Ageing, Health-Promoting Behaviour and Health Status. *Journal of Advanced Nursing 65* (1): 84–91.
4. World Health Organization. 2010. *World Health Statistics 2010*. Geneva: World Health Organization.
5. Alexandris, K., and B. Carroll. 1997. Demographic Differences in the Perception of Constraints on Recreational Sport Participation: Results from a Study in Greece. *Leisure Studies 16* (2): 107–125.
6. Joshi, V.D., R. Malhotra, J.F. Lim, T. Ostbye, and M. Wong. 2010. Validity and Reliability of the Expectations Regarding Aging (ERA-12) Instrument Among Middle-Aged SINGAPOREANS. *Annals of the Academy of Medicine, Singapore 39* (2): 394–398.
7. Hawkins, S.A., M.G. Cockburn, A.S. Hamilton, and T.M. Mack. 2004. An Estimate of Physical Activity Prevalence in a Large Population-Based Cohort. *Medicine and Science in Sports and Exercise 36* (2): 253–260.
8. Lee, L.L., A. Arthur, and M. Avis. 2008. Using Self-Efficacy Theory to Develop Interventions That Help Older People Overcome Psychological Barriers to Physical Activity: A Discussion Paper. *International Journal of Nursing Studies 45* (11): 1690–1699.
9. Tsai, E.H.L. 2005. A Cross-Cultural Study of the Influence of Perceived Positive Outcomes on Participation in Regular Active Recreation: Hong Kong and Australian University Students. *Leisure Sciences 27* (5): 385–404.
10. Van der Nest, A. C. (2007). The Motivation of Ultramarathon Runners: A Comparison of Different Age, Gender and Race Groups. Doctoral dissertation, University of Johannesburg.
11. Ridinger, L.L., D.C. Funk, J.S. Jordan, and K.K. Kaplanidou. 2012. Marathons for the Masses: Exploring the Role of Negotiation-Efficacy and Involvement on Running Commitment. *Journal of Leisure Research 44* (2): 155.
12. Ogles, B.M., and K.S. Masters. 2003. A Typology of Marathon Runners Based on Cluster Analysis of Motivations. *Journal of Sport Behavior 26* (1): 69.
13. Knechtle, B., C.A. Rüst, T. Rosemann, and R. Lepers. 2012. Age-Related Changes in 100-km Ultra-Marathon Running Performance. *Age 34* (4): 1033–1045.
14. Gillett, P., and S. Kelly. 2006. 'Non-Local' Masters Games Participants: An Investigation of Competitive Active Sport Tourist Motives. *Journal of Sport Tourism 11* (3–4): 239–257.
15. Shipway, R., and I. Jones. 2007. Running Away from Home: Understanding Visitor Experiences and Behaviour at Sport Tourism Events. *International Journal of Tourism Research 9* (5): 373–383.
16. Funk, D., J. Jordan, L. Ridinger, and K. Kaplanidou. 2011. Capacity of Mass Participant Sport Events for the Development of Activity Commitment and Future Exercise Intention. *Leisure Sciences 33* (3): 250–268.
17. Ory, M.G., P.J. Jordan, and T. Bazzarre. 2002. The Behavior Change Consortium: Setting the Stage for a New Century of Health Behavior-Change Research. *Health Education Research* 17 (5): 500–511.
18. Lachman, M.E., and S.L. Weaver. 1997. *The Midlife Development Inventory (MIDI) Personality Scales: Scale Construction and Scoring*. Waltham, MA: Brandeis University.
19. Campbell, R., M. Evans, M. Tucker, B. Quilty, P. Dieppe, and J.L. Donovan. 2001. Why Don't Patients do their Exercises? Understanding non-Compliance with Physiotherapy in Patients with Osteoarthritis of the Knee. *Journal of epidemiology and community health 55* (2): 132–138.

20. King, A.C., S. Blair, D. Bild, R. Dishman, P. Dubbert, B. Marcus, N. Oldridge, R. Paffenbarger, K. Powell, and K. Yeager. 1992. Determinants of Physical Activity and Interventions in Adults. *Medicine and Science in Sports and Exercise* 24 (6): S221–S236.
21. Sarkisian, C.A., R.D. Hays, S. Berry, and C.M. Mangione. 2002. Development, Reliability, and Validity of the Expectations Regarding Aging (ERA-38) Survey. *The Gerontologist 42* (4): 534–542.
22. Brawley, L.R., W.J. Rejeski, and L. Lutes. 2000. A Group-Mediated Cognitive-Behavioral Intervention for Increasing Adherence to Physical Activity in Older Adults1. *Journal of Applied Biobehavioral Research 5* (1): 47–65.
23. Ettinger, W.H., R. Burns, S.P. Messier, W. Applegate, W.J. Rejeski, T. Morgan, and T. Craven. 1997. A Randomized Trial Comparing Aerobic Exercise and Resistance Exercise with a Health Education Program in Older Adults with Knee Osteoarthritis: The Fitness Arthritis and Seniors Trial (FAST). *JAMA 277* (1): 25–31.
24. Newsom, J.T., M.S. Kaplan, N. Huguet, and B.H. McFarland. 2004. Health Behaviors in a Representative Sample of Older Canadians: Prevalences, Reported Change, Motivation to Change, and Perceived Barriers. *The Gerontologist 44* (2): 193–205.
25. King, A.C., W.J. Rejeski, and D.M. Buchner. 1998. Physical Activity Interventions Targeting Older Adults: A Critical Review and Recommendations. *American Journal of Preventive Medicine 15* (4): 316–333.
26. Van Trijp, H.C., W.D. Hoyer, and J.J. Inman. 1996. Why Switch? Product Category: Level Explanations for True Variety-Seeking Behavior. *Journal of Marketing Research 33*: 281–292.
27. Sharma, P., B. Sivakumaran, and R. Marshall. 2006. Investigating Impulse Buying and Variety Seeking: Towards a General Theory of Hedonic Purchase Behaviors. *NA-Advances in Consumer Research 33*: 388–389.
28. Guinn, B., V. Vincent, T. Semper, and L. Jorgensen. 2000. Activity Involvement, Goal Perspective, and Self-Esteem Among Mexican American Adolescents. *Research Quarterly for Exercise and Sport 71* (3): 308–311.
29. Vilhjalmsson, R., and G. Kristjansdottir. 2003. Gender Differences in Physical Activity in Older Children and Adolescents: The Central Role of Organized Sport. *Social Science & Medicine 56* (2): 363–374.
30. Kilpatrick, M., E. Hebert, and J. Bartholomew. 2005. College Students' Motivation for Physical Activity: Differentiating Men's and Women's Motives for Sport Participation and Exercise. *Journal of American College Health* 54 (2): 87–94.
31. Koronios, K., Psiloutsikou, M., Kriemadis, A, Zervoulakos, P., and Leivaditi, E. (2015). Factors Influencing Future Marathon Running Participation. Proceedings of the 8th Annual Euromed Academy of Business Conference: "Innovation, Entrepreneurship and Sustainable Value Chain In A Dynamic Environment", Verona, Italy.
32. Sarkisian, C.A., W.N. Steers, R.D. Hays, and C.M. Mangione. 2005. Development of the 12-Item Expectations Regarding Aging Survey. *The Gerontologist 45* (2): 240–248.
33. Steenkamp, J.B.E., and H. Baumgartner. 1995. Development and Cross-Cultural Validation of a Short form of CSI as a Measure of Optimum Stimulation Level. *International Journal of Research in Marketing 12* (2): 97–104.
34. McDaniel, S.R., and J.E. Mahan. 2008. An Examination of the ImpSS Scale as a Valid and Reliable Alternative to the SSS-V in Optimum Stimulation Level Research. *Personality and Individual Differences 44* (7): 1528–1538.
35. Elliott, A.C., and L.S. Hynan. 2011. A SAS® Macro Implementation of a Multiple Comparison post hoc Test for a Kruskal–Wallis Analysis. *Computer Methods and Programs in Biomedicine 102* (1): 75–80.
36. Jurkiewicz, C.L. 2000. Generation X and the Public Employee. *Public Personnel Management 29* (1): 55–74.
37. Chen, P.J., and Y. Choi. 2008. Generational Differences in Work Values: A Study of Hospitality Management. *International Journal of Contemporary Hospitality Management* 20 (6): 595–615.

# IoT Applications with 5G Connectivity in Medical Tourism Sector Management: Third-Party Service Scenarios

**Maria M. Psiha and Panayiotis Vlamos**

**Abstract** 5G is the next generation of mobile communication technology. Current generation of wireless technologies is being evolved toward 5G for better serving end users and transforming our society. Supported by 5G cloud technology, personal devices will extend their capabilities to various applications, supporting smart life. They will have significant role in health, medical tourism, security, safety, and social life applications. The next wave of mobile communication is to mobilize and automate industries and industry processes via Machine-Type Communication (MTC) and Internet of Things (IoT). The current key performance indicators for the 5G infrastructure for the fully connected society are sufficient to satisfy most of the technical requirements in the healthcare sector. Thus, 5G can be considered as a door opener for new possibilities and use cases, many of which are as yet unknown. In this paper we present heterogeneous use cases in medical tourism sector, based on 5G infrastructure technologies and third-party cloud services.

**Keywords** IoT applications • Machine-type communication • Medical tourism sector • Management • 5G infrastructure

## 1 Introduction

The mobile broadband industry continues to expand, transforming both businesses and lives. Today, the number of connected devices is larger than the population of the United States. End users and businesses are demanding more from the telecommunication industry. While end users request personalized services, better performance, better user experience, businesses need to get more information about their consumers, easier and secured access to devices and greater flexibility for provisioning new services. There is a key role to play for Equipment providers, Service Providers and IT players together to make this a reality by providing converged IT and Network infrastructure. There are a great many researchers

M.M. Psiha (✉) • P. Vlamos
Department of Informatics, Ionian University, Corfu, 49100, Greece
e-mail: psiha@ionio.gr; vlamos@ionio.gr



P. Vlamos (eds.), *GeNeDis 2016*, Advances in Experimental Medicine and Biology 989, DOI 10.1007/978-3-319-57348-9_12

studying 5G and its component technologies—in funded EU projects, in national programs, in individual companies and in research institutions. Despite the advances made in the design and evolution of fourth generation cellular networks, new requirements imposed by emerging communication needs necessitate 5G mobile network. 5G is an end-to-end ecosystem to enable a fully mobile and connected society. It empowers value creation towards customers and partners, through existing and emerging use cases, delivered with consistent experience, and enabled by sustainable business models [1].

Currently deployed Radio Access Networks (RAN) is experiencing a significant increase in data rate and capacity demands. Optimizations have been mainly studied as part of Mobile Cloud Computing (MCC), which considers the integration of cloud computing with the mobile environment [2]. The growth of mobile traffic and pressure on costs are driving a need to implement several changes in order to maintain quality of experience, to generate revenue, and optimize network operations and resource utilization [3]. Specifically, researchers predict 40% annual growth in mobile data through 2020 resulting in eightfold growth (Fig. 1) [5]. In July 2015, more than 6.2 billion subscribers were using GSM-HSPA—85% of the world's 7.3 billion population [6]. By the end of 2019, the global mobile broadband market is expected to include nearly 8.45 billion subscribers, with 8.1 billion using 3GPP technologies, representing about 97% market share Chetan Sharma Consulting anticipates 2015 U.S. cellular data revenues to exceed $132 billion, a growth of 22% over the prior year [5].

The security aspects of such MCC systems, especially related to ensuring the privacy of user data in the cloud was studied in [7]. The application of cloud based computing paradigm is currently having an ever expanding scope, with use cases such as cloud-based vehicular networks [8], and RAN [9, 10] being investigated.

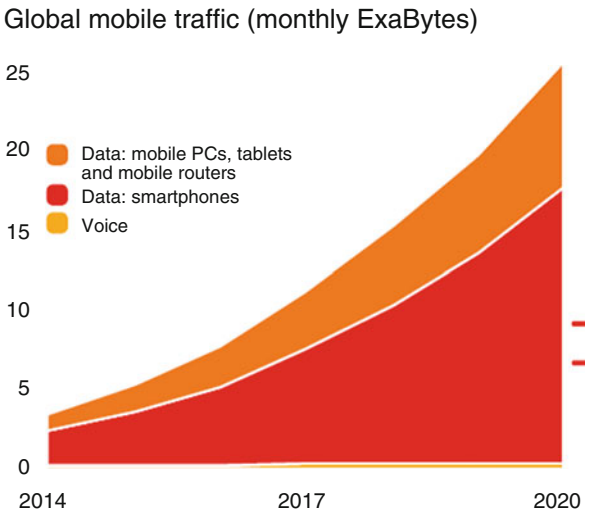


**Fig. 1** Global mobile traffic for voice and datas 2014–2020. Adapted from Ericsson [4]

In [9], the concept of RAN-as-a-Service is introduced, with a flexible architecture with centralized processing and increased interference handling capabilities in ultra-dense networks.

Many bodies have developed visions of 5G, including NGMN Alliance [1], ITU-R (Recommendation ITU-R IMT Vision, July 2015) and 5G PPP Infrastructure Association [11]. Together, they describe the primary aspects of 5G [11]:

- Increased performance of mobile technology in terms of more throughput, lower latency, ultrahigh reliability, higher connectivity density, and higher mobility.
- Support for the convergence of vertical applications onto a single common wireless network. This is enabled by a flexible usage and configuration of network functions to enable use cases with very diverse requirements by means of network slices. 5G should become the first radio communication system designed to smoothly integrate Human Type Communications (HTC) with Machine Type Communications (MTC), thus becoming an enabler for the Internet of Things (IoT).
- A new flexible radio interface or radio interfaces as enabler for the items above, for deployment both in current mobile bands and new spectrum that could go as high as up to the millimeter wave range.

There is already a wide consensus on the 5G service landscape, and in particular on the view that 5G will not only be a "business-as-usual" evolution of 4G mobile networks, with new spectrum bands, higher spectral efficiencies and higher peak throughputs, but will also target new services and new business models [12]. Future business models and value chains should be flexible and adaptable to allow each stakeholder group to focus on its core competencies, such as delivery of care, sector application development, platform, infrastructure or network service provisioning. On top of supporting the evolution of the current business models, 5G will expand to new ones to support different types of customers and partnerships [1]. Operators will support vertical industries, and contribute to the mobilization of industries and industry processes. A new role an operator can play in the future is one of a partner service provider, with two variants [1]: The first variant directly addresses the end customers where the operator provides integrated service offerings based on operator capabilities (connectivity, context, identity etc.) enriched by partner (3rd party/OTT) content and specific applications. Integrated streaming solutions can be an example here but even services such as payments are possible. The second variant empowers partners (3rd parties/OTTs) to directly make offers to the end customers enriched by the operator network or other value creation capabilities.

A shared vision is that by providing IoT to connect various types of machines, devices, or sensors, the productivity and efficiency in industries, and our society in general, will be improved. IoT, also called Machine-to-Machine (M2 M) communications, is seeing rapid adoption and expected in tens of billions of devices over the next 10 years. Drivers include improved LTE support, other supporting wireless technologies, and service-layer standardization such as OneM2M.

IoT will also have a wide range of requirements on networking such as reliability, security, performance (latency, throughput), among others. The creation of new

services for vertical industries will not be limited to connectivity but can require enablers from cloud computing, big data management, security, logistics and other network-enabled capabilities [1]. Municipalities, evaluating what constitutes "smart cities," are exploring how to optimize pedestrian and vehicular traffic, connect utility meters, and deploy trash containers that can report when they need emptying [5].

In this paper we focus on application of IoT in e-health sector. According to the World Health Organization (WHO), e-health is the transfer of health resources and health care by electronic means. It encompasses three main areas [11]:

- The delivery of health information, for health professionals and health consumers, through the Internet and telecommunications.
- Using the power of IT and e-commerce to improve public health services, e.g. through the education and training of health workers.
- The use of e-commerce and e-business practices in health systems management.

Furthermore, WHO and the EC in its green paper on mobile Health, define m-Health as the medical and public health practice supported by mobile devices, such as mobile phones, patient monitoring devices, personal digital assistants (PDAs), and other wireless devices [13].

The health sector has many applications that can benefit from mobile communications. Communications systems enable telemedicine, which provides clinical health care at a distance. It helps eliminate distance barriers and can improve access to medical services that would often not be consistently available in distant rural communities. It is also used to save lives in critical care and emergency situations. Wireless sensor networks based on mobile communication can provide remote monitoring & sensors for parameters such as heart rate and blood pressure.

## 2 Key Performance Indicators for the 5G Infrastructure in the Healthcare Sector

5G will be far more than just a new radio technology. It will combine existing Radio Access Technologies (RATs) in both licensed and unlicensed bands, and it will add novel RATs optimized for specific bands and deployments, scenarios and use cases [14]. 5G will also implement a radically new network architecture based on Network Function Virtualization (NFV) and Software Defined Networking (SDN) technologies. While advances in NFV and SDN have increased the ability to flexible allocate computing resources within the network, NFV-based flexible function placement is still in its infancy.

The results of multi-dimensional developments are networks based on LTE-Advanced technology and eventually 5G networks that will be capable of [5, 11]:

- Extreme broadband of over 20 Gbps
- 1 millisecond end-to-end round trip delay (latency)
- Supporting up to1000 times more capacity to meet accelerating data demand

- (Perception of) 100% coverage
- 90% reduction in network energy usage and up to 10 year battery life for low power, machine-type devices
- Teaching networks to be self-aware and simplify network management by extreme automation
- Super-high density for both humans and machines (1000x bandwidth per unit area, 10–100x number of connections)
- Continuous mobility and converged connectivity across multiple network types

The current key performance indicators for the 5G infrastructure for the fully connected society, as discussed and highlighted in the 5G Vision whitepaper developed by the 5G PPP Infrastructure Association [11] are sufficient to satisfy most of the technical requirements in the healthcare sector [11]:

- 1000 X in number of connected devices reaching a density $\geq$ 1 M terminals/km$^2$
- 1/10 X in energy consumption compared to 2010
- 1/5 X in end-to-end latency reaching 5 ms for e.g. tactile Internet and radio link latency reaching a target $\leq$1 ms for e.g. Vehicle to Vehicle communication
- 99.999% aggregate service reliability for safety-critical services
- Mobility support at speed $\geq$500 km/h for ground transportation
- Accuracy of outdoor terminal location $\leq$1 m
- Support for shared infrastructure, multi-tenancy and multi-Radio Access Technologies with seamless handover

Research towards future standardization of a new 5G air interface is currently in the exploration phase, where academia and industry are presenting their view on possible requirements and candidate techniques to be included in a future system design. Among others, the METIS-II presents the following main key 5G RAN design requirements in 5G [12]:

- The 5G RAN should be able to scale to extremes in terms of throughput, the number of devices, and the number of connections. To enable this, it should be able to handle and scale user plane (UP) and control plane (CP) individually
- The 5G RAN should support the Network Slicing vision from NGMN [1], aiming to address the deployment of multiple logical networks as independent business operations on a common physical infrastructure.
- The 5G RAN should natively and efficiently support multi-connectivity (inter-node, inter-air-interface) and network-controlled D2D (point-to-point, multi-cast and broadcast).

In order to overcome these challenges, Mobile-edge Computing (MEC) can be proposed as a cloud server running at the edge of a mobile network, within the RAN and in close proximity to mobile subscribers and performing specific tasks that could not be achieved with traditional network infrastructure [15]. This technology is currently being standardized in an ETSI Industry Specification Group (ISG) of the same name. Characterized by proximity, low latency and high bandwidth, this environment will offer localized cloud computing capabilities as well as exposure

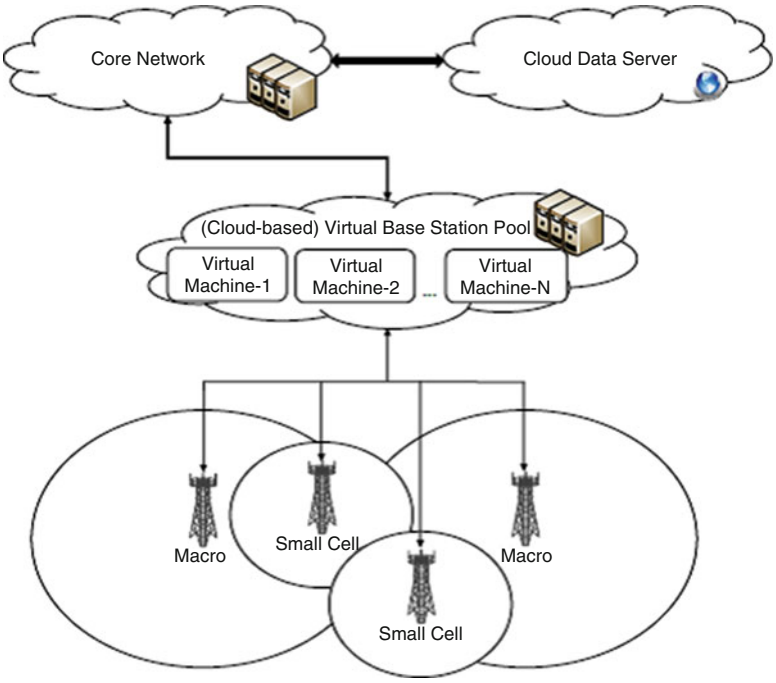


**Fig. 2** Typical 5G heterogeneous network architecture. Adapted from Prasad et al. [3]

to real-time radio network and context information. Operators can open the radio network edge to 3rd party partners, allow in them to rapidly deploy innovative applications and services towards mobile subscribers, enterprises and other vertical segments.

A typical 5G heterogeneous network architecture where UEs move around randomly, connecting to the best serving cell for its communication needs is presented in (Fig. 2) Rost and Prasad [16]. The macro base stations considered to be remote radio heads with higher transmit power and a wider coverage footprint, as compared to the small cells [3]. The architecture within the radio access network is similar to the 5G cloud-based virtual base station pool system, with the cloud data server having a direct interface with the core network.

## 3 Internet of Things and Machine-to-Machine Communications

IoT is a vast opportunity for wireless communications, with all 3GPP technologies potentially playing roles. Low-cost LTE modem options in 3GPP releases 10 through 13 reduce cost, improve communications range, and extend battery life

**Table 1** Wireless networks for IoT

| Technology | Coverage | Characteristics | Standardization/ Specifications |
|---|---|---|---|
| GSM/GPRS | Wide area Huge global coverage | Lowest-cost cellular modems, risk of network sunsets. Low throughput. | 3GPP |
| HSPA | Wide area Huge global coverage | Low-cost cellular modems. Higher power, high throughput. | 3GPP |
| LTE | Wide area Increasing global coverage | Wide area, expanding coverage, cost/power reductions in successive 3GPP releases. Low to high throughput options. | 3GPP |
| Wi-Fi | Local area | High throughput, higher power. | IEEE |
| ZigBee | Local area | Low throughput, low power | IEEE |
| Sigfox | Wide area emerging deployments | Low throughput, low power. Unlicensed bands (sub 1 GHz such as 900 MHz in the U.S.) | Sigfox |

Adapted from Rysavy Research/4G Americas [5]

[5]. Developers will use 3GPP wireless technologies for a large number of IoT applications. In other instances, developers will use local-area technologies, such as Wi-Fi, Bluetooth Low Energy, and ZigBee. New wide-area wireless technologies emerging specifically to support IoT include LoRa, Sigfox, OnRamp Wireless, and Weightless. The low-power operation of some of these technologies, including LTE, will permit battery operation over multiple years (Table 1).

Based on 5G cloud infrastructures, IoT can be a catalyst in e−/m-Health sector for both Health/Insurance Providers and users/patients by providing the following [11]:

- *Health/Insurance Provider Requirements*
  - Increase efficiency

    Optimize healthcare decision making processes
    Empower patients, informal careers and lesser qualified professionals
    Optimize sourcing (e.g. cloud, outsourcing)
    Reduce wastage of pharmaceuticals due to accidental expiry
    Track hospital assets
    Enable safe, secure and state of the art tele-surgery
    Interlink health—and social care
  - Engage cared for in proactive healthcare and wellness

    Behavior change capabilities
  - Ubiquitous Access

    Anytime and from everywhere (online, off-line, mobile)
    Certificates for smart device interaction

  - Flexible sharing with different providers/sources

    Service interoperability
    Data portability
    Data owner authentication and authorization
    Selective data sharing
    Non-repudiation

  - Information accountability

    Certification (legal, ethical, technological)
    Monitoring
    Governance
    Non repudiation

  - Auditability
  - Protect patients and stakeholders

    Prevent and counteract on counterfeited drugs
    Patient identification
    Object identification

- *User/Data Owner Requirements*

  - Support ability to choose where and how to obtain health care services
  - Control over own data
  - Accessible anytime and from everywhere (online and off-line, mobile)
  - Flexible sharing with different processors/sources
  - Consent for data sharing
  - Data portability
  - Monitoring Access
  - Social interactions
  - Storage by a trusted organization, offering data/access information accountability measures (considering the legislative boundaries for the information storage and retrieval as well as possible location dependent deployment constraints), including possibly entirely self-hosted either through individual, organizational or community-driven schemes

## 4 Expanding Use Cases in Medical Tourism Sector Management

The vision of 2020 and beyond also includes a great deal of growing use cases characterized by massive number of devices (e.g., sensors, actuators and cameras) and a wide range of characteristics and demands. These use cases include both low-cost/long-range/low-power MTC as well as broadband MTC with some characteristics closer to HTC [1]. The biggest difference between 5G and legacy design

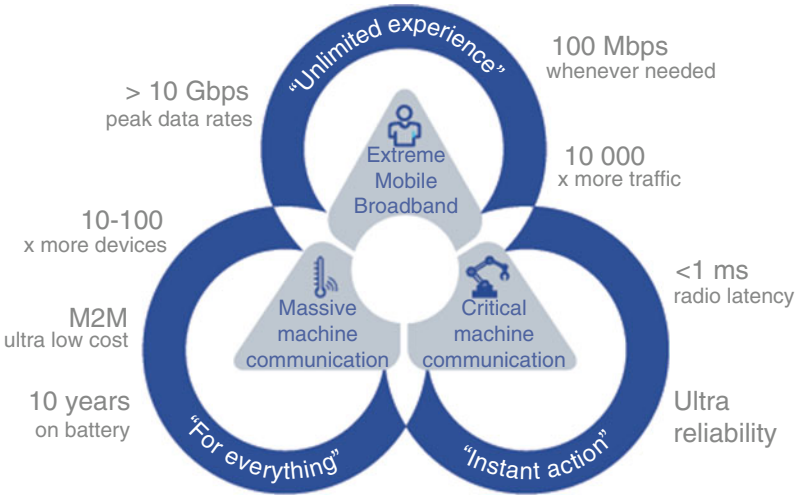


**Fig. 3** Heterogeneous use cases—diverse requirements. Adapted from Nokia White Paper [14]

requirements is the diversity of use-cases that 5G networks must support compared to today's networks that were designed primarily to deliver high-speed mobile broadband. In Medical Tourism Sector, 5G requirements can be broadly split into three use-case categories [14] (Fig. 3):

- Massive broadband that delivers gigabytes of bandwidth on demand. It is also referred to as enhanced Mobile Broadband (eMBB), requiring both extremely high data rates and low-latency communication in some areas, and reliable broadband access over large coverage areas.
- Critical MTC that demands immediate synchronized eye-to-hand feedback to remotely control robots and deliver the tactile Internet. These emerging use cases a high variety of applications and variability of their performance attributes [1]: From delay-sensitive video applications to ultra-low latency, from high speed entertainment applications in a vehicle to mobility on demand for connected objects, and from best effort applications to reliable and ultra-reliable ones such as health and safety.
- Massive MTC that connects up to tens of billions of sensors and machines. Scalable connectivity for an increasing number of devices per cell, wide area coverage and deep indoor penetration are key priorities

According to NGMN, there are 25 use cases for 5G, as representative examples, that are grouped into eight use case families. The use cases and use case families serve as an input for stipulating requirements and defining the building blocks of the 5G architecture (Fig. 4).

In this paper, we focus on IoT applications regarding medical tourism sector management. The global growth in the flow of patients and health professionals

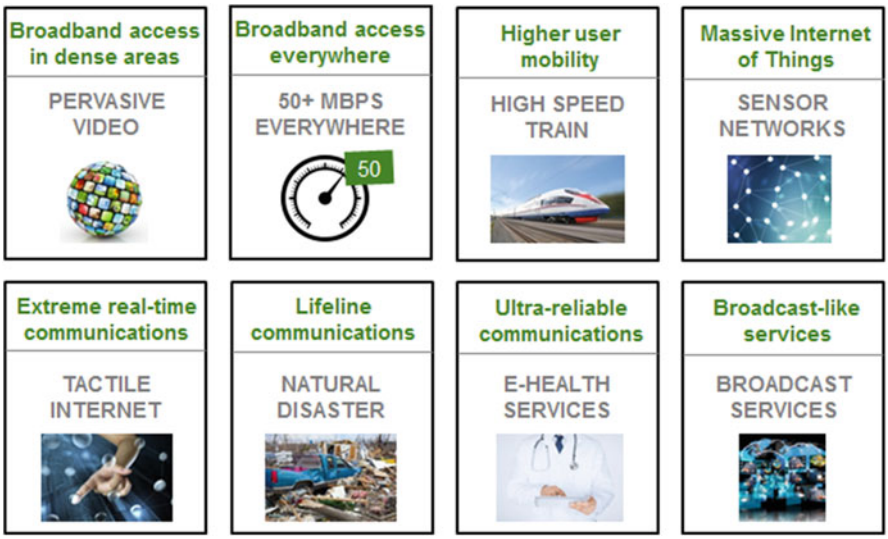


**Fig. 4** 5G use case families and related examples. Adapted from NGMN 5G White Paper [1]

as well as 5G medical technology, capital funding and regulatory regimes across national borders has given rise to new patterns of consumption and production of medical tourism services over recent decades. The main use cases in this area are:

1. Smart Wearables (Clothes)
   It is expected that the use of wearables consisting of multiple types of devices and sensors will become mainstream. The customers buy clothes from a manufacturer and take benefit of the health monitoring feature offered by the 3rd party, enriched by the operator's set of network and value creation capabilities [1]. A key challenge for this use case is the overall management of the number of devices as well as the data and applications associated with these devices.

   Temporary visitors abroad and medical tourisms could have benefits by using clothes with ultra-light, low power, waterproof sensors. These sensors can measure various environmental and health attributes of the visitor like pressure, temperature, heart rate, blood pressure, body temperature, breathing rate and volume, skin moisture, etc. Consider how skin embedded and 5G connected healthcare chips could constantly monitor vital signs, prevent conditions from becoming acute, and constantly adapting medication to meet changing conditions.
2. Active Device Location Tracking
   In the coming years advanced safety applications will appear to mitigate the road accidents, to improve traffic efficiency, and to support the mobility of emergency vehicles (e.g., ambulances, fire trucks). If all of the vehicles on a road were connected to a network incorporating a traffic management system, they could

potentially travel at much higher speeds and within greater proximity of each other without risk of accident—with fully-autonomous cars further reducing the potential for human error [17].

These applications foresee not only a vehicle to vehicle or vehicle to infrastructure communication, but also communication with vulnerable road users such as pedestrians and cyclists. An application such as controlled fleet driving will require an ultra-low end-to-end latency (1 millisecond delay time) for some warning signals, and higher data rates to share video information between cars and infrastructure. In addition a fully 'driverless' car would need to be driverless in all geographies, and hence would require full road network coverage with 100% reliability to be a viable proposition [1].

Figure 5 shows an example of the active device location tracking use case. This use case enables real-time, network measurement based tracking of active (GPS independent and network determined) terminal equipment, using 'best-in-class' third-party geo-location algorithms within a geo-location application hosted on the MEC server [15]. These algorithms are based on real-time network measurements from active users or eNBs, e.g., GNSS measurement, RSSI and Timing advanced measurement, Roundtrip-time (RTT) measurement. This solution provides an efficient and scalable solution for local measurement processing and event based triggers. The MEC application can request the raw measurement information to be provided rather than the user coordinates, since the latter can be computed locally using its locationing algorithm. Thus, it enables location based services for enterprises and consumers (e.g. on opt-in basis), for example in venues, retail locations and traditional coverage areas where GPS coverage is not available.

The application arguments could be the following [18]: Accuracy level (High/Medium/Low), Report type (User coordinates, Measure information), Extra tracking information (Operator PLMN id, Signal strength, etc.), Update frequency, Operate period, Concerned geo-region, Target user (Category, Access class, id). The mapping of the MEC application argument to the MEC service parameter is depicted in Fig. 6. The support services interpret the arguments and transport their values to RNIS (Accuracy level, Report type, Tracking information, Georegion,

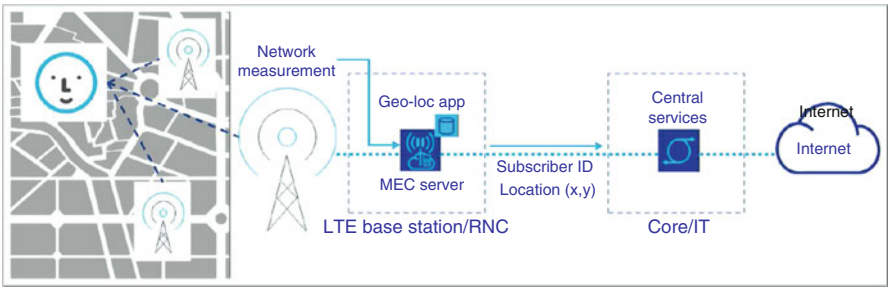


**Fig. 5** Active device location tracking using MEC server. Adapted from Introductory Technical White Paper [15]

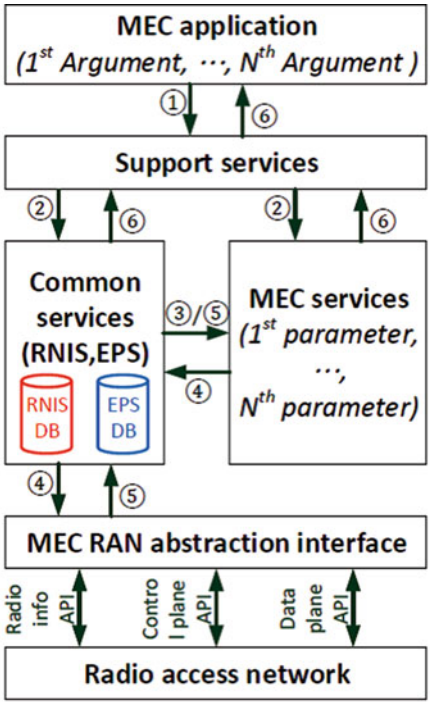


**Fig. 6** MEC server operation flow. Adapted from Chang et al. [18]

Target user) and the Locationing service (Update frequency, Operate period) inputs. The RNIS look up in its internal DB for determining the locationing technology and locationing method for target user served by geo-region network element, and these parameters as well as the measurement result will be used by Locationing service for the user coordinates computation.

Based on the fact that GPS accuracy is related to the quality of signal reception and has dependence on battery power, MEC applications will be suitable for visitors abroad in cases of medical emergencies where GNSS coverage is limited. In additional, MEC architecture could be used for personalized and more accurate tracker devices for Alzheimer's patients by overcoming the following GPS system limitations:

- Terrain: Signals can become degraded and the receiver system may not provide location information if the view of the sky is severely limited. This situation can occur in deep canyons, or under dense vegetation.

- Urban Canyons: Large or tall buildings grouped closely together can cause large multi-path and fading errors that may affect the ability to track offenders.
- Vehicles: Signals can be lost when an offender is riding in a car or other enclosed means of transportation if the receiver is not placed near a window within the vehicle.
- Weather: Signal strength can become degraded by moisture such as rainfall, fog, or snowfall.

## 5 Conclusion

The next wave of mobile communication is to mobilize and automate industries and industry processes. Tens of billions of smart devices will use their embedded communication capabilities and integrated sensors to act on their local environment and use remote triggers based on intelligent logic Within IoT application areas, (smart) sensing and/or actuating devices and objects are getting involved in human's life generating a tremendous amount of data. Therefore, in 5G, there is a need to push the envelope of performance to provide, where needed, for example, much greater throughput, much lower latency, ultra-high reliability, much higher connectivity density, and higher mobility range. MEC is emerging as a key technology for the evolution towards 5G IoT applications to meet the demand to move from a simple bit pipe to a smart service pipe, and it is a new ETSI standardization initiative. MEC allows operators to open their RAN edge service environment to authorized third-parties to rapidly deploy innovative application and service endpoints for the mobile subscribers, enterprises and vertical segments, and network. Based on the above needs, in this paper we review and extend third-party service use cases in medical tourism sector management concerning smart wearables and active device location tracking.

## References

1. NGMN 5G White Paper. 2015. 5G Initiative Team. Available at https://www.ngmn.org/uploads/media/NGMN_5G_White_Paper_V1_0.pdf.
2. Dinh, H.T., C. Lee, D. Niyato, and P. Wang. 2013. A Survey of Mobile Cloud Computing: Architecture, Applications, and Approaches. *Wireless Communications and Mobile Computing* 13 (18): 1587–1611.
3. Prasad, A., Lundén, P., Moisio, M., Uusitalo, M., and Li, Z. 2015. Efficient Mobility and Traffic Management for Delay Tolerant Cloud Data in 5G Networks, IEEE PIMRC 2015, Hongkong, China
4. Ericsson. 2015. Ericsson Mobility Report on the Pulse of the Networked Society.
5. Rysavy Research/4G Americas. 2015. Beyond LTE: Enabling the Mobile Broadband Explosion, Rysavy Research.
6. US Census Bureau. 2015. U.S. and World Population Clock. Available at http://www.census.gov/popclock/.

7. Huang D., Zhou Z., Xu L., Xing T., and Zhong Y. (2011), Secure Data Processing Framework for Mobile Cloud Computing, IEEE Conference on Computer Communications Workshops (INFOCOM WKSHPS), pp. 614–618.
8. Yu, R., Y. Zhang, S. Gjessing, W. Xia, and K. Yang. 2013. Toward Cloud Based Vehicular Networks with Efficient Resource Management. *IEEE Network* 27 (5): 48–55.
9. Sabella D., Rost P., Sheng Y., Pateromichelakis E., Salim U., Guitton-Ouhamou P., Di Girolamo M., and Giuliani G. (2013), RAN as a Service: Challenges of Designing a Flexible RAN Architecture in a Cloud-Based Heterogeneous Mobile Network, Future Network and Mobile Summit, pp. 1–8.
10. Rost, P., and C. Bernardos. 2014. Cloud Technologies for Flexible 5G Radio Access Networks. *IEEE Communications Magazine* 52 (5): 68–76.
11. 5G PPP Infrastructure Association. 2015. The 5G Infrastructure Public Private Partnership: The Next Generation of Communication Networks and Services. Available at https://5g-ppp.eu/wp-content/uploads/2015/02/5G-Vision-Brochure-v1.pdf.
12. METIS II White Paper. 2016. Preliminary Views and Initial Considerations on 5G RAN Architecture and Functional Design.
13. WHO EC Green Paper on mobile-Health. 2014. Available at http://ec.europa.eu/newsroom/dae/document.cfm?doc_id=5147.
14. Nokia White Paper. 2016. 5G masterplan – five keys to create the new communications era. Available at http://resources.alcatel-lucent.com/asset/200316.
15. Introductory Technical White Paper. 2014. Mobile-Edge Computing.
16. Rost, P., and A. Prasad. 2014. Opportunistic Hybrid ARQ-Enabler of Centralized-RAN Over Non-ideal Backhaul. *IEEE Wireless Communications Letters* 3 (5): 481–484.
17. GSMA Intelligence Analysis. 2014. Understanding 5G: Perspectives on future technological advancements in mobile.
18. Chang, Chia-Yu, Alexandris Konstantinos, Nikaein Navid, and Spyropoulos Thrasyvoulos. 2016. Analyzing MEC Architectural Implications for LTE/LTE-A. (Research Report RR-16-312). EURECOM, Department of Mobile Communications.

# Recognizing Emotional States Using Speech Information

**Michalis Papakostas, Giorgos Siantikos, Theodoros Giannakopoulos, Evaggelos Spyrou, and Dimitris Sgouropoulos**

**Abstract** Emotion recognition plays an important role in several applications, such as human computer interaction and understanding affective state of users in certain tasks, e.g., within a learning process, monitoring of elderly, interactive entertainment etc. It may be based upon several modalities, e.g., by analyzing facial expressions and/or speech, using electroencephalograms, electrocardiograms etc. In certain applications the only available modality is the user's (speaker's) voice. In this paper we aim to analyze speakers' emotions based solely on paralinguistic information, i.e., not depending on the linguistic aspect of speech. We compare two machine learning approaches, namely a Convolutional Neural Network and a Support Vector Machine. The former is trained using raw speech information, while the latter is trained on a set of extracted low-level features. Aiming to provide a multilingual approach, training and testing datasets contain speech from different languages.

**Keywords** Emotion recognition • Speech information • Convolutional neural networks • Transfer learning • Support vector machines

## 1 Introduction

It is common sense that the basic means of human communication is the vocalized speech. Apart from meaning, speech also carries emotions. Although the latter are more easily recognized through visual channels, e.g. facial features, gestures,

M. Papakostas
Computer Science and Engineering Department, University of Texas at Arlington, Arlington, TX, USA
e-mail: michalis.papakostas@mavs.uta.edu

G. Siantikos • T. Giannakopoulos • E. Spyrou (✉) • D. Sgouropoulos
Institute of Informatics and Telecommunications, National Center for Scientific Research–"Demokritos", Athens, Greece
e-mail: dickos@iit.demokritos.gr; tyiannak@iit.demokritos.gr; espyrou@iit.demokritos.gr; dsgou@iit.demokritos.gr



P. Vlamos (eds.), *GeNeDis 2016*, Advances in Experimental Medicine and Biology 989, DOI 10.1007/978-3-319-57348-9_13

etc., in many practical applications, e.g. in human-computer interaction through voice-user interfaces (VUIs), speech may be the only available modality for emotion recognition. The latter comprises probably the most challenging speech-related task, e.g., when compared to automatic speech recognition (ASR), speaker identification etc.

In general, one may argue that speech carries two distinct types of information [1]: *explicit* or linguistic information, which concerns articulated patterns by the speaker; and *implicit* or paralinguistic information, which concerns the variation in pronunciation of the linguistic patterns. The former may be qualitatively described, while the latter may be quantitatively measured, using certain spectral features and also features such as the pitch, the intensity etc. Using either or both types of information, one may attempt to classify an audio segment that consists of speech, based on the emotion(s) it carries. However, emotion recognition from speech appears to be a significantly difficult task even for a human, no matter if he/she is an expert in this field (e.g. a psychologist).

Many approaches are assisted by ASR aiming to fuse linguistic and paralinguistic information. The main disadvantage of these is that they are not able to provide language-independent models. Of course, another disadvantage is that there exists a plethora of different sentences, speakers, speaking styles and rates [2]. Thus, most approaches that aim to be language-independent tend to rely on paralinguistic speech information. Nevertheless, even in this case, such information may be significantly diverse, depending on cultural particularities. Additionally, a speaker's potential chronic emotional state may suppress the expressiveness of several emotions. Still, relying solely on paralinguistic information is probably the most appealing approach, when dealing with speakers emotion recognition.

Typically, the set of extracted features is labelled by an expert and learned using a machine learning approach, e.g., the well-known Support Vector Machines (SVMs), which shall be discussed later. However, during the last few years a new trend in the field of machine learning are the "Deep Neural Networks." One of their main advantages over traditional approaches is that they do not need to be trained using specific features. Instead, they translate raw data into compact intermediate representations, while they remove any redundancy. In this work we aim to compare both the aforementioned approaches. We will investigate whether a Convolutional Neural Network (CNN) (i.e., a deep learning approach) is able to replace the traditional approach of feature extraction, model training and classification and render paralinguistic features obsolete. Also we shall use several datasets from various languages, at an attempt to provide a language-independent approach.

The remaining of this paper is as follows: In Sect. 2 we present related work within the broader research area of emotion recognition from speech. In Sect. 3 we provide theoretical background concerning SVMs and CNNs. The application of the aforementioned techniques for the problem at hand is discussed in Sect. 4. Experimental results are presented and discussed in Sect. 5. Finally, conclusions are drawn in Sect. 6, where plans for future work are also discussed.

## 2 Related Work

Besides extracting information regarding events, structures (e.g., scenes, shots) or genres, a substantial research effort of several multimedia characterization methods has focused on recognizing the *affective* content of multimedia material. These methods try to map low-level audio-visual features to the *emotions* that underlie the respective multimodal information [3–5]. Automatic recognition of emotions in multimedia content can be very important for various multimedia applications. For example, recognizing affective content of music signals [6, 7] can be used in a system, where the users will be able to retrieve musical data with regard to affective content.

The most common approach to affective audio content recognition, so far, is to apply well-known classifiers (Hidden Markov Models, Support Vector Machines, etc.) for classifying signals into an *a-priori known number of distinct* categories of emotions, e.g., fear, happiness, anger [5, 8]. An alternative way to emotion analysis is the dimensional approach, according to which, emotions can be represented using specific dimensions that stem from psychophysiology [7, 9–11]. In [10], Valence-Arousal representation is used for affective video characterization. Towards this end, visual cues, such as motion activity, and simple audio features, e.g., signal energy are used for modelling the emotion dimensions. Finally, in [12] an SVM regressor has been used to recognize valence and arousal in speech segments from movies.

## 3 Machine Learning Approaches

### *3.1 Support Vector Machines*

Support Vector Machines (SVMs) [13] are well-known supervised learning models, which have been extensively used in classification and regression problems. Their goal is to find the optimal hyperplane separating data in a feature space. More specifically, an SVM model is built in a way that the margin between the mappings of the examples of the categories is maximized. Then, a hyperplane is constructed, which is used to separate (i.e., classify) unknown examples, based on the side they fall on. Although they are linear models, using appropriate kernels (i.e., a technique called “kernel trick”) they are able to handle non-linearly separable data in features spaces of higher dimensionality than the one of the original problem.

### *3.2 Convolutional Neural Networks*

During the last few years, deep neural networks have lead to breakthrough results on a variety of pattern recognition problems. Research fields such as computer vision

[14] and voice recognition [15] have benefitted. One of the most recognizable and effective deep architectures is an architecture called Convolutional Neural Network (CNN) [16].

Briefly, CNNs may be regarded as a special type of neural network that uses many identical copies of the same neuron. This allows the network to comprise of a significantly large number of neurons, thus being able to express computationally large models, also offering the advantage of keeping the number of actual network parameters (i.e., the set of values describing the neurons' behaviour) that actually need to be learned, relatively small.

CNNs can consist of an arbitrary number of layers depending on both the application and the choices of the designer of the network. These layers can be categorized into three distinct types:

- *Convolutional*: these layers consist of a rectangular grid of neurons. This requires that the previous layer is also a rectangular grid of neurons. Each neuron takes inputs from a rectangular section of the previous layer; the weights for this rectangular section are the same for each neuron in the convolutional layer. Thus, the convolutional layer is just an image convolution of the previous layer, where the weights specify the convolution filter. These weights are the parameters of the network and they are shared among multiple neurons as it has been previously mentioned. In addition, there may be several grids in each convolutional layer; each grid takes inputs from all grids in the previous layer, using potentially different filters.
- *Max-Pooling*: After each convolutional layer, a pooling layer may follow. This layer type takes small rectangular blocks from the convolutional layer and subsamples it to produce a single output from that block. There are several ways to do this pooling, such as taking the average, the maximum, or a learned linear combination of the neurons in the block. In this work, pooling layers will always be max-pooling layers, i.e., they shall take the maximum of the block they are pooling.
- *Fully-Connected*: Finally, after several convolutional and max-pooling layers, the high-level reasoning in the CNN is actuated via fully connected layers. A fully connected layer takes all neurons in the previous layer (be it fully connected, pooling, or convolutional), connecting them to each of its single neurons. Fully connected layers are not spatially located anymore (you can visualize them as one-dimensional), so there can be no convolutional layers after a fully connected layer.

## 4 Proposed Methodology

### *4.1 Data Representation*

Each audio sample (speech segment) is represented through the respective spectrogram. A spectrogram is a frequency-time representation of the signal, stemming

from the application of the short-time Fourier Transform on the original signal. The spectrogram representation when as input to the Convolutional Neural Network, is therefore handled as image. A 20 ms window length and 15 ms window step has been adopted (i.e. 25% overlap). The spectrograms have been extracted using the pyAudioAnalysis opensource Python library[1] [17]. Figure 1 illustrates an example of a spectrogram for each of the 4 classes that are included in the experiments, taken from the SAVEE dataset [18]. The spectrogram is always resized to $227 \times 227$ size to "fit" the adopted network structure. This enforces a default segment length. For varying signal lengths, the CNN is applied to several overlapping mid-term segments and a post-processing step is also applied to merge temporally successive decisions.

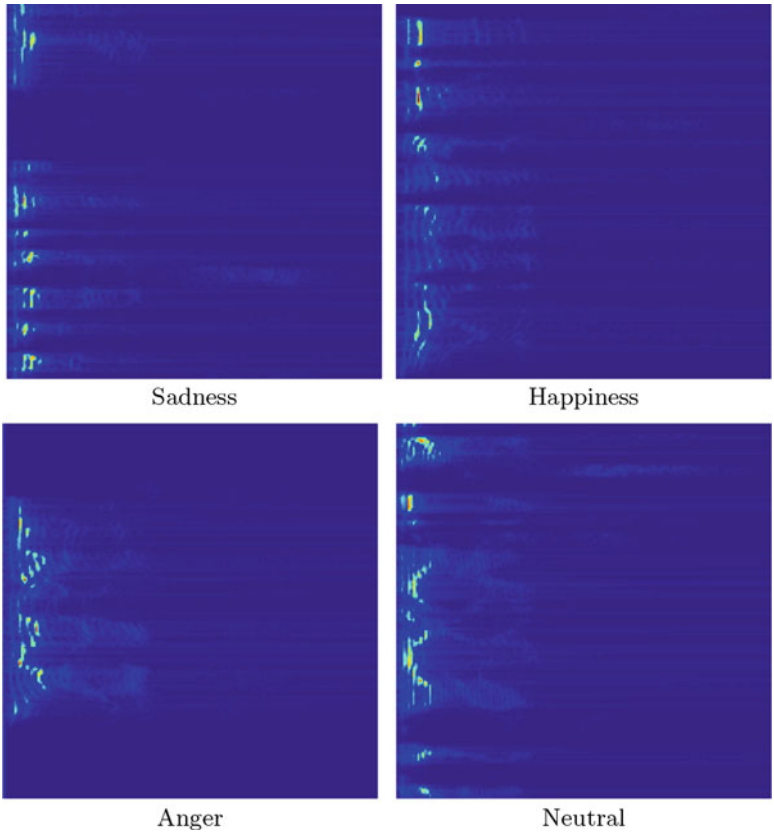


**Fig. 1** Example spectrograms from each of the 4 included classes

[1] https://github.com/tyiannak/pyAudioAnalysis.

**Table 1** Adopted short-term audio features

| Index | Name | Description |
|---|---|---|
| 1 | Zero crossing rate | Rate of sign-changes of the frame |
| 2 | Energy | Sum of squares of the signal values, normalized by frame length |
| 3 | Entropy of energy | Entropy of sub-frames' normalized energies. A measure of abrupt changes |
| 4 | Spectral centroid | Spectrum's center of gravity |
| 5 | Spectral spread | Spectrum's second central moment of the spectrum |
| 6 | Spectral entropy | Entropy of the normalized spectral energies for a set of sub-frames |
| 7 | Spectral flux | Squared difference between the normalized magnitudes of the spectra of the two successive frames |
| 8 | Spectral rolloff | The frequency below which 90% of the magnitude distribution of the spectrum is concentrated |
| 9–21 | MFCCs | Mel frequency cepstral coefficients: a cepstral representation with mel-scaled frequency bands |
| 22–33 | Chroma vector | A 12-element representation of the spectral energy in 12 equal-tempered pitch classes of western-type music |
| 34 | Chroma deviation | Standard deviation of the 12 chroma coefficients |

## *4.2 SVM-Based Classification*

The audio signal is transformed to a sequence of feature vectors which are used for the SVM models' training. Features are extracted from 20 ms windows and afterwards the final feature vectors are formed by concatenating the mean and variance values of the features over a mid-term window of 1 s. Table 1 summarizes the features that are computed. There are 34 features in total which result in a 68-dimensional feature vector for each mid-term window. An SVM with RBF kernel has been used in our experiments.

## *4.3 CNN-Based Classification*

For recognizing the emotions, we decided to utilize a CNN classifier that performs upon pseudo-RGB-colored frequency images. As recent literature has shown, deep hierarchical visual feature extractors can significantly outperform shallow classifiers trained on hand-crafted features and are more robust and generalizable when countering problems that include significant levels of inherent noise. The architecture of our deep CNN was initially proposed in [19]. The model is mainly based on the Caffenet [20] reference model, which is similar to the original AlexNet [14] and the network proposed in [21]. For our experiments we used the *BVLC Caffe*[2] deep-learning framework.

[2]https://github.com/BVLC/caffe.

The network architecture consists of two convolution layers with stride of 2 and kernel sizes equal to 7 and 5, respectively, followed by max pooling layers. As a next step, a convolution layer with three filters of kernel size equal to 3 is applied, followed again by a max pooling layer. The next two layers of the network are fully connected layers with dropout, followed by a fully connected layer and a softmax classifier, that shapes the final probability distribution. All max pooling layers have kernel size equal to 3 and stride equal to 2. For all the layers we used the ReLu as our activation function. The output of the network is a distribution on our three target classes, while the output vector of the semifinal fully connected layer has size equal to 4096. The initial learning rate of 0.001, which decreases after 700 epochs by a factor of 10.

Since training a new CNN from scratch would require big loads of data and high computational demands, we used transfer learning to fine-tune the parameters of a pre-trained architecture. The notion of "transfer" learning refers to the transfer of knowledge from a "learned" task (source task) at a given domain (source domain) to a related, yet unsolved task (target task), at the same or possibly at another domain (target domain), aiming to improve the learning process [22].

The original CNN was trained on the 1.2 M images of the ILSVRC-2012 [23] classification training subset of the ImageNet [24] dataset. Following this approach, we managed to decrease the required training time and to avoid overfitting our classifier, by ensuring a good weight initialisation, given the relatively small amount of available data. Finally, the data are preprocessed by augmenting the frame dimensionality to $240 \times 320$. The input to the network corresponds to the $227 \times 227$ center crops and their mirror images.

## 5 Experimental Results

For training and evaluation of the aforementioned approaches, we used 3 widely known emotional speech datasets, all of which are freely available from their authors. More specifically, these datasets are:

- **EMOVO** [25] is an emotional speech corpus, containing speech in Italian language from 6 actors who performed 14 sentences. The emotions represented here are *disgust*, *fear*, *anger*, *joy*, *surprise* and *sadness*.
- **SAVEE** [18] is a larger dataset, since besides speech, it contains video of the participating actors while expressing the same 6 emotions as in the EMOVO case. The data consists of 15 TIMIT sentences per emotion played by 4 English male speakers.
- **EMO-DB** [26] is a German acted database, consisting of 493 utterances performed by 10 (5 male and 5 female) actors expressing the emotions of *anger*, *boredom*, *disgust*, *fear*, *happiness*, *sadness* and *neutral*.

**Table 2** Accuracy (%) when using each single dataset for testing

| Test dataset | SVM | CNN |
|---|---|---|
| SAVEE | 30 | 25 |
| EMOVO | 45 | 29 |
| EMO-DB | **80** | 51 |

Each time, training has been performed using both the remaining datasets. Overall best performance is indicated in bold.

For our task, we chose 4 of the common emotion classes, namely *Happiness*, *Sadness*, *Anger* and *Neutral*. A major difficulty resulting from the choice of datasets, is the great differences between languages, since besides the linguistic differences, there is also big variability in the way each emotion is expressed. For each classification method 3 different experiments were carried out where a single dataset is used for testing and the remaining 2 for training.

Accuracies of all experiments are summarized in Table 2. Best result was achieved when using SAVEE and EMOVO databases for training and EMO-DB for testing. In all cases the SVM outperformed the CNN. We feel that the poor classification performance of the CNN was due to the lack of generalization, which is due to the unsuccessful transfer of learning at a different domain.

## 6 Conclusions and Future Work

In this paper we investigated the use of deep learning in emotion recognition from speech, aiming to assess whether it may be used over traditional machine learning approaches. More specifically, we trained both a Convolutional Neural Network on raw spectrograms and a Support Vector Machine, using a set of low-level features. As it is indicated by the experimental results, the performance of the SVM was by far superior. Moreover, the SAVEE and EMOVO databases have proven to be adequate, when tested when the EMO-DB database. However, the overall conclusion is that multilingual emotion recognition remains one of the most challenging problems. Our plans for future work include the usage of more datasets for training and evaluation. We also aim to investigate other pre-trained deep learning networks, since we feel that deep learning may significantly contribute to the problem at hand. Finally, among our plans is to apply such approaches into real-life problems, e.g., emotion recognition within training and/or educational programs.

**Acknowledgements** The work presented in this document is a result of MaTHiSiS project. This project has received funding from the European Union's Horizon 2020 Programme (H2020-ICT-2015) under Grant Agreement No. 687772.

## References


1. Anagnostopoulos, C.N., T. Iliou, and I. Giannoukos. 2015. Features and classifiers for emotion recognition from speech: a survey from 2000 to 2011. *Artificial Intelligence Review* 43(2):155–177.
2. El Ayadi, M., M.S. Kamel, and F. Karray. 2011. Survey on speech emotion recognition: features, classification schemes, and databases. *Pattern Recognition* 44(3):572–587.
3. Cowie, R., E. Douglas-Cowie, N. Tsapatsoulis, G. Votsis, S. Kollias, W. Fellenz, and J. Taylor. 2001. Emotion recognition in human-computer interaction. *IEEE Signal Processing Magazine* 18:32–80.
4. Hanjalic, A. 2006. Extracting moods from pictures and sounds: towards truly personalized tv. *IEEE Signal Processing Magazine* 23:90–100.
5. Wang, Y., and L. Guan. 2008. Recognizing human emotional state from audiovisual signals. *IEEE Transactions on Multimedia* 10:936–946.
6. Lu, L., D. Liu, and H. Zhang. 2006. Automatic mood detection and tracking of music audio signals. *IEEE Transactions on Audio, Speech and Language Processing* 14:5–18.
7. Yang, Y.-H., Y.-C. Lin, Y.-F. Su, and H. Chen. 2008. A regression approach to music emotion recognition. *IEEE Transactions on Audio, Speech and Language Processing* 16:448–457.
8. Nogueiras, A., A. Moreno, A. Bonafonte, and J.B. Marino. 2001. Speech emotion recognition using hidden Markov models. In *Proceedings of Eurospeech*, 2679–2682.
9. Grimm, M., K. Kroschel, E. Mower, and S. Narayanan. 2007. Primitives-based evaluation and estimation of emotions in speech. *Speech Communication* 49(10–11):787–800.
10. Hanjalic, A., and X. Li-Qun. 2005. Affective video content representation and modeling. *IEEE Transactions on Multimedia* 7:143–154.
11. Wollmer, M., F. Eyben, S. Reiter, B. Schuller, C. Cox, E. Douglas-Cowie, R. Cowie. 2008. Abandoning emotion classes – towards continuous emotion recognition with modelling of long-range dependencies. In *Proceedings of the 9th Interspeech*, 597–600.
12. Giannakopoulos, T., A. Pikrakis, and S. Theodoridis. 2009. A dimensional approach to emotion recognition of speech from movies. In *2009 IEEE International Conference on Acoustics, Speech and Signal Processing*, 65–68. Piscataway, NJ: IEEE.
13. Vapnik, V. 1998. *Statistical Learning Theory*, vol. 1. New York: Wiley.
14. Krizhevsky, A., I. Sutskever, and G.E. Hinton. 2012. Imagenet classification with deep convolutional neural networks. In *Advances in Neural Information Processing Systems*, 1097–1105.
15. Hinton, G., L. Deng, D. Yu, G.E. Dahl, A.R. Mohamed, N. Jaitly, A. Senior, V. Vanhoucke, P. Nguyen, and T.N. Sainath, et al. 2012. Deep neural networks for acoustic modeling in speech recognition: the shared views of four research groups. *IEEE Signal Processing Magazine* 29(6):82–97.
16. Simard, P.Y., D. Steinkraus, and J.C. Platt. 2003. Best practices for convolutional neural networks applied to visual document analysis. In *ICDAR*, vol. 3, 958–962.
17. Giannakopoulos, T. 2015. Pyaudioanalysis: an open-source python library for audio signal analysis. *PloS One* 10(12):e0144610.
18. Haq, S., and P. Jackson. 2009. Speaker-dependent audio-visual emotion recognition. In *Proceedings of International Conference on Auditory-Visual Speech Processing*, Norwich, UK.
19. Donahue, J., L. Hendricks, S. Guadarrama, M. Rohrbach, S. Venugopalan, K. Saenko, and T. Darrell. 2015. Long-term recurrent convolutional networks for visual recognition and description. In *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition*, 2625–2634.
20. Jia, Y., E. Shelhamer, J. Donahue, S. Karayev, J. Long, R. Girshick, S. Guadarrama, T. Darrell. 2014. Caffe: convolutional architecture for fast feature embedding. In *Proceedings of the 22nd ACM International Conference on Multimedia*, 675–678. New York: ACM.
21. Zeiler, M.D., and R. Fergus. 2014. Visualizing and understanding convolutional networks. In *European Conference on Computer Vision*, 818–833. Berlin: Springer.

22. Torrey, L., and J. Shavlik. 2010. Transfer learning. In *Handbook of Research on Machine Learning Applications and Trends: Algorithms, Methods, and Techniques*, 242–264. Hershey, PA: IGI Global.
23. Russakovsky, O., J. Deng, H. Su, J. Krause, S. Satheesh, S. Ma, Z. Huang, A. Karpathy, A. Khosla, and M. Bernstein, et al. 2015. Imagenet large scale visual recognition challenge. *International Journal of Computer Vision* 115(3):211–252.
24. Deng, J., W. Dong, R. Socher, L.J. Li, K. Li, and L. Fei-Fei. 2009. Imagenet: a large-scale hierarchical image database. In *IEEE Conference on Computer Vision and Pattern Recognition, 2009*, 248–255. Piscataway, NJ: IEEE
25. Costantini, G., I. Iaderola, A. Paoloni, and M. Todisco. 2014. Emovo corpus: an Italian emotional speech database. In *Proceedings of the Ninth International Conference on Language Resources and Evaluation (LREC'14)*, ed. N.C.C. Chair, K. Choukri, T. Declerck, H. Loftsson, B. Maegaard, J. Mariani, A. Moreno, J. Odijk, S. Piperidis. Reykjavik, Iceland: European Language Resources Association (ELRA).
26. Burkhardt, F., A. Paeschke, M. Rolfes, W. Sendlmeier, and B. Weiss. 2005. A database of German emotional speech. In *Proceedings of Interspeech, Lissabon*, 1517–1520.

# Real Time 3D Representation and Tracking of Guidewire for Image Guided Cardiovascular Interventions

**Rashid Mehmood, Naveed Iqbal, Abdullah Tahir, M. Mohsin Riaz, and Rab Nawaz**

**Abstract** Visual tracking and 3D representation of guidewire in fluoroscopic image sequence for beating heart image guided interventions is very challenging task. The degraded image quality due to low dose fluoroscopy further complicates the problem. In this paper a robust guidewire tracking is proposed for mean shift algorithm using integrated colour, texture and depth features. The target colour, texture and depth features are encoded into gray level intensity histogram, filtered local binary pattern histogram and filtered local depth pattern histograms respectively. For depth features a 3D image acquisition system for C-Arm, X-Ray imaging system is simulated for real time three dimensional shape recovery of guidewire and associated vessels for vertical beating heart motion using shape from focus technique. The proposed technique provides 3D visualization of guide wire and vessels to the physician as well as real time robust guidewire tip tracking. Experimental results of guidewire tip tracking and 3D shape recovery on image sequence acquired through beating heart simulated phantom show the significance of the proposed technique.

**Keywords** Fluoroscopic images • Guidewire • Shape from focus • 3D reconstruction • Depth map • Mean shift tracking

R. Mehmood (✉) • N. Iqbal • R. Nawaz
National University of Science and Technology (NUST), Islamabad, Pakistan
e-mail: rashidmehmood@mcs.edu.pk

A. Tahir
Gwangju Institute of Science and Technology (GIST), Oryong-Dong, Buk-Gu, Gwangju 500-712, Republic of Korea

M.M. Riaz
Center for Advanced Studies in Telecommunication (CAST), COMSATS Institute of Information Technology, Islamabad, Pakistan



P. Vlamos (eds.), *GeNeDis 2016*, Advances in Experimental Medicine and Biology 989, DOI 10.1007/978-3-319-57348-9_14

## 1 Introduction

Heart failure is becoming a leading cause of death around the world for all age group people especially the old ones. In computer aided diagnostic (CAD) and image guided cardiac interventions, guidewires are used for different applications. A thin hair like guidewire shown in Fig. 1a is inserted into vessels through thick tube guiding catheter. During cardiovascular interventions, the guidewire and its terminating end called guidewire tip requires continuous monitoring and tracking for different operations like balloon inflation, stunting, visual navigation and haptic feedbacks etc. Accurate positioning and tracking of guidewire tip is a challenging task due to its thin and deformable structure. To minimize the radiation exposure, geriatric practices recommend low dose fluoroscopy that results in degraded image acquisition. The presence of noise in low contrast fluoroscopy images and shape variations due to cardiac motion requires more robustness in guidewire tracking.The complex tracking application coupled with required accuracy, speed, and robustness limits the use of conventional methods.

Image based guidewire tracking and 3D position reconstruction are required to provide a better insight into the true 3D position of the guidewire tip. Techniques for visual guidewire tracking start from heuristic techniques followed by a graph theoretical approaches [1]. A semiautomatic system for guidewire tracking [2] uses Hough transform to fit a polynomial of second degree. Incremental spline fitting technique using spatial and temporal information track the guidewire by utilizing the information of previous frame [3]. Learning-based tracking method utilizes probabilistic boosting tree as classifier to segment the guidewire [4]. A background subtraction method was presented in [5] to detect the guidewire tip. 2D guide wire tracking [6] captures the guide wire movement by separating the observed motion into forward and lateral components. A probabilistic method referred in [7] perceive entities such as guidewire tip, body and catheter tip for continuous tracking using learning and appearance. Guidewire tracking [8] suggest the segmentation of guidewire region based on filter for ridge detection, curvilinear structures noise reduction and priori probability map. Due to curvilinear structure and presence of similar objects nearby guidewire tracking is considerably differ from these conventional methods. The robustness of tracking methodology can be enhanced with additional features especially depth features by 3D reconstruction.

In this paper, the tracking is performed through mean shift algorithm [9] using integrated gray level intensity, texture and depth features. The local binary pattern technique [10] is modified for robustness against noise and low visibility constraint by defining a filtered local binary pattern. The target colour, features are encoded into gray level intensity histogram, whereas texture and depth features are encoded as filtered local binary and local depth pattern histograms respectively. For depth features a 3D image acquisition system for C-Arm, X-Ray imaging system is simulated for real time three dimensional shape recovery of guidewire

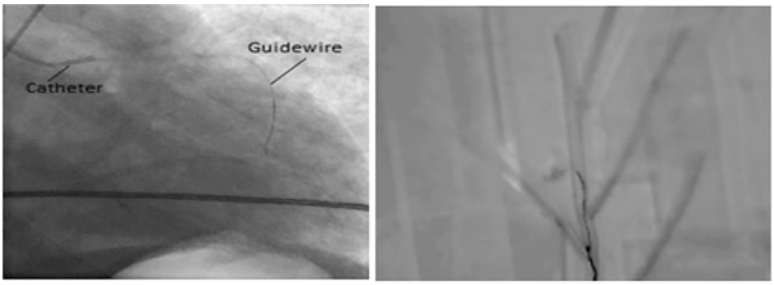


**Fig. 1** (**a**) Catheter and Guidewire are visible in original fluoroscopic image for cardio-interventions (**b**) Guidewire visible in Phantom image for cardio-intervention simulation

and associated vessels for vertical beating heart motion using Shape from focus (SFF) technique. SFF provides precise pixel level depth map as compare to other depth recovery techniques that provide an approximate depth map. The concept of image defocusing for X-Ray imaging systems under vertical beating heart motion [11] is exploited for image acquisition. The captured images are processed through Sum of Modified Laplacian (SML) focus measure for depth map recovery. Depth map features are integrated for robust MS target representation and real time 3D visualization. Experiments for guidewire tip tracking and 3D shape recovery are performed on beating heart simulated phantom shown in Fig. 1b. The phantom has heart vessel structure and provision of guidewire movement in different directions. The proposed technique provides 3D visualization of guide wire and vessels to the surgeon as well as robust tracking of guidewire tip.

## 2 Methodology

The functional block diagram of proposed technique for real time guidewire tracking and 3D shape representation is shown in Fig. 2. Image sequences are captured for visual tracking and a stack of multi-focus images are selected through frame grabber, SFF based depth map features and 3D shape representation is obtained through Sum of Modified Laplacian based focus measure and depth map is encoded into local depth pattern. The target colour, texture and depth features are encoded into intensity histogram, filtered local binary pattern histogram (FLBP) and filtered local depth pattern (FLDP) histograms respectively. The MS algorithm using integrated features is applied for robust guidewire tracking and 3D shape of guidewire and vessels is generated for visualization.

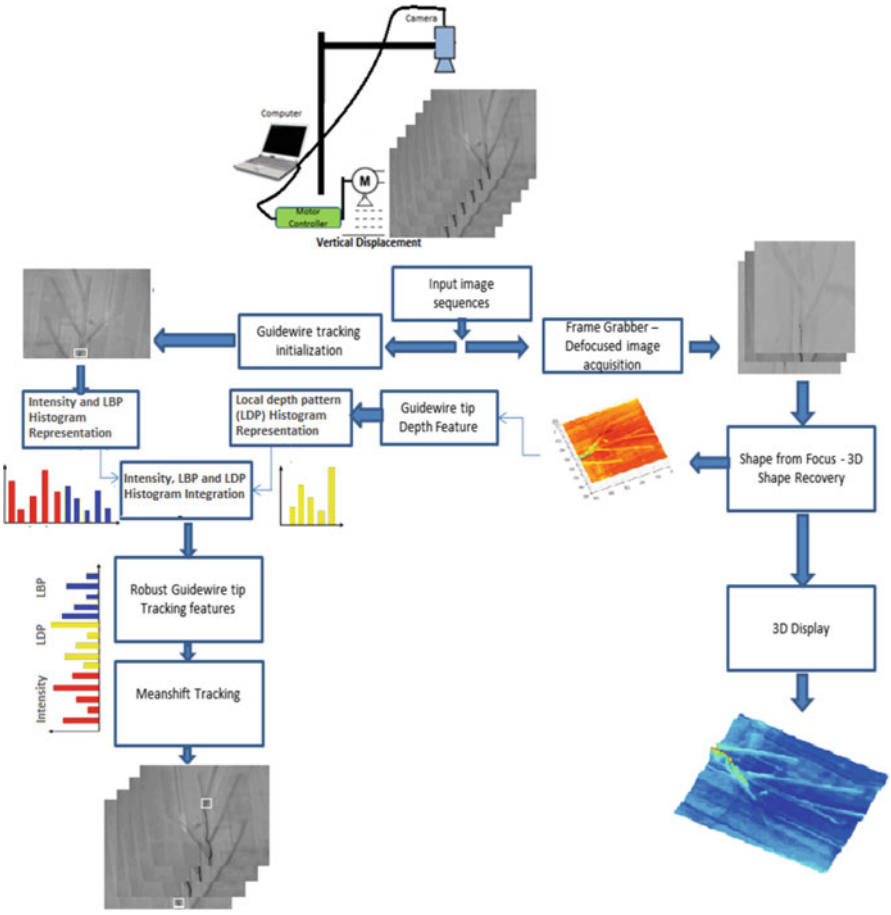


**Fig. 2** Block diagram of the proposed method

## *2.1 Image Acquisition and Pre Processing*

We have simulated the imaging conditions for acquisition of fluoroscopy images under C-arm, X-Ray used for beating heart cardiovascular interventions. In real time scenario, the patient heart vessels are imaged by X-Ray and visual enhancement is made using contrast agents. The beating heart produces prominent movement in vertical direction and produce blurring / defocusing effects due to change in relative depth of heart surface with respect to stationary X-Ray imager [11]. In our proposed technique, we have used these blurring effects for meaningful use in acquisition of multifocus images for 3D shape representation and depth map recovery through shape from focus technique. The experimental setup for proposed technique consists of electronically controlled beating heart simulator, heart vessel

phantom with provision of guidewire insertion and movement in different directions, camera and computer.The camera is fixed over phantom while the stimulator can vertically move upto the height of 10 mm and goes back to its base position in a repetitive loop. A continuous image sequence is captured for guidewire tracking and a set of multifocus images are captured during each vertical movement with registered depth levels.

## *2.2 Depth Feature and 3D Shape Reconstruction*

Recovering depth maps and 3D shapes of real life objects from 2D images is an important and challenging task in computer vision. Numerous 3D shape reconstruction techniques are used based on accommodation cues like motion, shading, stereo, illumination and focus. SFF is a passive optical method used to estimate 3D structure of an object using focus variation [12]. The main objective of SFF is to compute the depth of each point of the object from the camera lens with reference to best focused pixels in the image stack. The distance of focus plane from the lens center depends on the lens focal length and the distance from the point on object. Once these distances for all points on the surface of the object are found, the depth and 3D shape can be recovered. Different focus measures are used to highlight the relative focus levels in images by enhancing the in-focus regions and suppressing the out-of-focus regions. In [13] an image acquisition system is proposed to implement SFF technique for 3D shape recovery of natural complex agronomic scenes. This has motivated us to use SFF concept for 3D construction of real time beating heart surface for application in robot assisted cardiovascular interventions.In this paper, the image sequences are captured from a vertical mounted camera over heart phantom placed on vertical moving beating heart simulator. The vertical movement produces the defocusing of phantom images that are captured while the phantom is moving up. The multi-focus / blurred images are then processed for 3D shape reconstruction using shape from focus technique.

A low pass filter approximation is used to express this blurriness, thus relate sharper image to high frequencies corresponds to contrasting textured regions. Therefore sharpness measure directly relates to quantify high frequencies.We can consider this measure like the following function

$$f_k(x, y) = max_k\big(FM_k(x, y)\big) \tag{1}$$

where $k = 1, 2, \ldots, N$, $N$ is the number of fluoroscopic images in sequence, $FM_k(x, y)$ is the focus measure applied in a local window around each pixel $(x, y)$ for the $k_{th}$ image. Among the most used Focus measure operators in Shape from Focus, there are the Tenenbaum gradient (TEN), the sum of modified Laplacian (SML) and Gray level variance (GLV) [14]. In our application, we use the most popular and computationally efficient sum of modified Laplacian (SML) [12] focus measure. In

SML focus measure, the focus value is calculated by summing the resultant absolute values of convolution of image and Laplacian operator over a small window. The mathematical expression for SML calculation is shown in the equation.

$$SML = \sum_{x=1}^{N} \sum_{y=1}^{N} |\frac{\partial^2 I(x,y)}{\partial^2 x}| + |\frac{\partial^2 I(x,y)}{\partial^2 y}| \tag{2}$$

where $I(x, y)$ is the image pixel contained in local neighborhood of size $N$. The depth map $D(x, y)$ is obtained by maximizing the focus measure along the optical axis in $k$ number of images.

$$D(x,y) = \arg\max_{k} \left(I_k(x,y)\right) \tag{3}$$

where $k = 1, 2, \ldots, K$. Finally, Gaussian interpolation is used to refine the depth map against discreetness and transients. The detailed mathematical explanation can be found in [12, 13].

## 2.3 *Local Depth Map Pattern for Robust Mean Shift Guidewire Tracking*

Mean Shift (MS) [9] is a commonly used target tracking technique due to its ease of implementation and real time response. In MS tracking, a target is usually defined by a rectangular or an elliptical region in the image [9]. The target model $T_m$ is represented by the histogram of gray level intensity / colour feature bins,

$$T_m = N \sum_{i=1}^{n} \eta\left(\|x_i\|^2\right) \delta\left[\phi\left(x_i\right) - m\right] \tag{4}$$

where the $\delta$ function relate pixel $x_i$ to the $m_{th}$ bin, $\eta$ is Ephanechnikov kernel function and $N$ is the normalization constant. Relying only on intensity histogram features, the conventional MS algorithm can not perform satisfactory tracking of complex guidewire movements in presence of similar features like heart vessels.

The cues such as shape, depth, motion, texture, disparity etc can also be used for target feature representation [15]. Most existing MS based target tracking schemes use single features like the color / intensity histogram to represent the target. Some techniques also used joint color-texture histogram [10] and joint color-depth [16] representation for robustness. However these approaches are not well effective when dealing with objects of similar colour and shape features like the case of guidewire. In this paper, we propose a robust target representation approach for MS tracking

using spectral, spatial and range features related through joint histogram of grey level intensity, texture and depth respectively. The grey level intensity is represented through conventional histogram method whereas the texture features are represented through local binary pattern histogram [10]. The depth features are formed through SFF technique as in Sect. 2.2 and represented as local depth pattern histogram. All three histograms are integrated to jointly represent the guidewire feature for robust tracking. Local Binary Pattern (LBP) [10] represents the image texture through spatial relation of pixels in gray level images. In order to enhance the anti-noise immunity of LBP, robust extended local binary pattern (RELBP) [17] descriptor replaces the individual pixel intensities by a Median filter response prior to LBP encoding. The technique work well for texture representation of noisy images especially corrupted with salt and pepper noise. However, in guidewire tracking the fluoroscopic images may contains different types of noises and have low contrast / illumination problems. For guidewire tracking using MS method, RELBP requires a sort of adaptive filter selection. Based on RELBP concept, we have proposed a novel method to represent the gray level spatial relation using adaptive filter application before LBP encoding. Rather fixing the Median filter for whole sequence we applied selected filters against performance at target initialization and whenever the target model update is required to coup with changing target shape. We have used two filters examined by Liu [17] i.e Gaussian and Median for noise immunity and Top hat transform filter [18] for contrast and illumination variations. These filters are applied on target region and an evaluation measure is used to rank the selection criterion. Signal to noise ratio (SNR) is used as a measure of performance. The filter producing highest value of SNR will be selected as filter $\psi$ for LBP representation.

Let $I$ be the actual image having tracking window $w$ with sub-windows of size $3 \times 3$ represented by $f$. The tracking window is chosen manually at initial frame and updated using MS [9] algorithm. The modified LBP of $f$ is,

$$h_f = s(\psi(f - \bar{f})) \tag{5}$$

Where $s(x) = 1$ for $x \geq 0$ and $s(x) = 0$ for $x < 0$, $\bar{f}$ is the mean gray level value of $f$. The filter $\psi$ is selected on the basics of SNR of original and filtered window i.e.,

$$\xi_i \xleftarrow{\text{SNR}} \left(f, f_i\right) \tag{6}$$

where $i = 1, 2, 3$ for median, Gaussian and top-hat filter respectively.

$$\psi = \begin{cases} \psi_1 & for \quad \left(\xi_1 > \xi_2 \& \xi_1 > \xi_3\right) \\ \psi_2 & for \quad \left(\xi_2 > \xi_1 \& \xi_2 > \xi_3\right) \\ \psi_3 & otherwise \end{cases} \tag{7}$$

Where $\xi$ corresponds to SNR. Note that the filter $\psi$ will be selected at initial stage and each time the model need updation. The combined LBP of $w$ is histogram $h_f$ arranged in $m$-number of bins and named as filtered local binary pattern (FLBP). Let $D$ be the depth map obtained using SFF technique proposed in Sect. 2.2. By considering the depth map as gray level image [19] the same procedure can be adopted to obtain local depth map features $h_d$ named as filtered local depth map pattern (FLDP). For both FLBP and FLDP, the standard LBP encoding scheme [10] is used for histogram formulation, and the joint histograms of pixel intensities ($h_i$), LBP ($h_f$) and LDP ($h_d$) are concatenated for target model representation.

$$h = \left[h_i, h_f, h_d\right] \tag{8}$$

The proposed target model representation provides true discriminative features require for tracking of featureless guidewire structure. Rest of implementation for guidewire tracking is similar to conventional MS tracking approach [9]. This target model representation can also be used for other tracking applications especially where the target have nearby similar colour and shape objects.

## 3 Results and Discussion

The results of the proposed tracking and 3D shape reconstruction algorithms are evaluated using cardiac vascular phantom placed on a beating heart simulator. In the experiments the guidewire was moved to different orientation within the vascular lumen phantom and sequences are captured through camera. Displacement of camera height with respect to simulator changes the image focus regions. The depth map is obtained by registering these multifocus images against vertical distance using shape from focus technique. The depth map is further refined through Gaussian interpolation based shape reconstruction technique. Some of the example image sequences and corresponding 3D mesh representation are shown in Figs. 3 and 4 where a color scheme corresponds to the depth of each pixel relative to the camera.

The guidewire tip tracking is manually initialized in first frame. For comparative performance analysis we have used conventional MS [9], MS combined with LBP features [10] and our proposed modified MS tracking technique. In the first experiment Fig. 4, the guidewire sequence 1 has 32 frames of $640 \times 480$ pixels with guidewire moving in too and froe in single vessel. The white coloured box containing the tip of guidewire is manually initialized in first frame and then automatically tracked in subsequent frames of whole sequence. The results shows that the guidewire tip tracking performance of conventional MS algorithm is very poor as it has lost the guidewire tip very soon whereas the MS combined with LBP features stayed on the guidewire however could not track tip in whole sequence. On the other hand proposed technique using MS intensity, texture and depth features

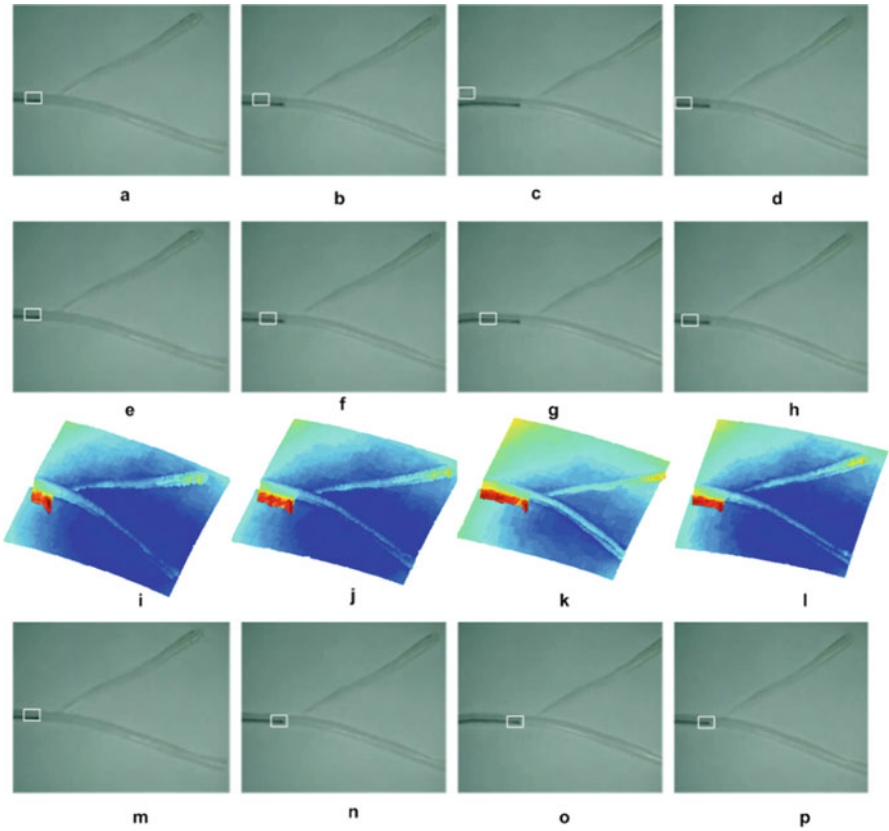


**Fig. 3** Tracking of Guidewire tip sequence 1 using ((**a**)–(**d**)) Conventional MS ((**e**)–(**h**)) MS combined with LBP ((**i**)–(**l**)) Corresponding 3D representation ((**m**)–(**p**)) Proposed technique

robustly tracked the guidewire tip in whole sequence. The average numbers of iterations are 2.30 for conventional MS, 3.65 for MS combined with LBP and 3.30 for proposed tracking technique respectively.

In the second experiment Fig. 4, the guidewire sequence 2 has 662 frames of $640 \times 480$ pixels. This sequence is more complex due to guidewire movements in different directions. The tracking results are again similar to the previous sequence where only the proposed technique using MS alongwith FLBP and FLDP features successfully tracked the tip of guidewire in whole sequence and other techniques could not perform task satisfactory. The average numbers of MS iterations in this case are 2.25 for conventional MS, 3.42 for MS combined with LBP and 3.18 for proposed tracking technique respectively.

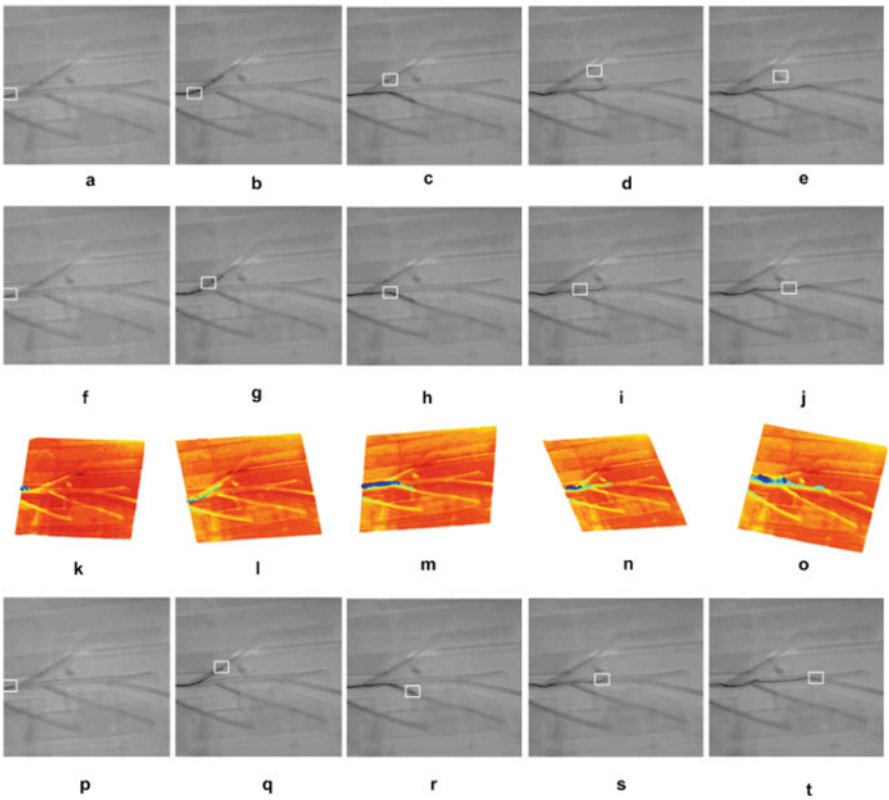


**Fig. 4** Tracking of Guidewire tip sequence 2 using ((**a**)–(**e**)) Conventional MS ((**f**)–(**j**)) MS combined with LBP ((**k**)–(**o**)) Corresponding 3D representation ((**p**)–(**t**)) Proposed technique

## 4 Conclusion

In this paper, a robust guidewire tip tracking and 3D shape representation method based on Mean Shift algorithm is proposed. The proposed technique presents a real time method to extract and track the position of a guide wire tip during cardiovascular interventions under simulated X-ray fluoroscopy and beating heart motion. The method integrates intensity, texture and depth map features for robust MS tracking. Filtered local binary pattern histogram and filtered local depth pattern histograms are used for encoding texture and depth features to have more robustness in presence of noise and low signal to noise ratio. Shape from focus (SFF) is used for depth map and three dimensional shape reconstruction of guidewire. The proposed technique provides 3D visualization of guide wire and vessels to the surgeon as well as real time robust guidewire tip tracking. Experimental results of guidewire tip tracking and 3D shape recovery on image sequence acquired through beating heart simulated phantom shows the significance of the proposed technique.

## References


1. Zarge, J.A., and N.R. Corby. 1994. Method and apparatus for real-time tracking of catheter guide wires in fluoroscopic images during interventional radiological procedures. U.S. Patent 5289373.
2. Palti-Wasserman, D., A.M. Burkstein, and R.P. Beyar. 1997. Identifying and tracking a guide wire in the coronary arteries during angioplasty from X-ray images. *IEEE Transactions on Biomedical Engineering* 44(2):152–164; doi:10.1109/10.552245.
3. Baert, S., M. Viergever, and W. Niessen. 2003. Guide-wire tracking during endovascular interventions. *IEEE Transactions on Medical Imaging* 22(8):965–972; doi:10.1109/TMI.2003.815904.
4. Barbu, A., V. Athitsos, B. Georgescu, S. Boehm, P. Durlak, D. Comaniciu. 2007. Hierarchical learning of curves application to guidewire localization in fluoroscopy. In *IEEE Conference on Computer Vision and Pattern Recognition (CVPR)*, 1–8; doi:10.1109/CVPR.2007.383033.
5. Takemura, A., K.R. Hoffmann, M. Suzuki, Z. Wang, H.S. Rangwala, and H. Harauchi. 2008. An algorithm for tracking microcatheters in fluoroscopy. *Journal of Digital Imaging* 21(1):99–108; doi:10.1007/s10278-007-9016-9.
6. Lessard, S., C. Lau, R. Chav, G. Soulez, D. Roy, J.A. de Guise. 2010. Guidewire tracking during endovascular neurosurgery. *Medical Engineering and Physics* 32(8):13–21. doi:10.1016/j.medengphy.2010.05.006.
7. Wang, P., Y. Zhu, T. Chen, P. Durlak, U. Bill, and D. Comaniciu. 2009. Hierarchical guidewire tracking in fluoroscopic sequences. In *Proceeding of SPIE*, vol. 7259, 72591L; doi:10.1117/12.812508.
8. Wagner, M.G., C.M. Strother, and C.A. Mistretta. 2016. Guidewire path tracking and segmentation in 2D fluoroscopic time series using device paths from previous frames. In *Proceeding of SPIE 9784, Medical Imaging*; doi:10.1117/12.2216540.
9. Comaniciu, D. 2003. Kernel based object tracking. *IEEE Transactions on Pattern Analysis and Machine Intelligence* 25(5):564–577; doi:10.1109/TPAMI.2003.1195991.
10. Ning, J. 2009. Robust object tracking using joint color-texture histogram. *International Journal of Pattern Recognition and Artificial Intelligence* 23(7):1245–1263; doi:10.1142/S0218001409007624.
11. Xue, P., and D.L. Wilson. 1998. Effects of motion blurring in x-ray fluoroscopy. *Medical Physics* 25(5):587–599; doi:10.1118/1.598240.
12. Nayer, S., and Y. Nakagawa. 1990. Shape from focus. *IEEE Transactions on Pattern Analysis and Machine Intelligence* 16(8):824–831; doi:10.1109/34.308479.
13. Billiot, B., F. Cointault, L. Journaux, J.-C. Simon, and P. Gouton. 2013. 3D Image acquisition system based on shape from focus technique. *Sensors* 13(4):5040–5053. doi:10.3390/s130405040.
14. Mir, H., P. Xu, and P. Van. 2014. An extensive empirical evaluation of focus measures for digital photography. In *Proceedings of SPIE 9023, Digital Photography X*, 90230I; doi:10.1117/12.2042350.
15. Walia, G.S., and R. Kapoor. 2016. Recent advances on multicue object tracking- a survey. *Artificial Intelligence Review* 46(1):1–39; doi:10.1007/s10462-015-9454-6.
16. Zhao, Y., Z. Liuy, L. Yang, and H. Cheng. 2012. Combing RGB and depth map features for human activity recognition. In *Annual Summit and Conference on Signal and Information Processing Association (APSIPA ASC)*.
17. Liu, L., Lao, S., and P.W. Fieguth. 2016. Median robust extended local binary pattern for texture classification. *IEEE Transactions on Image Processing* 25(3):1368–1381; doi:10.1109/TIP.2016.2522378.

18. Chen, T., Q.H. Wu, R. Rahmani-Torkaman, and J. Hughes. 2002. A pseudo top-hat mathematical morphological approach to edge detection in dark regions. *Pattern Recognition* 35(1):199–210; doi:10.1016/S0031-3203(01)00024-3.
19. Yin, S., X. Dai, P. Ouyang, L. Liu, and S. Wei. 2014. A multi-modal face recognition method using complete local derivative patterns and depth maps. *Sensors* 14(10):19561–19581; doi:10.3390/s141019561.

# Utilizing a Homecare Platform for Remote Monitoring of Patients with Idiopathic Pulmonary Fibrosis

**Christos Panagopoulos, Foteini Malli, Andreas Menychtas, Efstathia-Petrina Smyrli, Aikaterini Georgountzou, Zoe Daniil, Konstantinos I. Gourgoulianis, Panayiotis Tsanakas, and Ilias Maglogiannis**

**Abstract** Homecare and home telemonitoring are a focal point of emerging healthcare schemes, with proven benefits for both patients, caregivers and providers, including reduction of healthcare costs and improved patients' quality of life, especially in the case of chronic disease management. Studies have evaluated solutions for remote monitoring of chronic patients based on technologies that allow daily symptom and vital signs monitoring, tailored to the needs of specific diseases. In this work, we present an affordable home telemonitoring system for patients with idiopathic pulmonary fibrosis (IPF), based on an application for mobile devices and Bluetooth-enabled sensors for pulse oximetry and blood pressure measurements. Besides monitoring of vital signs, the system incorporates communication via videoconferencing and emergency response, with support from a helpdesk service. A pilot study was conducted, in order to verify the proposed solution's feasibility. The results support the utilization of the system for effective monitoring of patients with IPF.

**Keywords** Homecare • Assisted living • Idiopathic pulmonary fibrosis • Electronic reminders • Medication adherence • Patient compliance • Patient monitoring

C. Panagopoulos • A. Menychtas • E.-P. Smyrli • A. Georgountzou
BioAssist S.A., Patras, Greece
e-mail: cpan@bioassist.gr

F. Malli • Z. Daniil • K.I. Gourgoulianis
Respiratory Medicine Department, University of Thessaly Medical School, University Hospital of Larissa, Larissa, Greece

P. Tsanakas
School of Electrical and Computer Engineering, National Technical University of Athens, Athens, Greece

I. Maglogiannis (✉)
Department of Digital Systems, University of Piraeus, Piraeus, Greece
e-mail: imaglo@unipi.gr



P. Vlamos (eds.), *GeNeDis 2016*, Advances in Experimental Medicine and Biology 989, DOI 10.1007/978-3-319-57348-9_15

## 1 Introduction and Related Work

Innovative technologies are increasingly applied in the field of medicine, offering both patients and providers a wide range of benefits and transforming traditional healthcare models. With the growing availability of home medical equipment and the development of cloud-based services for secure storage, transfer and exchange of health data, homecare and home telemonitoring are now a reality, responding to the ever changing needs of patient care and becoming progressively more affordable.

Although early applications of telemonitoring focused on acute episodic care or post-surgery assessment, substantial positive impact can be achieved in follow-up of chronic conditions, such as cardiovascular or pulmonary diseases, as chronic patients are the heaviest users of healthcare services [1, 2]. Studies have indicated various benefits that can be reaped from the adoption of home telemonitoring, including reduced costs for providers, improved efficiency and superior coordination between caregivers, as well as higher quality of life for patients [1–7].

Remote patient monitoring and telecare are also a focal point of new directions in respiratory care. The American Association for Respiratory Care has presented a vision of respiratory care in 2015 and beyond that focuses on outpatient management, with increased use of electronic health records, telemedicine and telecare in all care settings and emphasis on homecare [8].

A number of studies have been conducted on the application and benefits of home telemonitoring for patients with chronic obstructive pulmonary disease (COPD), with the utilization of technologies that allow monitoring of symptoms and vital signs [2, 4, 6, 9–11]. The results of these studies indicate potential for improved care, decrease in healthcare and acute care utilization and thus care costs, improved patient adherence and self-management, increased access to healthcare and peace of mind for patients and their relatives. Similar studies on patients with cystic fibrosis have additionally demonstrated improved health results [1, 12–14]. The focus on COPD is understandable, considering the disease's prevalence globally. However, there is absence of studies on patients with less common chronic pulmonary conditions, who are likely to benefit from the same technologies.

In this work, we present a homecare system for telemonitoring of patients with idiopathic pulmonary fibrosis, based on commodity hardware. The system enables daily monitoring of a patient's vital signs, includes communication features that facilitate doctor-patient contact and provides emergency response. A pilot study has been conducted at the Respiratory Medicine Department of the University Hospital of Larissa, with the participation of the department's physicians and patients, in order to assess the feasibility of the proposed solution.

## 2 Idiopathic Pulmonary Fibrosis

Idiopathic pulmonary fibrosis (IPF), is a chronic, progressive and irreversible lung disease of unknown etiology that occurs in middle-aged and elderly adults. According to most studies, IPF is more common in men and the mean age of onset is typically 67–69 years [15]. The disease is characterized by increasing respiratory symptoms, progressive worsening of dyspnea and pulmonary function, progressive fibrosis of the lungs, acute respiratory decline and it is usually fatal. Studies suggest a median survival time of 2–3 years after diagnosis [16]. In most cases, the patient suffers from a gradual worsening of lung function over years, but there is also a minority of patients that remains stable or declines rapidly. The natural history of the disease is variable and unpredictable at the time of diagnosis, while patients may have sub-clinical or overt co-morbid conditions, including pulmonary hypertension, gastroesophageal reflux and emphysema [16].

The confident diagnosis of IPF is important, as it has implications for prognosis and the creation of a disease management plan. As many other idiopathic interstitial pneumonias and lung diseases present identical symptoms to IPF, but behave differently in terms of progress, treatment responsiveness and prognosis, increased accuracy can be achieved with a multidisciplinary approach [15, 16, 18].

According to the official guidelines for diagnosis and management of IPF [16], published by the American Thoracic Society and the European Respiratory Society, long-term oxygen therapy is recommended for patients with IPF and clinically significant resting hypoxemia, as well as lung transplantation in appropriate patients. In many cases, pulmonary rehabilitation should also be used, as well as corticosteroids in patients with acute exacerbation of IPF. It is emphasized, however, that although evidence-based recommendations apply to the typical patient, for individuals the best treatment plan may differ and can be adjusted depending on the patient's values and preferences. In addition, there is not sufficient evidence to support the use of any pharmacologic therapy for IPF to date, but some agents may have possible benefits for individual patients.

The above highlight the importance of palliative care in improving patients' quality of life and the need for monitoring of patients with IPF, in order to appreciate worsening of symptoms and oxygenation, detect treatment complications, identify the course of the disease and initiate timely, appropriate therapeutic interventions. Detailed guidelines for monitoring of the clinical course of the disease, including disease progression, worsening of symptoms and comorbidities can be found in [16]. A practice that is common with other pulmonary diseases is the monitoring of oxygen saturation by pulse oximetry.

Oxygen saturation should be measured in all IPF patients at rest and with exertion, in order to assure adequacy of oxygenation. The technologies mentioned in the previous section allow for daily measurements of such vital signs in real conditions, providing continuous monitoring of the patient's status, with no significant rise in cost for the provider or the patients themselves. In addition, home telemonitoring should facilitate monitoring of patients that live in rural areas,

who might not be able to schedule follow up visits as frequently as others. Most importantly, a telemonitoring service is expected to provide IPF patients with better awareness of their condition and reassurance that a health professional will be notified in case of need, as it has been reported in studies on patients with other chronic conditions.

## 3 Utilized Patient Monitoring Platform and Use Case Scenarios

The utilized patient monitoring platform is a homecare system for assisted independent living that incorporates health monitoring features, communication and social networking between users, as well as features for emergency response, with the support of a helpdesk service. The system exploits wireless medical sensors and wearables for vital signs and physical activity tracking. All medical information is securely stored in cloud infrastructure and controlled access to the data is managed by the user.

The platform consists of four main sub-systems, an application for smart devices, a web-based application, a helpdesk application and a cloud back-end platform. The application for end-users is an Android application. Besides the core functionality for communicating with the back-end, the mobile application allows for the integration of Bluetooth devices, sensors and wearables. The web-based application includes functionalities for interacting with all user types, configuring the user and application parameters, and also for visualizing the biosignals and health records. The helpdesk application is accessible by healthcare operators, which receive the emergency requests from patients and trigger appropriate actions. Finally, the platform back-end is set of several cloud-based services and components. The architecture of the utilized platform is illustrated in Fig. 1.

### *3.1 Use Case Scenarios*

In this section we discuss the platform's functionalities and the main use case scenarios adopted in this study. Patients access the system through the mobile application, which enables the following functionalities.

**Vital Signs Monitoring and Personal Health Record (PHR)** When the patient is required to perform a measurement, they use the appropriate sensor. The measurement is automatically transmitted to the tablet and uploaded to the patient's PHR. The patient can also view past measurements on the tablet.

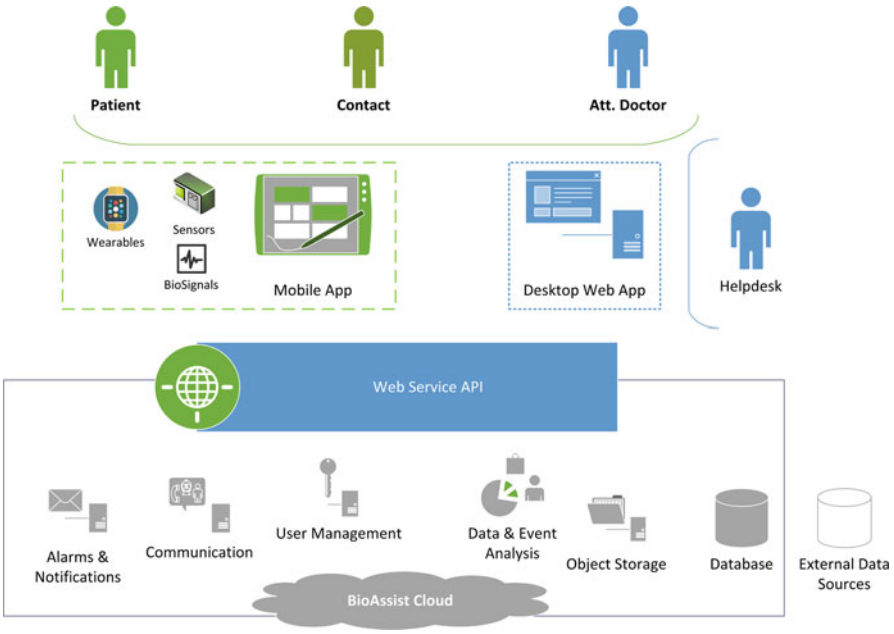


**Fig. 1** Homecare platform system architecture

**Videoconferencing and Social Contact** Patients can communicate with their doctors via videoconferencing. While videoconferencing with a doctor is active, the patient can perform measurements of their vital signs and the results are displayed to both users. Relatives and friends can be added to the patient's contact list and access the system from their own devices and communicate with the patient via videoconferencing, as well as receive valuable information about the patient's well-being and notification in case of need. Patients can also view photos and videos of their contacts and upload content of their own.

**Reminders** Patients or their caregivers can set reminders, for health-related tasks, such as doctor appointments, or non-medical tasks, such as daily activities and social engagements.

**Emergency Call** In case of emergency, the patient can contact the service's helpdesk, with a single touch, to receive assistance and medical advice.

The main use cases concerning the patient are illustrated in Fig. 2.

Doctors access the system through the web application, which provides tools for monitoring their patients.

**Patient Monitoring Parameters** For each patient, the doctor can set a schedule of daily biosignal measurements, along with the respective acceptable ranges. The


**Fig. 2** Patient use cases

system can be set to automatically create the appropriate reminders for the patient. In case a measurement exceeds the acceptable range, an alert is sent to the doctor, as well as the helpdesk.

**PHR** The doctor can view the patient's PHR and update certain information, such as prescribed medications. They can also choose to receive automated weekly reports for each patient, containing all new data in the patient's PHR.

The main use cases concerning the doctor are illustrated in Fig. 3.

## 4 Pilot Setup and Evaluation

A 6-month pilot study has been conducted at the Respiratory Medicine Department of the University Hospital of Larissa, with the participation of physicians and patients. The patients' enrollment in the pilot did not substitute or affect in any way their schedule of regular visits to the clinic.

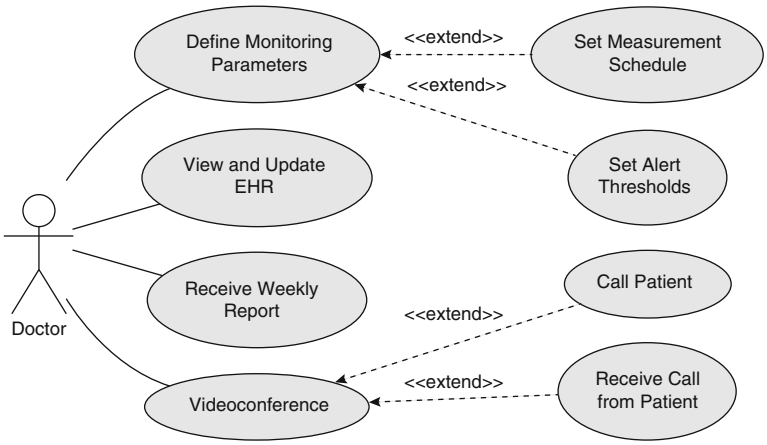


**Fig. 3** Doctor use cases

**Table 1** Patients' clinical characteristics

| Variable | Value (mean ± SD) |
|---|---|
| Age (years) | 67.6 ± 8.4 |
| Gender (male/female) | 14/6 |
| Smoking habit (non-smoker/ex-smoker) | 12/8 |
| Pack-years | 51.26 ± 14.33 |
| FVC (%pred) | 70.77 ± 17.39 |
| $FEV_1$/FVC | 87 ± 13.7 |
| $DL_{CO}$ (%pred) | 40.23 ± 19.88 |
| RV (%pred) | 69.74 ± 20.85 |
| TLC (%pred) | 64.27 ± 13.11 |

## *4.1 Patients*

A total of 20 patients have been involved in the pilot study, of which 6 are female and 14 are male, 15 with IPF and 5 with combined IPF and emphysema. The mean age is 67.6 years. Six of these patients receive long-term oxygen therapy at home.

Diagnosis of the patients' condition (IPF or combination of IPF with emphysema) was based on internationally accepted criteria [16, 17]. The only exclusion criteria were lack of ability to use the provided equipment or refusal of the patient to participate in the study. Table 1 provides a summary of the patients' clinical characteristics. The geographic dispersion of the pilot participants is displayed in Fig. 4.

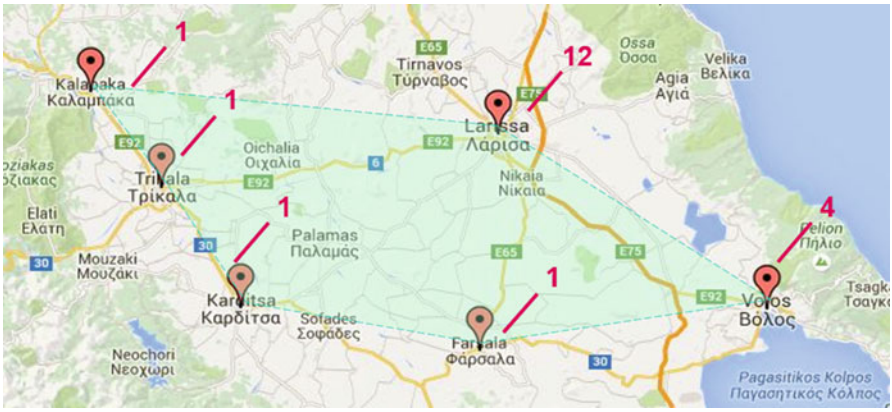


**Fig. 4** Geographic dispersion of pilot participants

## *4.2 Study Protocol*

Each patient was provided with an Android tablet with the mobile application pre-installed, as well as Bluetooth-enabled pulse oximeter and blood pressure meter. Internet connectivity at the patients' residences was ensured before enrollment.

Patients were instructed by their attending doctor to perform daily measurements of oxygen saturation and blood pressure. The attending doctor set the measurement schedule and respective thresholds for each patient through the web application, as well as the list of prescribed medication regimens (if applicable), and set reminders to enforce adherence to the schedule, if needed.

All measurements were automatically saved in the patients' PHRs and were accessible to the attending doctor. The attending doctor was able to view measurements at any time, but also in the weekly reports that were automatically created for each patient by the system. In case of measurements that exceeded the respective threshold, the doctor was immediately notified via SMS or email.

The attending doctor contacted each patient on a weekly basis via the platform's videoconferencing functionality. Patients were also encouraged to add their close relatives in their contact list, in order to be able to communicate through the system with them, too. Patients were assisted by a helpdesk service that handled technical support, but also emergency incidents.

Regular assessments of the patients' status were performed using well-established questionnaires (Saint George's Respiratory Questionnaire [19] and InterRAI [20]). The patients have also been asked to answer to user satisfaction questionnaires. The data collected will be analyzed in the future for impact assessment.

### *4.3 Results*

All patients have been consistently adherent to their measurements schedule and medication regimen (when applicable) for the duration of pilot. Most patients did not require reminders to enforce their treatment schedule.

No significant technical issues or problems with the system's usability were presented. Approximately 70% of the participants were able to use the system with confidence even without support. Similarly, the system presented no difficulty for caregivers either.

Most of the participants live close to their families and thus did not take advantage of the system's social features. However, these features were appreciated and actively used by the relatives of those patients that live alone.

During the course of the pilot, patients mostly used the emergency call feature in cases of technical issues. Within these 6 months, a total of three medical emergencies occurred. Two of these emergency calls where placed by the patients themselves and one call was placed by a patient's daughter. All incidents where handled in a timely manner and the appropriate form of help was routed immediately.

## 5 Discussion and Conclusions

In this work, we have presented the utilization of a homecare platform for remote monitoring of patients with IPF. The system is based on commodity hardware, making it an affordable telemonitoring option that has the potential to positively impact patients' quality of life, facilitate doctor-patient communication and provide timely support in emergencies.

The results of the first 6 months of our pilot study indicate that most patients -even those of greater age- are able to use the system confidently, without major difficulty or need for constant support. Most importantly, no patient has abandoned use of the system, which appears to have integrated well with their daily routines. The consistency that the participants have demonstrated in their monitoring schedules can be partially attributed to the high level of adherence that is usually characteristic of IPF patients, but would not be possible if the patients did not feel comfortable using the system. Correspondingly, doctors have easily familiarized themselves with the system and incorporated it in their care process, while continuous monitoring of their patients has enabled them to achieve more accurate and confident assessment of each patient's status and timely decide on appropriate adjustments to their treatment.

Patients have made use of the emergency call service in cases of need, which appears to be a very important feature for their relatives, as it provides an immediately available, reliable and comforting source of support in times of need. Similarly, the patient's relatives seem to appreciate the system's communication capabilities, even more than the patients themselves.

Overall, the results are supportive and indicative of the benefits that the system offers to patients, relatives and doctors. As the study continues, data gathered via questionnaires will allow for impact analysis and assessment of user satisfaction.

**Acknowledgments** Part of the work reported here has been carried out in the framework of the European project *Ubiquitous iNteroperable Care for Ageing People* (*UNCAP)*, funded by the European Union's Horizon 2020 research and innovation programme.

## References

1. Bella, S., F. Murgia, A.E. Tozzi, et al. 2009. Five Years of Telemedicine in Cystic Fibrosis Disease. *Clin Ter* 160: 457–460.
2. Paré, G., P. Poba-Nzaou, C. Sicotte, et al. 2013. Comparing the Costs of Home Telemonitoring and Usual Care of Chronic Obstructive Pulmonary Disease Patients: A Randomized Controlled Trial. *European Research in Telemedicine / La Recherche Européenne en Télémédecine* 2: 35–47. doi:10.1016/j.eurtel.2013.05.001.
3. Klersy, C., A. De Silvestri, G. Gabutti, et al. 2011. Economic Impact of Remote Patient Monitoring: An Integrated Economic Model Derived from a Meta-Analysis of Randomized Controlled Trials in Heart Failure. *European Journal of Heart Failure* 13: 450–459. doi:10.1093/eurjhf/hfq232.
4. Dixon, L.C., D.J. Ward, J. Smith, et al. 2016. New and Emerging Technologies for the Diagnosis and Monitoring of Chronic Obstructive Pulmonary Disease: A Horizon Scanning Review. *Chronic Respiratory Disease*. doi:10.1177/1479972316636994.
5. Darkins, A., P. Ryan, R. Kobb, et al. 2008. Care Coordination/Home Tele-health: The Systematic Implementation of Health Informatics, Home Tele-health, and Disease Management to Support the Care of Veteran Patients with Chronic Conditions. *Telemedicine and e-Health* 14: 1118–1126. doi:10.1089/tmj.2008.0021.
6. Trappenburg, J.C.A., A. Niesink, G.H. de Weert-van Oene, et al. 2008. Effects of Telemonitoring in Patients with Chronic Obstructive Pulmonary Disease. *Telemedicine and e-Health* 14: 138–146. doi:10.1089/tmj.2007.0037.
7. Davis, C., M. Bender, T. Smith, and J. Broad. 2015. Feasibility and Acute Care Utilization Outcomes of a Post-Acute Transitional Telemonitoring Program for Underserved Chronic Disease Patients. *Telemedicine and e-Health* 21: 705–713. doi:10.1089/tmj.2014.0181.
8. Kacmarek, R.M., C.G. Durbin, T.A. Barnes, et al. 2009. Creating a vision for respiratory care in 2015 and beyond. *Respiratory Care* 54: 375–389.
9. Gorst, S.L., C.J. Armitage, S. Brownsell, and M.S. Hawley. 2014. Home Telehealth Uptake and Continued Use Among Heart Failure and Chronic Obstructive Pulmonary Disease Patients: a Systematic Review. *Annals of Behavioral Medicine* 48: 323–336. doi:10.1007/s12160-014-9607-x.
10. Gorst, S.L., E. Coates, and C.J. Armitage. 2016. "It's Sort of a Lifeline": Chronic Obstructive Pulmonary Disease Patients' Experiences of Home Telehealth. *Health Psychology* 35: 60–68. doi:10.1037/hea0000246.
11. Sund, Z.M., T. Powell, R. Greenwood, and N.A. Jarad. 2009. Remote Daily Real-Time Monitoring in Patients with COPD – A Feasibility Study Using a Novel Device. *Respiratory Medicine* 103: 1320–1328. doi:10.1016/j.rmed.2009.03.01.
12. Bella, S., F. Murgia, and C. Cotognini. 2013. Program of Home Telemonitoring in Patients with Cystic Fibrosis Over a Period of 2 Years: A Contribution to the Rationalization of Care. *La Clinica Terapeutica*: e313–e317. doi:10.7417/CT.2013.1595.

13. Cox, N.S., J.A. Alison, T. Rasekaba, and A.E. Holland. 2012. Telehealth in Cystic Fibrosis: A Systematic Review. *Journal of Telemedicine and Telecare* 18: 72–78. doi:10.1258/jtt.2011.110705.
14. Tagliente, I., L. Trieste, T. Solvoll, et al. 2016. Telemonitoring in Cystic Fibrosis: A 4-Year Assessment and Simulation for the Next 6 Years. *Interactive Journal of Medical Research* 5: e11. doi:10.2196/ijmr.5196.
15. Dempsey, O.J. Nov. 2006. Clinical Review: Idiopathic Pulmonary Fibrosis—Past, Present and Future. *Respiratory Medicine* 100 (11): 1871–1885.
16. Raghu, G., H.R. Collard, J.J. Egan, F.J. Martinez, J. Behr, K.K. Brown, T.V. Colby, J.-F. Cordier, K.R. Flaherty, J.A. Lasky, D.A. Lynch, J.H. Ryu, J.J. Swigris, A.U. Wells, J. Ancochea, D. Bouros, C. Carvalho, U. Costabel, M. Ebina, D.M. Hansell, T. Johkoh, D.S. Kim, T.E. King, Y. Kondoh, J. Myers, N.L. Müller, A.G. Nicholson, L. Richeldi, M. Selman, R.F. Dudden, B.S. Griss, S.L. Protzko, and H.J. Schünemann. Mar. 2011. An Official ATS/ERS/JRS/ALAT Statement: Idiopathic Pulmonary Fibrosis: Evidence-Based Guidelines for Diagnosis and Management. *American Journal of Respiratory and Critical Care Medicine* 183 (6): 788–824.
17. Cottin, V. 2013. The Impact of Emphysema in Pulmonary Fibrosis. *European Respiratory Review* 22: 153–157. doi:10.1183/09059180.00000813.
18. King, T.E., A. Pardo, and M. Selman. Dec. 2011. Idiopathic Pulmonary Fibrosis. *The Lancet* 378 (9807): 1949–1961.
19. SGRC Official Website: http://www.healthstatus.sgul.ac.uk/sgrq
20. InterRAI Organization Official Website: http://www.interrai.org/

# IoT Contextual Factors on Healthcare

**Konstantinos Michalakis and George Caridakis**

**Abstract** With the emergence of the Internet of Things, new services in healthcare will be available and existing systems will be integrated in the IoT framework, providing automated medical supervision and efficient medical treatment. Context awareness plays a critical role in realizing the vision of the IoT, providing rich contextual information that can help the system act more efficiently. Since context in healthcare has its unique characteristics, it is necessary to define an appropriate context aware framework for healthcare IoT applications. We identify this context as perceived in healthcare applications and describe the context aware procedures. We also present an architecture that connects the sensors that measure biometric data with the sensory networks of the environment and the various IoT middleware that reside in the geographical area. Finally, we discuss the challenges for the realization of this vision.

**Keywords** Internet of Things • Context-awareness • Sensors • Healthcare

## 1 Introduction

Improving the efficiency of healthcare infrastructure is a major challenge of modern-day society [1]. Most of the medical supervision and management is still manually executed by nursing staff [2]. The adoption of information and

K. Michalakis
Department of Cultural Technology and Communication, Aegean University, University Hill, Mytilene, Greece
e-mail: kmichalak@aegean.gr

G. Caridakis (✉)
Department of Cultural Technology and Communication, Aegean University, University Hill, Mytilene, Greece

Intelligent Systems, Content and Interaction Laboratory, National Technical University of Athens, Athens, Greece
e-mail: gcari@aegean.gr



P. Vlamos (eds.), *GeNeDis 2016*, Advances in Experimental Medicine and Biology 989, DOI 10.1007/978-3-319-57348-9_16

communication technologies (ICT) within the healthcare section has led to notions like e-health and m-health [3]. Emerging concepts and procedures of ICT, such as the Internet of Things, and Cloud Computing [4] can offer new ways to provide efficient healthcare to the communities.

With the advent of the Internet of Things (IoT), a wide range of applications and services is conceivable. The basic idea of the IoT is the pervasive presence of "things" around us that can interact with each other and through the Internet infrastructure with other things or systems across the world, providing personalized services on run-time [5]. The Internet of Things empowers all those connected objects with a seemingly "smart" behavior, adding appropriate reactions to events and situations, caused by users or the environment.

Healthcare represents one of the most attractive applications of the IoT. It has the potential to provide services such as remote medical treatment, automated health monitoring, telemedicine and elderly care. Through the evolution of medical devices with added smart functionality and their connection to the IoT infrastructure, a new network for healthcare is developed, called the IoThNet [6]. It can access the IoT backbone, facilitating the communication of medical data and deployment of medical services. Solanas et al. [3] coined the term Smart Health (s-health), to describe this fusion of healthcare with ICT.

A full deployment of the IoT, overall and thus also in healthcare, has yet to be implemented and only some systems partially covering the IoT vision have been deployed [7]. Technologies from various fields will contribute towards this direction, overcoming challenges like reliability, interoperability, security, privacy etc. Among those, Context-awareness (CA) plays a prominent role in refining and enhancing the acquired/sensed data either medical, personal or environmental. It was originally conceived as a feature of Ubiquitous and Pervasive systems and was expanded to the area of the IoT, where a huge number of sensors will be deployed, making it infeasible to process all sensed data. Context-awareness will provide the techniques to decide which data is needed and which not, decreasing the computational costs and making the systems quicker and more efficient [8].

Especially in the field of healthcare, and in applications such as health monitoring, wearable objects will output great volumes of data, which will require filtering techniques. Furthermore, contextual data about the environment and conditions of a user's state may be relevant and a fusion of all those parameters can provide contextual information of higher value than a simple merging of sensory output [9]. Context awareness provides the tools and techniques for this procedure.

The rest of this paper is organized as follows: Sect. 2 reviews the literature and Sect. 3 proposes a new architecture scheme for the IoThNet, with CA as a focal point. Context extraction and context awareness are analyzed at Sect. 4, under perspective of the proposed system, while a case study is presented to show the functionality. Section 5 reviews some healthcare applications and showcases potential use cases of the proposed system. Section 6 discusses challenges that lay ahead on the roadmap of a fully deployed IoThNet. Finally, Sect. 7 concludes with final remarks and presents future and ongoing work.

## 2 Related Work

The first crucial step of the realization of IoThNet is the design of the architecture, which outlines the data transmissions and communications needed for the desired functionality. Islam et al. [6] reviewing the field identify some unique characteristics of healthcare such as the need for complicated body sensors and the urgency of system behaviors/decisions. There are many prototype architecture schemes on general IoT platforms in the literature, but the usage of one of those would fail to incorporate those characteristics of healthcare.

Jones et al. [10] describes a generic architecture for smart healthcare. It is a good starting point since it includes many features widely used in the field, like BANs. The Body Area Network (BAN) concept enables wireless communication between various miniaturized body sensors and a central body unit [11]. Jones' scheme was designed for mobile health monitoring scenarios, thus lacking the vision of IoThNet, e.g. ignoring environmental data.

The BAN works in conjunction with the Personal Area Network (PAN), which is responsible to connect all devices and sensors that reside in the personal area, but are not part of the Body Area (which mostly means they are not wearable smart objects). This subsystem is critical for obtaining all the contextual data that may not originate by the user, yet they may affect him on a very direct way. Objects like temperature, pressure or luminosity sensors, cameras and GPS are among the more common elements of PAN [9].

Zhu et al. [12] propose a scheme for a sensing platform for e-Health. It is part of the SPHERE umbrella project, providing a system scenario on Ambient Assisted Living (AAL). Also, Islam et al. [6] present various schemes for the IoThNet topology, adding the IoT connectivity to BANs, for remote monitoring in wearables and personalized healthcare. Lu and Fu [13] introduce the notion of Ambient Intelligent Compliant Objects (AICOs) as the building blocks of the Smart Health infrastructure. AICOs can capture the context and reliably transmit it to the higher layer, creating ambient intelligence.

## 3 Proposed Architecture

Blending the ideas and notions of the previously mentioned efforts, we propose the architecture scheme depicted in Fig. 1. Context Awareness plays a critical role in the proposed scheme, tagging the sensed medical data with added value. The core of the Wireless Sensory Network consists of the BAN and the PAN.

- BAN: It consists of all the wearable sensors of the person, such as: cardiograph, glucose meters, pulse oximeter, skin electrodes, accelerometer, temperature probe etc. [14]. Communication inside the BAN is wireless, with low power sensors sending their low volume data to the Mobile Base Unit (MBU), which often will be either a smart phone, or a smart watch.

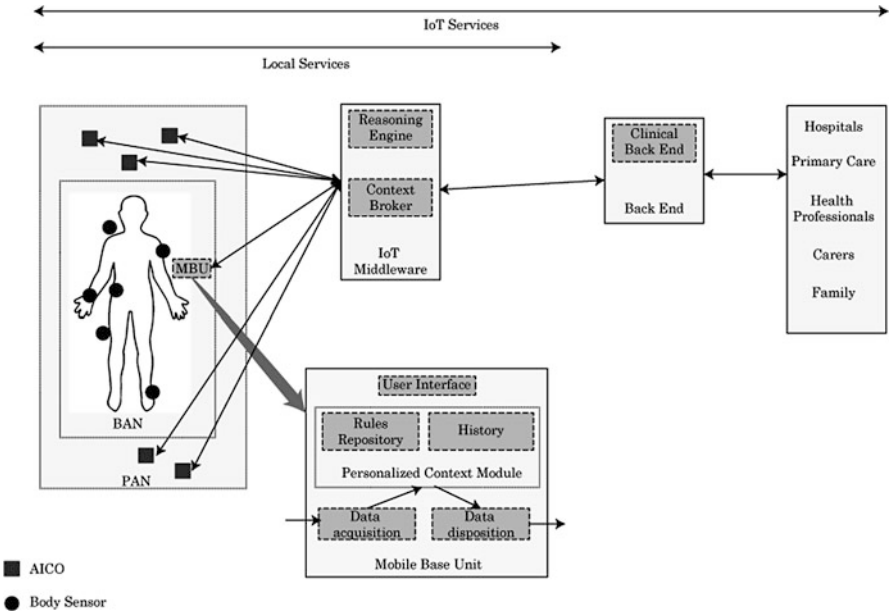


**Fig. 1** Proposed architecture of IoThNet

- MBU: This unit is responsible for the communication inside the BAN, but also for extraBAN connectivity [10]. Its functionality is a three step procedure:

1. Data acquisition from BAN sensors
2. Preprocessing of data on the Personalized Context Module. Taking into consideration the history of the users and the Rules set for specific needs, the sensed data are prefiltered, discarded or tagged with extra context before they are sent to the next layer.
3. Data disposition to the IoT middleware

Apart from this functionality, the MBU features a UI, which can visually inform the user on certain body indications, deviations in measurements, as well as to allow him to adjust the module's processing behavior.

- PAN: The Personal Area Network consists of various AICOs, which are smart objects located around the (temporary) space of the user, such as cameras and microphones, environmental sensors, smart machines etc.
- Lu and Fu [13] have used AICOs to efficiently recognize activities, information with high value when developing an automated healthcare system.
- IoT Middleware: It is part of the IoT backbone. Usually at a fixed location, this module is responsible to apply appropriate algorithms on the acquired data from the AICOs and the MBUs of its area of interest and make the correct decisions. It consists of two basic components: the Reasoning Machine that runs the algorithms and the Context Broker that fetches the appropriate contextual data

for every scenario [15]. Having the whole picture in hand, the IoT middleware can reach to more accurate conclusions than the MBU and it lies at the end of the Local Services area. Beyond that, the Middleware communicates through the IoT infrastructure with the outer world, getting automated or manual feedback and adjusting the required actions accordingly.

- Back End: This in general describes all the IoT modules that reside on the backbone and are responsible for wider range calculations. The Clinical Back End is not the only one, but it is the one responsible for Healthcare issues. Modules of the Clinical back end may be found at hospitals and other medical institutions and have the ability to contact health professionals, carers or the family of the person of interest. This is the last automated step, providing all the necessary data to qualified attenders so that they can take the correct actions based on the crisis information acquired through the whole procedure.

The proposed architecture combines both Local Services and IoT services, (i.e. automated health profile retrieval, automated calls for medical emergencies) providing inoperability and varied levels of accuracy and speed in action taking. The context is gradually built from the low level data from sensors of the Body to the medium level sensors of the Personal Area and the high level contextual data found in Medical Libraries, Databases and other sources. The final product of Context Aware Computing is information stripped of all unnecessary data, tagged with derived and contextual data and ready to be processed by the specialized staff (manually or automatically).

## 4 Context-Awareness in Healthcare

Context awareness (CA) in Healthcare refers to the ability of the system to be aware of the various parameters of the environment into which a patient resides, including the patient and intelligently react upon this awareness [16]. Context in healthcare is not different compared to other fields. Many sensor data can be used both in medical treatment cases and in general smart home applications.

There are many categorization schemes of context in the literature. Abowd and Mynatt [17] use a conceptual approach presenting the five Ws as the minimum information needed to understand context. We will view this categorization under the healthcare perspective.

- "Who" is answered not only with the identity of the user but also those around him/her. The surrounding people can be classified depending on the relevancy to the user's healthcare: medical staff, personal curator, doctor, relative, acquaintance or irrelevant. Anonymization and privacy should be handled delicately.
- "Where" is interested in the location of the user, especially related to medical centers. Possible classifications could be: inside hospital/medical center, home, close to medical facilities, remote.

- "When" deals with temporal connections especially relevant to healthcare events. Recently after an accident, around time for the medicine treatment, during extreme weather conditions are some probable tags of the timestamp.
- "What" is interested in the objects of interest of the user. The object is a general term describing any activity performed, any physical object used, any biometric value measured. It provides the inanimate things surrounding the users that affect their condition.
- "Why" is the hardest question to be answered, requiring the fusion of all the previous Ws. Usually, the answer to "Why" is the end product of the CA computing, which determines the system's next actions. Detecting a fall, the system tries to reason why the user fell and accordingly it can decide if there is need for immediate action or the fall was a normal part of an activity.

Those five questions combined together can give a satisfactory description of a person's medical state. The Context, as described in the five Ws, is generated through a procedure called Context Life Cycle. In general the Context Life Cycle consists of four steps: Acquisition, Modeling, Reasoning and Dissemination [8]. This life cycle can be applied to every field, including the Medical and Healthcare.

a) *Context Acquisition*. The main input of context is through sensors located at the BAN or PAN of a person. Sensors measuring temperature, glucose, pulse, acceleration etc. on wearable devices, but also cameras and smart objects located at the area provide contextual data to the CA agent. Context is not only sensed through sensors [18]. A patient's health record, the past activities and temporal and spatial preferences may also provide useful data. Thus, context can be categorized into *sensed* (which can be measured directly by sensors), *profiled* (which can be retrieved, usually by medical databases) and *derived* (complex context computed by primary contextual sources i.e. a person's activity).
b) *Context Modeling/Reasoning*. After the context acquisition, a CA agent is responsible to model and reason on it. Many techniques exist for both steps, with the rules and ontology being the most prominent in literature. Paganelli and Giuli [19] propose an ontology based context model for monitoring on chronic patients.
c) *Context Dissemination*. The process ends with the dissemination of the derived contextual information towards the appropriate channels of interest. This step depends on the alert level caused by the deductions of the CA computing procedure. Typically the dissemination targets include both the medical staff appropriate to take action in emergencies and the registered relatives of the patient.

Our proposed architecture of Fig. 1 includes the previously mentioned steps of CA computing. Due to the nature of Healthcare, this context life cycle is repeated twice: at the Mobile Base Unit and at the IoT Middleware. Their difference lies only in scope. Since the MBU is located on the person's body, it is limited only to those sensors that are directly related to that person. On the other hand, the IoT

Middleware, having at its disposal other sensors of the area, as well as medical databases and other external data, can execute more complex deductions of the person's medical state. What the first level lacks in scope though, it gains in frequency of updates and speed of reaction.

### *4.1 Use Case*

We will demonstrate the flow of context in our architecture through a scenario:

Lucian is middle-aged suffering from kinetic problems caused by a recent accident. He is recovering at home, using some wearables to track his health state, organized by an application on his smart phone. Lately he started trying to walk again slowly around the house.

At some point, Lucian's pulse sensor is indicating abnormal measures that flow into the MBU module, initiating a CA computing process. The MBU, responsible for the low level procedure, pulls measures from the other sensors of the BAN, which show normality. Furthermore, retrieving Lucian's history that shows increased stress for that specific period of the day, the Reasoning Engine of the MBU reasons that the emergency does not demand any action and closes the process by storing the event to the database.

At another point, more than one BAN sensors indicate abnormality (increased pulse rate, fluctuations from the accelerometer etc.). Immediately, the MBU pings the other sensors, some of which also respond with alarming measurements. The UI of the MBU alerts Lucian with a sound initiating an emergency situation, which he may accept or decline. In case of a time over or a positive user input, the acquired contextual data is sent to the IoT middleware, which will conduct the second level of CA computing. Retrieving data from AICOs around the area, the IoT middleware can deduce that Lucian is in fact motionless and soundless, which indicates a possible fall and faint. This logical deduction of the acquired context is disseminated through the IoT infrastructure to all interested part i.e. closest hospital, relatives and personal curator, thus concluding the CA computing process.

Various components and systems have been proposed in the literature that could fit into our proposed architecture. Islam et al. [6] stress the need for an embedded context prediction (ECP) service applied over the IoThNet. Since most context reasoning techniques work with probabilities, a CA computing procedure always tries to predict the outcome of the acquired context, e.g. abnormal health indicators at pulse and accelerometer may predict a fall for the supervised person.

Activity Recognition is another important feature of CA computing since it helps determine the physiological state of a person. Correlating it with vital signs, a more concrete understanding of the person's current context is possible [20]. This process can be executed only at the IoT Middleware of our proposed architecture, since

only this module is linked with the AICOs located at the Personal Area, which help determine the activity performed. Lu and Fu [13] use AICOs to build a robust activity recognition component in Attentive Homes.

Prioritization and reliability are two crucial characteristics of a well performing CA system. Although in many case scenarios, sensors respond with accuracy and submission, this is not always the case. Incorrect measurements are probable because of the low cost requirement of the billions of sensors applied through the IoT in its full realization [7]. Also in case of high stress situations, multiple data flows may cause loss of important information, so some kind of prioritization is required. Viswanathan et al. [20] propose a novel QoS-aware wireless communication solution that deals with those issues, mainly through multihop routing via neighboring BANs.

Finally, the ERMHAN project provides a system with components that incorporate various notions like the variable alarm levels and a context broker that notifies the interested parts when some context has changed. Also it implements an ontology and rule based reasoning machine that can work for home based medical care and assistance [21].

## 5 Applications in Healthcare

The IoT is anticipated to give access to a variety of healthcare services for a wide range of the population, providing automated medical treatment and efficient reaction in emergencies [22]. Islam et al. [6] provide an extended list of such services and applications. We will review some of them under the Context-Awareness perspective of our proposed architecture.

- *Ambient Assisted Living* (AAL) is a healthcare variant of the Smart Home. The main purpose is to provide an independent way of living for the elderly and other people, ensuring greater autonomy and supervision to detect any problem. Since AAL is mostly restricted to a certain living space, our architecture works efficiently, providing local services based quickly and efficiently. The context is available on spot, by the sensors deployed on the BAN and PAN of the person in interest. It could be argued that the architecture was especially designed to face the challenges set by AAL.
- *Medical Status monitoring*. Similar to AAL, it limits its range of responsibilities to the constant monitoring of medical status. Among the most usual measurements are: Glucose Sensing, Electrocardiogram, Blood pressure, Body Temperature and Oxygen Saturation. The Context life cycle is similar to that of AAL. Sensors on the body indicate abnormalities that need to be investigated by acquiring richer contextual data from surrounding sensors.
- *Fall detection*. Being among the leading causes of death over 65, accidental falls have received enough attention by IoT researchers. Accelerometers and

gyroscopes are the most common sensors used but some studies propose unobtrusive use of ambient video surveillance [23].

- *Activities of daily living*. Related to fall detection, recognizing the activity is contextual information of high value in all healthcare applications. Although not itself an application, this functionality can be viewed as an autonomous procedure which can cooperate with healthcare (and other) applications. In our proposed architecture, it is executed by the IoT Middleware, which then disseminates the type of recognized activity to all interested modules (among which is the healthcare module).
- *Medication management*. Noncompliance and neglect of medication intake are common especially when cognitive disabilities are present. The IoT infrastructure can provide services against this, by adding appropriate sensors on medicine packaging. The context is rather simple in this application. The patient has either taken his medication or not at the intended time, information that can be transmitted to designated curators.
- There are many other applications like the *Wheelchair Management*, *Rehabilitation System, mobile-Healthcare solutions, Community Health* and *Children Health Information* that can be positively affected by IoThNet functionality. In each case, the context can be acquired, reasoned and disseminated using some of the components of the proposed architecture, which works independently of the service in use.

## 6 Challenges

The concept of utilizing the IoT infrastructure for automated healthcare sets many challenges that need to be addressed, on various independent research areas. Solanas et al. [3] address the challenges that their coined s-health needs to overcome. Similarly, context aware computing as a functionality that acts complementarily faces its own challenges.

- *Standardization and sensor integration*—Due to the wide range of the IoT applications, various stakeholders, institutions and leading companies have already developed different non-compatible protocols and standards. Although compatibility solutions may be possible for larger objects, the low complexity of sensors requires some standardization. RFID and 6LoWPAN seem the most probable candidates as the protocols for the Wireless Sensor Network, but appropriate standard should be set upon other procedures as well [24].
- *Multidisciplinary research*—Since many of the IoT related technological challenges posed on the field of healthcare exist on other fields as well, it is crucial that those multidisciplinary research groups that address those issues interact and collaborate. Similarly, research on context awareness, can benefit from cooperation of varied groups that work on context acquisition or reasoning techniques, whether they are applied to healthcare services or not.

- *Security and privacy*—People show a greater sensitivity when sharing their personal health data. It follows that privacy and security are of higher importance for such services of the IoT compared to others. They both must be ensured throughout the healthcare application scenario. Several proposals have been provided for encryption and security policies [25], while privacy issues have been addressed by non-obtrusive camera use, but still there is enough protest against collecting private data despite the assurances given.
- *Cloud computing*—The creation of smart environments for automated medical care will require the collection and analysis of huge numbers of data relevant in the context of smart health. Cloud computing can provide the backbone for intense computing procedures. CA agents and other IoT middleware could use Cloud resources to perform computations of less emergent scenarios, so that they can be available for more urgent situations. Yet, it is not straightforward to implement Cloud computing on IoT services if security, privacy and accessibility issues aren't solved first [26].

## 7 Conclusions

The emergence of IoT with its wide scope has enabled a range of services among which one of the most prominent is the automated medical treatment and healthcare, called smart health. This paper proposes a framework for the development of IoThNet, the IoT variable for healthcare, which combines the BAN and PAN areas of the user with the existing IoT infrastructure to provide a seamless functionality.

At the core of this framework lies the Context Aware Computing, which plays a critical role at implementing efficiently many of the applications and services required smart health, as it provides rich contextual information from various sensors and data sources. The Context Life Cycle of acquiring, modeling, reasoning and disseminating the context is tackled by the framework and the interconnections between the various smart objects are established.

In our vision of the IoT, the Mobile Base Units of the users and all the IoT Middleware will have a context aware module that can perform the necessary CA functions for gathering and reasoning on context data. Such modules will have GUIs to allow the users to interact with the system, provide new rules and customize its functionality, in order to provide a more complete Human Computer Interaction.

Our future plans are to develop and validate a prototype that will deliver the promised functionality. Our focus will be on the contextual factors that affect the functionality of smart health, while providing a robust system that can be connected with existing IoT middleware and other infrastructure. Although the road is still long ahead of us, the IoT is emerging as a life-changer, especially in the field of healthcare. It is thus of great importance to improve and establish critical technologies like Context Aware Computing.

## References


1. Catarinucci, L., D. De Donno, L. Mainetti, L. Palano, L. Patrono, M.L. Stefanizzi, and L. Tarricone. 2015. An IoT-Aware Architecture for Smart Healthcare Systems. *IEEE Internet of Things Journal* 2 (6): 515–526.
2. Redondi, A., M. Chirico, L. Borsani, M. Cesana, and M. Tagliasacchi. 2013. An Integrated System Based on Wireless Sensor Networks for Patient Monitoring, Localization and Tracking. *Ad Hoc Networks* 11 (1): 39–53.
3. Solanas, A., C. Patsakis, M. Conti, I.S. Vlachos, V. Ramos, F. Falcone, O. Postolache, P.A. Perez-Martinez, R. Di Pietro, D.N. Perrea, and A. Martínez-Ballesté. 2014. Smart Health: A Context-Aware Health Paradigm Within Smart Cities. *IEEE Communications Magazine* 52 (8): 74–81.
4. Doukas, C., and I. Maglogiannis. 2012, July. Bringing IoT and Cloud Computing Towards Pervasive Healthcare. 2012 Sixth International Conference on Innovative Mobile and Internet Services in Ubiquitous Computing (IMIS), 922–926. IEEE.
5. Atzori, L., A. Iera, and G. Morabito. 2010. The Internet of Things: A Survey. *Computer Networks* 54 (15): 2787–2805.
6. Islam, S.R., D. Kwak, M.H. Kabir, M. Hossain, and K.S. Kwak. 2015. The Internet of Things for Healthcare: A Comprehensive Survey. *IEEE Access* 3: 678–708.
7. Miorandi, D., S. Sicari, F. De Pellegrini, and I. Chlamtac. 2012. Internet of Things: Vision, Applications and Research Challenges. *Ad Hoc Networks* 10 (7): 1497–1516.
8. Perera, C., A. Zaslavsky, P. Christen, and D. Georgakopoulos. 2014. Context Aware Computing for the Internet of Things: A Survey. *IEEE Communications Surveys & Tutorials* 16 (1): 414–454.
9. Alemdar, H., and C. Ersoy. 2010. Wireless Sensor Networks for Healthcare: A Survey. *Computer Networks* 54 (15): 2688–2710.
10. Jones, V., V. Gay, and P. Leijdekkers. 2010, February. Body Sensor Networks for Mobile Health Monitoring: Experience in Europe and Australia. Fourth International Conference on Digital Society, 2010. ICDS'10, 204–209. IEEE.
11. Schmidt, R., T. Norgall, J. Mörsdorf, J. Bernhard, and T. von der Grün. 2002. Body Area Network BAN—A Key Infrastructure Element for Patient-Centered Medical Applications. *Biomedizinische Technik/Biomedical Engineering* 47 (s1a): 365–368.
12. Zhu, N., T. Diethe, M. Camplani, L. Tao, A. Burrows, N. Twomey, D. Kaleshi, M. Mirmehdi, P. Flach, and I. Craddock. 2015. Bridging e-Health and the Internet of Things: The SPHERE Project. *IEEE Intelligent Systems* 30 (4): 39–46.
13. Lu, C.H., and L.C. Fu. 2009. Robust Location-Aware Activity Recognition Using Wireless Sensor Network in an Attentive Home. *IEEE Transactions on Automation Science and Engineering* 6 (4): 598–609.
14. Pantelopoulos, A., and N.G. Bourbakis. 2010. A Survey on Wearable Sensor-Based Systems for Health Monitoring and Prognosis. *IEEE Transactions on Systems, Man, and Cybernetics, Part C (Applications and Reviews)* 40 (1): 1–12.
15. Guan, D., W. Yuan, S. Lee, and Y.-K. Lee. 2007. Context Selection and Reasoning in Ubiquitous Computing. In *2007 International Conference on Intelligent Pervasive Computing (IPC)*, October 2007, 184–187 [Online]. doi:10.1109/IPC.2007.102.
16. Bricon-Souf, N., and C.R. Newman. 2007. Context Awareness in Healthcare: A Review. *International Journal of Medical Informatics* 76 (1): 2–12.
17. Abowd, G.D., and E.D. Mynatt. 2000. Charting Past, Present, and Future Research in Ubiquitous Computing. *ACM Transactions on Computer-Human Interaction (TOCHI)* 7 (1): 29–58.
18. K. Henricksen. 2003. *A Framework for Context-Aware Pervasive Computing Applications*. Computer Science, School of Information Technology and Electrical Engineering, The University of Queensland, September 2003. http://henricksen.id.au/publications/phd-thesis.pdf. Accessed 12 July 2016.

19. Paganelli, F., and D. Giuli. 2007, May. An Ontology-Based Context Model for Home Health Monitoring and Alerting in Chronic Patient Care Networks. AINA Workshops (2), 838–845.
20. Viswanathan, H., B. Chen, and D. Pompili. 2012. Research Challenges in Computation, Communication, and Context Awareness for Ubiquitous Healthcare. *IEEE Communications Magazine* 50 (5): 92–99.
21. Paganelli, F., E. Spinicci, and D. Giuli. 2008. ERMHAN: A Context-Aware Service Platform to Support Continuous Care Networks for Home-Based Assistance. *International Journal of Telemedicine and Applications* 2008: 4.
22. Bui, N., and M. Zorzi. 2011, October. Healthcare Applications: A Solution Based on the Internet of Things. Proceedings of the 4th International Symposium on Applied Sciences in Biomedical and Communication Technologies, 131. ACM.
23. Hansen, T.R., J.M. Eklund, J. Sprinkle, R. Bajcsy, and S. Sastry. 2005, November. Using Smart Sensors and a Camera Phone to Detect and Verify the Fall of Elderly Persons. European Medicine, Biology and Engineering Conference, vol. 20, no. 25, 2486.
24. Imadali, S., A. Karanasiou, A. Petrescu, I. Sifniadis, V. Vèque, and P. Angelidis. 2012, October. eHealth Service Support in IPv6 Vehicular Networks. 2012 IEEE 8th International Conference on Wireless and Mobile Computing, Networking and Communications (WiMob), 579–585. IEEE.
25. Garcia-Morchon, O., T. Falck, T. Heer, and K. Wehrle. 2009, July. Security for Pervasive Medical Sensor Networks. 6th Annual International Mobile and Ubiquitous Systems: Networking & Services, MobiQuitous, 2009. MobiQuitous' 09, 1–10. IEEE.
26. Soldatos, J., N. Kefalakis, M. Hauswirth, M. Serrano, J.P. Calbimonte, M. Riahi, K. Aberer, P.P. Jayaraman, A. Zaslavsky, I.P. Žarko, and L. Skorin-Kapov. 2015. Openiot: Open Source Internet-of-Things in the Cloud. In *Interoperability and Open-Source Solutions for the Internet of Things*, 13–25. Springer International Publishing.

# Methods and Patterns for User-Friendly Quantum Programming

**Alexandros Singh, Konstantinos Giannakis, Kalliopi Kastampolidou, and Christos Papalitsas**

**Abstract** The power and efficiency of particular quantum algorithms over classical ones has been proved. The rise of quantum computing and algorithms has highlighted the need for appropriate programming means and tools. Here, we present a brief overview of some techniques and a proposed methodology in writing quantum programs and designing languages. Our approach offers "user-friendly" features to ease the development of such programs. We also give indicative snippets in an untyped fragment of the Qumin language, describing well-known quantum algorithms.

**Keywords** Quantum programming • Quantum programming language • Functional programming • Qumin

## 1 Introduction

With Moore's law reaching an apparent plateau, attention to unconventional computing paradigms is ever increasing. Quantum computation, that is, computing based on quantum mechanical principles, is among the most sought-after of these. While quantum computing is still in relative infancy, quantum algorithms show very promising results. For example Grover's algorithm, which can be used as a database search algorithm, offers a quadratic speed-up over its classical counterparts, outpacing any classical algorithm [1].

Grover's algorithm can also be used to brute force a symmetric cryptographic key with orders of magnitude more efficiency than any other classical algorithm. Another popular quantum algorithm is Shor's algorithm which can factor any integer $N$ in polynomial time and could make many modern cryptographic systems (such as RSA) obsolete [2].

The above observations have attracted the attention, not only of academia, but also of the industry and various funding sources. The pursuit of novel and efficient

A. Singh (✉) • K. Giannakis • K. Kastampolidou • C. Papalitsas
Department of Informatics, Ionian University, Corfu, Greece
e-mail: p13sing@ionio.gr; kgiann@ionio.gr; p12kast@ionio.gr



P. Vlamos (eds.), *GeNeDis 2016*, Advances in Experimental Medicine and Biology 989, DOI 10.1007/978-3-319-57348-9_17

computing technologies has already led to the raise of investments and funding schemes that aim to profit from proposed current and future quantum computing systems, with D-Wave System being a notable example [3].

Quantum programming has experienced a surge of interest, with many theoretical models being proposed from quantum circuits to lambda calculi/type systems [4–8], quantum logics, and quantum assembly languages [9–11]. Quantum Programming Languages (QPL) allow us to argue about quantum algorithms beyond the hardware-like level of quantum circuits which they are frequently described in. Such a higher level description of quantum algorithms would include features such as data structures, procedures, and syntactic constructions such as control flow statements: recursion, loops, conditionals, etc.

Works like [12] have tried to formulate some basic requirements one would expect a QPL to fulfil. These vary accordingly to the underlying paradigm, with frequent requirements amongst others being: completeness, extensibility, abstracting away and being independent from the underlying machinery, and being expressive enough to allow one to define quantum data structures, oracles etc., handling of measurement, handling of quantum memory/registers. A QPL that fulfils the aforementioned requirements would open the road for the application of quantum computing in various areas such as networks, databases, cryptography and telecommunications, leading to revolutionary innovations in many fields crucial to our modern computing-intensive world.

In this work we present a brief overview of some techniques, algorithms and patterns we consider helpful in writing quantum programs and designing languages that offer "user-friendly" features to ease the development of such programs. We also give indicative code snippets in a fragment of the Qumin language.

Qumin has an experimental implementation in a Python programming language environment [13], using the libraries `numpy` for matrix/vector calculations and `parsimonious` for parsing. The implementation consists of the interpreter for the language, tools for parsing and typechecking and auxiliary tools for parsing type signatures and automatically generating various types.

This paper is organized as follows: Sect. 2 includes the related work. In Sect. 3 we describe an extension of the untyped lambda calculus, whereas Sect. 4 is our main contribution. Specifically, we discuss and illustrate by examples, the proposed techniques for programming in a quantum framework. Finally, a discussion of our results and plans for future work is included in Sect. 5.

## 2 Related Works

For a comprehensive introduction to quantum computing we refer the reader to the work of Nielsen and Chuang in [14]. Various models and paradigms have been defined for quantum programming and a handful of fully-fledged quantum programming languages have already been implemented, as we discuss below.

The field of quantum algorithms has produced a number of very interesting works. Among them, Shor's [2] and Grover's algorithms [1] are some of the better known ones. Quantum programming has experienced a surge of interest, with many theoretical models being proposed from the well-established quantum circuits to experimental (typed and untyped) lambda calculi, type systems [4, 6–8], and quantum assembly languages [9–11].

Such models include the popular QRAM model: a register machine capable of performing quantum operations (such as preparing a quantum state, unitary transformations and measurement of quantum registers), which is controlled by a classical computer. Some descriptions and/or implementations of QPLs include the functional languages Quipper [6], QML [4], QPL [11], QLISP [10], and the imperative languages QCL [12, 15] and LanQ [16].

In [17] the authors Sanders and Zuliani also present a quantum programming language, the qGCL based on the Guarded Command Language, along with its formal semantics. Additionally, the above work includes some examples of actual quantum algorithms expressed in the aforementioned language.

## 3 A Naive Extension of the Untyped Lambda Calculus

To prepare the ground for our upcoming discussion of algorithms and patterns, it would be beneficial to first discuss the theory of untyped lambda calculus, extended with some primitive operations and constants, in order to facilitate operations in Hilbert spaces $H$, which we will refer to as $\lambda_H$.

| | |
|---|---|
| t := | (term) |
| $x$ | (variable) |
| $v$ | (vector) |
| $U$ | (operator) |
| $(U \cdot v)$ | (operator application) |
| $(v \otimes v)$ | (tensor product) |
| $measure(v)$ | (measurement) |
| $\lambda x.t$ | (abstraction) |
| $t\ t$ | (application) |

Where, for a given Hilbert space $H$,

- $v$ belongs to the set of normalized vectors of $H$.
- $U$ belongs to the set of matrix representations of unitary operators of $H$.
- $U \cdot v$ is operator application, by way of matrix multiplication: Uv.
- $v \otimes v$ is the tensor/Kronecker product of two vectors/matrices.
- $measure(v)$ is measurement of state $v$ in the computational basis. (returns state after collapse)

In practice, the parentheses and the multiplication dot can be omitted when the meaning is clear. For example, Deutsch's algorithm is expressed in $\lambda_H$ as such:

$$\lambda U_f.measure((H \otimes I)U_f(H \otimes H)(|0\rangle \otimes |1\rangle))$$

Where $U_f$ is the matrix that corresponds to the oracle of a binary function:

$$f : \{0, 1\} \to \{0, 1\}$$
$$U_f(|x, y\rangle) = |x, y \oplus f(x)\rangle$$

## 4 Programming in Qumin

We will focus on the dynamically typed fragment of the language Qumin. The central construct we are interested in is that of an function as captured by the lambda abstraction. For example $\lambda x.x + 5$ is written in Qumin as such:

$$\texttt{lambda(x)\{(x + 5)\}}$$

Lambda abstractions can be invoked in-line by including arguments in a parenthesis as such:

$$\texttt{lambda(x, y)\{(x + 5)\}(3, 5)}$$

Which would evaluate to `8`.

Qumin, being a functional programming language, places great significance in the notion of functions. Functions are first-class citizens, in that they can be passed around and returned as any other primitive, like lists or numbers, and can be bound to identifiers. The returned value of a function is the last evaluated expression in its body. For example, a function that takes another function and applies it to an argument:

$$\texttt{lambda(f, x)\{f(x)\}(lambda(x)\{(x + x)\}, 5)}$$

Which evaluates to `10`.

To define a named function, we attach a lambda abstraction to an identifier. For example $f(x) = x + 5$ is written in Qumin as such:

```
let f = lambda(x){
        (x + 5)
}
```

And can be invoked as such:

$$\texttt{f(5)}$$

Which of course evaluates to 10.

Qumin also supports implicit partial application:

```
let f(x,y){
    (x + y)
}
let partiallyApplied = f(10)
partiallyApplied(30) => 40
```

Finally, specifically in the case of binary functions, we can also call them in infix notation: `(argument1 function argument2)`. For example:

```
let myOp = lambda(x,y){
    parindent (x + (3 * y))
}
(5 myOp 10) => 35
```

Arithmetic operators `(+,-,*/)` in Qumin are defined as any other function would be, we just call them infix for clarity.

## *4.1 Quantum Programming in Qumin*

### 4.1.1 Vectors and Matrices

Vectors and matrices are of central importance in quantum computing, where they represent the state/qubits of a system and unitary operators/gates respectively. In Qumin vectors and matrices are implemented using lists and lists of lists. For example a state $|\psi\rangle = a|0\rangle + b|1\rangle$ in the two-dimensional space $H$, is written in Qumin as such:

```
let psi = [ab]
```

While, for example, the identity matrix that corresponds to the identity operator in $H$ would be written as:

```
let identity = [[1 0]
                [0 1]]
```

Naturally, as the dimension of $H$ increases, the process of writing matrices by hand quickly gets unwieldy. For example, for 4 qubits one would be expected to write a 16x16 (256 values) matrix by hand. To tackle this problem, we can eschew the use of matrix representations and work with linear operators as functions. This alleviates the aforementioned problem of having to manually define multi-dimensional matrices by hand. E.g. the identity operator is always $f(x) = x$, regardless of the space's dimension. Unfortunately this has the side-effect of making things like finding eigenvalues/eigenvectors much more difficult, while also introducing a severe slowdown in computations.

### 4.1.2 Matrix Generators

The solution to the aforementioned dilemma is given by a group of functions called (matrix) generators. Generators allow us to make use of a linear operator in its function form where convenient, and in its matrix form otherwise. A generator is a function that when given an linear operator $f : H \to H$ and a basis $\{v_i\}$ of H, generates $f$'s matrix representation on $H$ with respect to the basis. This allows us to write linear operators as functions, composing them and manipulating them as one would expect to manipulate a mathematical operator, and when we want to make use of its matrix representation, all we have to do is invoke the generator on it.

---

**Matrix Generator Algorithm.**
**Inputs:** $f : H \to H, \{v_i\}$
**Outputs:** $M_{dim(H)\times dim(H)}$
**0:** M ← [ ]
**1:** For $v$ in $\{v_i\}$:
**2:** append $f(v)$ to M
**3:** transpose M

---

For example, the identity operator is defined as such:

```
let identity = lambda(vec){
        vec
}
```

Then generating, for example, the identity matrix on a 16-dimensional (4-qubit) Hilbert space, amounts to running:

```
generateMatrix(identity,16)
```

Apart from allowing us to avoid writing big matrices by hand, generators allow us to define operators in a mathematical, easily-understood, and general with respect to dimension, way. For example the Quantum Fourier Transform is written in Qumin as such:

```
--load generator

let omega = lambda(jj,k,N){
        exp((fold(*, [2 pi 0+1i jj k]) / N))
}

let qfSum = lambda(limit,vec,index,N){
        if ((limit = 0)){
                0
        }
        else {
                ((omega(index,limit,N) * car(vec)) +
```

```
                qfSum((limit - 1), cdr(vec), index, N))
        }
}

let outer = lambda(vec,index,N){
        if((N = index)){
                []
        }
        else{
          append(((1 / sqrt(N)) * qfSum(N,vec,index,N)),
                              outer(vec,(index + 1),N))
        }

}

let qft = lambda(vec){
        let N = len(vec)
        outer(vec,0,N)
}
```

As we can see, the Qumin implementation closely follows the mathematical expression of QFT:

$$y_k = \frac{1}{\sqrt{N}} \sum_{j=0}^{N-1} x_j \omega^{jk}$$

Where:

$$\omega^{jk} = e^{2\pi i \frac{jk}{N}}$$

The function `omega` implements $\omega^{jk}$ (ie the $N^{th}$ root of unity), `qfSum` implements the sum $\sum_{j=0}^{N-1} x_j \omega^{jk}$, and `outer` builds the transformed vector $(y_k)$ by multiplying each result of `qfSum` by $\frac{1}{\sqrt{N}}$.

### 4.1.3 Deutsch's Algorithm

We will now proceed to show an implementation of Deutsch's algorithm. Once again, we look back to $\lambda_H$. Quantum computation in $\lambda_H$ is based on three primitive operations: $\cdot$, $\otimes$ and *measure*, which in Qumin are defined as functions named $\cdot$, $\otimes$ and `measure` respectively. If one wishes to avoid using unicode, he can use

the aliases `apply` for $\cdot$ and `tensor` for $\otimes$ instead. For example, we already have presented Deutsch's algorithm in $\lambda_H$ so let us present the Qumin version:

```
--load generator
--load operators

let fConstant = lambda(x){
        [1 0]
}

let fBalanced = lambda(x){
        x
}

let deutsch = lambda(f){
        let H = generateMatrix(hadamard,2)
        let I = generateMatrix(identity,2)
        let Uf = oracle(generateMatrix(f,2))
        let state = ([1 0]  ⊗ [0 1])
        measure(((H ⊗ I) · (Uf · ((H ⊗ H) · state))))
}
```

As we can see, the body of `deutsch` closely resembles the corresponding lambda version: $\lambda U_f.measure((H \otimes I)U_f(H \otimes H)(|0\rangle \otimes |1\rangle))$

Running Deutsch's algorithm on the first example function, $f(x) = 0$ gives us:

```
deutsch(fConstant)

=> Probability of state 0 is 0.5
Probability of state 1 is 0.5
Probability of state 2 is 0.0
Probability of state 3 is 0.0
System collapsed to state: 0
```

While it on the second example function, $f(x) = x$ gives us:

```
deutsch(fBalanced)

=> Probability of state 0 is 0.0
Probability of state 1 is 0.0
Probability of state 2 is 0.5
Probability of state 3 is 0.5
System collapsed to state: 3
```

As expected.

One may notice that in the implementation of Deutsch's algorithm we made use of a function called `oracle`. The `oracle` function converts classical operators to unitary ones, allowing us to use them in our quantum computations. To do this,

`oracle` expects as input a binary function $f$ and creates a new operator $U$ that operates on a composite space, the tensor product of the domain of f as a qudit and an additional helper qudit. That is, for $f(x)$, `oracle` creates $U(x, y)$ defined as such: $U(x, y) = (x, y \otimes f(x))$.

## 5 Conclusion and Future Work

Notable works on quantum aspects of computing, like the well-known quantum algorithms of Shor and Deutsch have shown some prosperous signs. There is a need for deep understanding and examination of the computation processes that could be implemented. Works like this contribute in the field of quantum programming. Overall, since Quantum Computing is a quite new scientific field, the theoretical foundation of technologies and methodologies regarding this branch is still under research. Aiming to this direction, our work proposed a specific methodology to program and express quantum algorithms and computation processes.

As for future work, it would be of interest to use the language as a tool to study the computational aspects of quantum computation, such as using it to simulate variants of quantum automata that have interesting and useful properties, such as measure-once automata [18] and periodic quantum automata [19]. Apart from that, further implementations of quantum algorithms would also be of interest, serving to expose potential new features that are crucial to their implementation. Finally, the language could be used as an educational tool for familiarization with notions related to quantum computation and quantum algorithms.

## References

1. Grover, L.K. 1997. Quantum mechanics helps in searching for a needle in a haystack. *Physical Review Letters* 79(2):325.
2. Shor, P.W. 1994. Algorithms for quantum computation: discrete logarithms and factoring. In *Proceedings of the 35th Annual Symposium on Foundations of Computer Science, 1994*, 124–134. Los Alamitos: IEEE.
3. D-Wave Systems, S. 2016. D-wave 2x. http://www.dwavesys.com/. [D-Wave 2X]
4. Altenkirch, T., and J. Grattage. 2005. A functional quantum programming language. In Logic in Computer Science, 2005. LICS 2005. Proceedings. 20th Annual IEEE Symposium on, 2005, 249–258. Chicago, IL, USA: IEEE.
5. Altenkirch, T., J. Grattage, J.K. Vizzotto, and A. Sabry. 2007. An algebra of pure quantum programming. *Electronic Notes in Theoretical Computer Science* 170:23–47.
6. Green, A.S., P.L. Lumsdaine, N.J. Ross, P. Selinger, and B. Valiron. 2013. Quipper: a scalable quantum programming language. In *ACM SIGPLAN Notices*, vol. 48, 333–342. New York: ACM.
7. Selinger, P., B. Valiron, et al. 2009. Quantum lambda calculus. In *Semantic Techniques in Quantum Computation*, 135–172. Cambridge: Cambridge University Press.
8. Van Tonder, A. 2004. A lambda calculus for quantum computation. *SIAM Journal on Computing* 33(5):1109–1135.

9. Blaha, S. 2002. Quantum computers and quantum computer languages: quantum assembly language and quantum c language. arXiv preprint quant-ph/0201082
10. Desmet, B., E. D'Hondt, P. Costanza, and T. D'Hondt. 2006. Simulation of quantum computations in lisp. In *3rd European Lisp Workshop, Co-Located with ECOOP*.
11. Selinger, P. 2004. Towards a quantum programming language. *Mathematical Structures in Computer Science* 14(04):527–586.
12. Ömer, B. 1998. A procedural formalism for quantum computing. Tech. rep., Department of Theoretical Physics, Technical University of Vienna.
13. QUIT Group, I.U. 2016. Qumin language project. https://github.com/wintershammer/QImp/. [Github repositiory, accessed 6/10/2016].
14. Nielsen, M.A., and I.L. Chuang. 2010. *Quantum Computation and Quantum Information*. Cambridge: Cambridge University Press.
15. Ömer, B. 2005. Classical concepts in quantum programming. *International Journal of Theoretical Physics* 44(7):943–955.
16. Mlnarik, H. 2007. Operational semantics and type soundness of quantum programming language lanQ. arXiv preprint arXiv:0708.0890.
17. Sanders, J.W., and P. Zuliani. 2000. Quantum programming. In *Mathematics of Program Construction*, 80–99. Berlin: Springer.
18. Moore, C., and J.P. Crutchfield. 2000. Quantum automata and quantum grammars. *Theoretical Computer Science* 237(1):275–306.
19. Giannakis, K., C. Papalitsas, and T. Andronikos. 2015. Quantum automata for infinite periodic words. In *6th International Conference on Information, Intelligence, Systems and Applications (IISA), 2015*, 1–6. Piscataway, NJ: IEEE.

# Bullying in Virtual Learning Communities

**Stefanos Nikiforos, Spyros Tzanavaris, and Katia Lida Kermanidis**

**Abstract** Bullying through the internet has been investigated and analyzed mainly in the field of social media. In this paper, it is attempted to analyze bullying in the Virtual Learning Communities using Natural Language Processing (NLP) techniques, mainly in the context of sociocultural learning theories. Therefore four case studies took place. We aim to apply NLP techniques to speech analysis on communication data of online communities. Emphasis is given on qualitative data, taking into account the subjectivity of the collaborative activity. Finally, this is the first time such type of analysis is attempted on Greek data.

**Keywords** Bullying • Virtual Learning Communities • Natural Language Processing • Sociocultural Learning Theories

## 1 Introduction

Bullying has become a major problem in recent days concerning different groups of people: educators, parents, government, scientists. The digital form of bullying, cyber bullying, has been widely expanded mainly through the internet. Despite the research results so far, there are a lot of questions to be answered [1, 2]. In this work it is attempted to use NLP techniques for speech analysis within Virtual Learning Communities (VLCs) in order to investigate new aspects of the problem [3–5], mainly in the context of sociocultural learning theories [6–8].

## 2 Related Work

Research in the field of NLP related to cyber bullying has given results so far in locating bullying [9, 10], or harassment episodes [11], or identifying roles of the participants in them [12, 13]. There are also works aiming at the distinction between

S. Nikiforos (✉) • S. Tzanavaris • K.L. Kermanidis
Department of Informatics, Ionian University, Corfu, Greece
e-mail: c13niki@ionio.gr



P. Vlamos (eds.), *GeNeDis 2016*, Advances in Experimental Medicine and Biology 989, DOI 10.1007/978-3-319-57348-9_18

bullying and teasing [13], others attempting to locate language standards or analyze emotions of the participants [14], while others propose live control systems on social networks using virtual agents regulations combined with user evaluation and behavior modification [15].

The major drawback of the existing works is the behavioral treatment type of the issue. This method is surface and gives provisional results, without creating learning (internal process and permanent behavior modification). Moreover, they mainly use quantitative data, disregarding the subjectivity and the need of adaptation of analytical models by language/country [2, 16].

In that context sociocultural learning theories can be a promising framework, since they are taking into account such social aspects [6, 17, 18]. In the hereby study it is attempted a setup of four case studies, where basic principles of sociocultural theories are examined at the level of VLC: teacher's role to behavior modification, ***learning at*** collective level, problem solving activity motivates struggle and, inner speech inside virtual community.

From a psychological point of view, the study of the aspects above consist a critical point to behavior (bullying) motivation [19, 20]. Recognition of motives is a secondary phenomenon arising only at the level of members' personality and continuously being produced during the course of its development. It is possible to explain this underlying motive only objectively, from 'outside'. To recognize the real motives of its activity, the VLC must also proceed along an 'opposite go back way' speech analysis, with the difference, however, that along this way he will be oriented by signals-experiences, emotional 'marks' of living in it [19]. Setting or re-setting ideal motives in a virtual community via inner speech using authentic activities worth a lot for a teacher, since he can helps this way community and its every member.

A lot of methods have being proposed for a collaborative activity into a physical learning community in order to get transformed and existing as a virtual one. Problem-based learning, project based learning, learning by design are some of them. In the present study is used 'Problem Project Based Learning with Formative Interventions in Authentic Activities' model for implement collaborative solving activity in a VLC, where Problem Projects are not restrict designed rather formative intervened [21]. During the collaborative activity, the VLC removes to a new balance point every time a formative intervention happens. This way, the results of the educational research are of more value since they are outcomes under real circumstances—an associated 'creative chaos' [22]—rather than pre-structured and strictly controlled instructional processes.

The above approach can be considered as blended one which combines self-paced learning, synchronous or asynchronous web collaborative learning, and face-to-face classroom learning, enhancing at the same time inner speech development inside VLC.

In the present research is suggested that the socio-cultural framework of the VLCs should be taken into account for analysis of speech and emotions. We propose

speech and artifacts analysis on VLCs aiming to answer the following research questions: *Does cyber bullying exist on VLCs? What is the development of cyber bullying during the transformation process of a community? Which are the motives of the participants in bullying episodes? How can we tackle the problem targeting to the transformation of the motives and the permanent behavior modification?*

In the following section are described the case studies contributed to these questions.

## 3 Case Studies

In order to analyze bullying in the Virtual Learning Communities using Natural Language Processing (NLP) techniques, mainly in the context of sociocultural learning theories, the following setup of four case studies took place.

### *3.1 Case Study 1: Community and Individuals: The Influence of the Community to Behavior Modification*

In this case study (CS) a Virtual Learning Community was created in order to implement an educational cultural project. Participants were mixed: an already existing physical learning community of 21 persons (being partners for over 6 years) and another team of 9 persons that had shown aggressive behavior in the past.

Implementation of the project took place in four main stages: During the first stage, participants communicated in a free style manner chat through wikispaces[1] platform. Second stage started after the formulation of the problem-based project. Participants discussed about the project and made their suggestions. In the third stage, participants began to act for the 'solution' of the problem-based project [23, 24]. In the final stage, participants uploaded and notified the final deliverables/artifacts.

The main target of the discussion and artifact analysis in this VC is to imprint the community incorporation progress.

The dataset of this CS consists of 655 words of chat between the participants.

The main research questions are: *Is the process of joining the community reflected to the speech of the participants? Is the speech of the individual participants influenced by the (inner) speech of the community? Is there any shift in the speech per stage?*

[1] www.wikispaces.com.

### 3.2 Case Study 2: Combining Two Communities: The (Active) Role of the Instructor to Behavior Modification

In CS2 a VC was created in order to implement an educational cultural project. Participants in this VC were mixed: an already existing physical learning community of 21 persons and another existing physical learning community of 22 persons. In both communities participants were partners for over 5 years. The project took place in the same stages as in the above mentioned CS1. Instructors of each community had different roles: one had an active instructive role and the other had no participation in the virtual environment (he only participated in the physical class). The main target of the discussion and artifact analysis in this VC is to imprint the transformation of the two already existing communities into a new one.

The dataset of this CS consists of 5.913 words of chat between the participants.

The main research question is: *Does the active role of the instructor affect the behavior of the participants?*

### 3.3 Case Study 3: Non Collaborative Activities: Collaborative Problem Solving Activity Motivates Struggle

In CS3, a physical learning community - participants were partners for over 6 years—was transformed into a VLC through the wikispaces platform. Twenty persons participated, without having any problem-based activity. The online environment was used in a free style manner (mainly as a chat forum). Instructors had neither active, nor instructive role.

The dataset of this CS consists of 325 words of chat between the participants.

Comparing CS3 with CS4 where collaborative problem solving activity was on, research questions of interest are: *Does the non* collaborative *problem solving activity affect (i) the speech and (ii) behavior of the participants?*

### 3.4 Case Study 4: Problem-Based Activities

In CS4, 21 participants in a physical learning community (the same as in CS1 and CS3) were transformed into a VLC via wikispaces platform, implementing an educational cultural project. Projects were either assigned by the instructor or selected by the participants according to their interests.

This CS was implemented in two consecutive teaching periods.

The main target of the discussion and the artifact analysis in this CS is to identify possible differences in the speech and behavior of the participants among the teaching periods.

The dataset of this CS consists of 7.106 words of chat between the participants in the first teaching period and of 3.973 words in the second one.

The main research questions are: *Are there any differences in the speech of the participants between the two consecutive teaching periods? Is aggressive behavior (bullying) observed in the same level in the second teaching period compared to the first one?*

Next step for the hereby research will be data analysis, attempting to answer the questions above. Nevertheless posing such questions could be of general interest, e.g. for teachers and school researchers as bullying arises to schoolish reality.

## 4 Conclusion

The main contribution of the present research is the study of bullying in VLCs (Virtual Learning Communities) using NLP techniques, mainly in the context of sociocultural learning theories. We aim to apply NLP techniques to speech analysis on communication data of online communities. Despite the fact that the present research is at the preprocessing data stage, this is probably the first time such analysis is attempted in VLCs, and so over on Greek data, since similar researches could not be located. Identifying motives of the participants during a bullying episode in the base of inner speech is also innovative. Emphasis during analysis is given on qualitative data, taking into account the subjectivity of the project framework.

Recognition of motives using Natural Language Processing consist a critical point to behavior (bullying) treatment. Setting or re-setting ideal motives in a VLC via inner speech using authentic activities worth a lot for a teacher, since he can helps this way community and its every member.

## References

1. Fluck J (2014) Why Do Students Bully? An Analysis of Motives Behind Violence in Schools. Youth & Society: 0044118X14547876.
2. Menesini, E., A. Nocentini, B.E. Palladino, A. Frisén, S. Berne, R. Ortega-Ruiz, and P.K. Smith. 2012. Cyberbullying Definition Among Adolescents: A Comparison Across Six European Countries. *Cyberpsychology Behavior and Social Networking* 15 (9): 455–463.
3. Bielaczyc, K., and A. Collins. 1999. Learning Communities in Classrooms: A Reconceptualization of Educational Practice. In *Instructional Design Theories and Models*, ed. C. Reigeluth, 169–292. Mahwah, NJ: Erlbaum.
4. Mairesse, F., M.A. Walker, M.R. Mehl, and R.K. Moore. 2007. Using Linguistic Cues for the Automatic Recognition of Personality in Conversation and Text. *Journal of Artificial Intelligence Research.* 30: 457–500.
5. McMillan, W.D., and D.M. Chavis. 1986. Sense of Community: A Definition and Theory. *Journal of Community Psychology* 14 (1): 6–23.

6. Engeström, Y. 1999. Activity Theory and Individual and Social Transformation. In *Perspectives on Activity Theory: Learning in Doing: Social, Cognitive & Computational Perspectives*, ed. Y. Engeström et al., 19–39. New York: Cambridge University Press.
7. Engeström, Y., and A. Sannino. 2010. Studies of Expansive Learning: Foundations, Findings and Future Challenges. *Educational Research Review* 5 (1): 1–24.
8. Scardamalia, M., and C. Bereiter. 2006. Knowledge Building: Theory, Pedagogy, and Technology. In *Cambridge Handbook of the Learning Sciences*, ed. K. Sawyer, 97–118. New York: Cambridge University Press.
9. Nahar, V., X. Li, and C. Pang. 2013. An Effective Approach for Cyberbullying. Detection. *Communications in Information Science and Management Engineering* 3 (5): 238–247.
10. Reynolds K, Kontostathis A, Edwards L (2011) Using Machine Learning to Detect Cyberbullying. Machine Learning and Applications and Workshops (ICMLA), 10th international conference on, December 2011, vol 2. IEEE, pp 241–244
11. Yin, D., Z. Xue, L. Hong, B.D. Davison, A. Kontostathis, and L. Edwards. 2009. Detection of Harassment on web 2.0. *Proceedings of the Content Analysis in the WEB* 2: 1–7.
12. Vanhove, T., Leroux, P., Wauters, T., and De Turck, F. 2013. Towards the Design of a Platform for Abuse Detection in OSNs Using Multimedial Data Analysis. 2013 IFIP/IEEE International Symposium on Integrated Network Management (IM May 2013). IEEE, 1195–1198
13. Xu, J.M., Jun, K.S., Zhu, X., Bellmore, A. 2012. Learning from Bullying Traces in Social Media. Proceedings of the 2012 Conference of the North American chapter of the association for computational linguistics: human language technologies association for computational linguistics, pp. 656–666
14. Sanchez, H., and S. Kumar. 2011. Twitter Bullying Detection. UCSC ISM245 Data Mining Course Report. *NSDI* 12: 15–15.
15. Bosse T, Stam S (2011) A Normative Agent System to Prevent Cyberbullying. Web Intelligence and Intelligent Agent Technology (WI-IAT), August 2011. IEEE/WIC/ACM International Conference on, Vol. 2. IEEE, pp. 425–430
16. Flor M, Yoon SY, Hao J, Liu L, von Davier AA (2016) Automated Classification of Collaborative Problem Solving Interactions in Simulated Science Tasks. Proceedings of the 11th workshop on innovative use of NLP for building educational applications, San Diego, California, June 16, 2016. Association for Computational Linguistics, pp 31–41
17. Sokolov, A. 1972. *Inner Speech and Thought*. New York: Plenum Press.
18. Vygotsky, L.S. 2000. Mind in Society: The Development of Higher Psychological Processes (transl A. Mpimpou & S. Vosnaidou). Gutenberg, Athens
19. Leontyev A (2009) Activity and Consciousness. Marxists Internet Archive. Retrieved from http://marxistsfr.org/archive/leontev/works/activity-consciousness.pdf. Accessed 15 Sep 2016
20. Vygotsky, L.S. 2008. Thought and Language (transl. A. Rodi). Gnosi, Athens
21. Tzanavaris, S. 2015. Collaborative Learning in Virtual Communities: Socio-Psychological and Pedagogical Approach. Dissertation, Panteion University, Dept of Psychology, Athens
22. Paavola, S., and K. Haakarinen. 2005. The Knowledge Creation Metaphor – An Emergent Epistemological Approach to Learning. *Science & Education Springer* 14 (6): 535–557.
23. Stahl, G. 2004. Building Collaborative Knowing. What We Know About CSCL. *Computer-Supported Collaborative Learning Series* 3: 53–85.
24. Wells, G. 2002. The Role of Dialogue in Activity Theory. *Mind Culture and Activity* 9 (1): 43–66.

# Programmatic Assessment of Professionalism in Psychiatry Education: A Literature Review and Implementation Guide

**Christos Plakiotis**

**Abstract** Programmatic assessment is being adopted as a preferred method of assessment in postgraduate medical education in Australia. Programmatic assessment of professionalism is likely to receive increasing attention. This paper reviews the literature regarding the assessment of professionalism in psychiatry. A search using the terms 'professionalism AND psychiatry' was conducted in the ERIC database. Only original articles relevant to professionalism education and assessment in psychiatry were selected, rather than theoretical or review papers that applied research from other fields of medicine to psychiatry. Articles regarding the need for professionalism education in psychiatry were included as they provided a rationale for curriculum development in this field as a precursor to assessment. Key findings from the literature were summarised in light of the author's own experience as an educator and assessor of both medical students and trainees in psychiatry, and incorporated into a guide to implementing programmatic assessment of professionalism in psychiatry. Within psychiatry, the specific evidence base for use of particular tools in assessing professionalism is limited. However, used in conjunction with psychiatrists' views about what is important in professionalism education, as well as knowledge from other medical disciplines regarding professionalism assessment tools, this evidence can inform implementation of programmatic assessment of professionalism in undergraduate, postgraduate and continuing professional development settings. Given the emergent nature of such assessment initiatives, they should be subjected to rigorous evaluation.

**Keywords** Programmatic assessment • Professionalism • Psychiatry education • Medical education • Competency-based assessment

C. Plakiotis (✉)
Monash Ageing Research Centre (MONARC), Monash University, Melbourne, VIC, Australia

Department of Psychiatry, School of Clinical Sciences at Monash Health, Monash University, Melbourne, VIC, Australia

Aged Persons Mental Health Service, Monash Health, Melbourne, VIC, Australia

Aged Psychiatry Academic Unit (Monash University), c/o Medical Administration, Kingston Centre, Warrigal Road, Cheltenham, VIC, 3192, Australia
e-mail: Chris.Plakiotis@monash.edu



P. Vlamos (eds.), *GeNeDis 2016*, Advances in Experimental Medicine and Biology 989, DOI 10.1007/978-3-319-57348-9_19

# 1 Background

## *1.1 Programmatic Assessment in Medical Education*

Educational theory and practice has seen a change in how assessment is viewed, from assessment *of* learning to assessment *for* learning. The latter involves the gathering and integration of evidence from multiple complementary sources regarding each learner's abilities and areas for improvement, providing a highly informative framework to enhance learning. A key objective is to determine whether any particular candidate's performance today is as good as it can be and how to accomplish this, rather than whether one candidate performs superiorly to another. This shift has led to conceptual changes in the collection and organisation of assessment data, how judgement is perceived in the assessment process, and the adequacy of current psychometric approaches in measuring assessment quality [1].

Programmatic assessment goes one step further in not only emphasising the need for assessment to facilitate learning but also to effectively inform progression decisions [2]. It aims to optimise the learning, decision-making and curriculum quality-assurance functions of any assessment program for the benefit of the organisation, teachers and students [3]. In programmatic assessment, modern methods complement—rather than supplant—traditional ones [1, 4–7]. Assessments are carefully mapped against learning outcomes [3] and are generally regarded as individual data points geared towards low-stakes formative assessment, through their emphasis on learning and feedback. Intermediate- and high-stakes summative assessment decisions are based on the meaningful combination of multiple data points [2]. Comprehensive organisational systems support this process and the timing of assessment outcomes and consequent decisions is separated. Mentoring can be used to support self-management of learning, assisting learners to analyse assessment outcomes and approach learning objectives in light of these [3]. In addition to maximising learning, improved validity and reliability of measurements and documentation of competence development are further objectives [8].

Programmatic assessment-for-learning has a clear rationale derived from educational research and practice and is applicable to any stage of training, providing a constructivist understanding of learning is maintained. However, implementing large-scale programmatic assessment requires the cooperation of multiple stakeholders and may not always be feasible. Limited applications (e.g. improvements in mentoring or feedback) may be more practicable but their benefits may be reduced [3].

Studies of programmatic assessment have demonstrated both strengths and weaknesses in this approach. Bok et al. [8] explored the interaction between educational practice and a large-scale programmatic assessment initiative implemented as part of a competency-based learning curriculum. Implementing the program was not straightforward. Students progressively viewed low-stakes formative assessments as summative but appreciated peer feedback as a formative feedback tool. Learners required supervision and social support to scaffold self-directed

learning. Assessors required comprehensive training and guidance to assist them in combining data from multiple assessments into an all-inclusive, portfolio-based evaluation. Similarly, in a qualitative study conducted in a graduate-entry medical school setting, Heeneman et al. [9] found that while programmatic assessment served to motivate students' learning, formative assessments were perceived as summative. The reflective portfolio was valued for generating knowledge through feedback on an ongoing basis. For some students, however, perceived hindrances to the reflective elements of programmatic assessment (e.g. the experience of 360-degree feedback as overwhelming) dominated their attitude towards learning.

### *1.2 The Construct and Assessment of Medical Professionalism*

Arnold [10] provided an overview of the construct of professionalism from a general medicine perspective: (1) altruism (selflessly serving patients' needs); (2) respect for others (a cornerstone of humanism); (3) honour and integrity (high standards of behaviour and adherence to codes of practice); (4) accountability (to patients, the profession and society); (5) excellence (dedication to surpassing the ordinary and to continuous learning); and (6) duty (commitment to service) [11].

Arnold [10] also classified available methods for the assessment of professionalism, classifying relevant studies into three categories: (1) evaluation of professionalism as part of clinical performance (e.g. peer assessments); (2) measurement of professionalism as a comprehensive entity (e.g. through group surveys or critical-incident analysis); and (3) measurement of specific elements of professionalism, such as humanism (e.g. using Objective Structured Clinical Examination [OSCE] or 360-degree feedback). Self-assessment, self-regulation, and self-reflection were also relevant here, as were personality and value inventories and moral reasoning tests. Although existing assessment methods were plentiful, a need to refine their psychometric properties and to improve both qualitative and quantitative techniques was identified. Defining professional behaviours as contextual expressions of value conflicts and developing assessment tools to examine their resolution was a recommended focus of future research. Further research topics were the possible customisation of assessment tools to medical career stage and understanding the impact of environmental factors on professionalism assessment.

## 2 Objectives

This paper briefly reviews the literature regarding the assessment of professionalism at all levels of learning within psychiatry. Suitable articles were identified using the search terms 'professionalism AND psychiatry' in the ERIC educational database. Only original articles relevant to professionalism education and assessment in psychiatry were selected, rather than theoretical or review papers that applied

research from other fields of medicine to psychiatry. Articles regarding the need for professionalism education in psychiatry were included as they provided a rationale for curriculum development in this field as a precursor to assessment. Key findings from the literature were summarised in light of the author's own experience as an educator and assessor of both medical students and trainees in psychiatry, and applied to a schema developed by van der Vleuten et al. [3] to demonstrate how programmatic assessment of psychiatric professionalism can be undertaken across an entire learning curriculum.

## 3 The Perceived Need for Professionalism Education in Psychiatry

A desire for additional education regarding training- and practice-based ethical and professional dilemmas was expressed by trainees from all clinical disciplines and levels of training, but especially by women, in a survey conducted by Roberts et al. [12] at the University of New Mexico School of Medicine. One hundred and thirty-six residents (58% response) and 200 medical students (65% response) responded to the survey. There was no simple relationship between interest in ethical matters and training level. Residents' perceived needs in ethics education varied according to specialty, with psychiatry residents indicating a particular desire for better education in training-stage ethical dilemmas. In particular, psychiatry residents reported that more education regarding supervisor-trainee conflict, undertaking duties outside one's experience, and introducing students to patients as doctors was required. Compared to primary care or other specialty residents, psychiatry residents also indicated a marginally greater need for further education in a range of practice- and profession-related topics. The authors suggested that medical academics should focus on these topics in undergraduate and graduate training programs to better address trainees' needs for ethics and professionalism education.

Roberts et al. [13] surveyed all qualified psychiatrists in the rural states of Alaska and New Mexico to understand their views regarding ethics training. The 97 psychiatrists who responded were moderately interested in receiving ethics and professionalism training, with level of interest being inversely related to duration of practice and less than that of doctors-in-training (as shown in other studies). Both genders rated topics similarly, but women were generally more interested than men. The authors concluded that creating continuing medical education opportunities in professionalism and ethics that are responsive to the requirements of practicing psychiatrists may be challenging but important nonetheless, given the core competency status now afforded to these domains.

Lapid et al. [14] surveyed residents at six psychiatry residency programs (134 respondents, 61% response rate) regarding their views on ten domains of professionalism and their perceived need for ethics education, particularly regarding boundaries in psychiatrist-patient, supervisor-trainee and peer-peer relationships.

Further education regarding most of the relationship and boundary issues enquired about was requested by psychiatry trainees, especially those who experienced ethical quandaries more often.

One hundred and fifty one psychiatry residents at seven United States' psychiatry residency programs were surveyed by Jain et al. [15] to ascertain their views regarding the goals of professionalism and ethics education, the ethical principles that should underpin the curriculum, and how teaching should occur. Residents reported receiving some ethics education during residency training but less so than during medical school. The residents endorsed all 11 medical education goals in professionalism and ethics and indicated a preference for clinically- and expert-oriented teaching methods rather than web-based approaches.

In an accompanying paper [16], the same authors reported further findings from the above survey regarding trainees' identified need for education in informed consent, professional and ethical principles, and care of the vulnerable patient. As in the preceding paper, trainees experiencing more ethical dilemmas rated the need for further education in these domains more highly. All topics examined were rated as warranting more education.

Morreale et al. [17] examined the importance of items related to professional behaviour (personal characteristics, interaction with patients, social responsibility and interaction with the healthcare team) via an electronic survey of medical staff in the Department of Psychiatry at Wayne State University School of Medicine: 35 third-year medical students, 41 residents and 42 psychiatrists. Professional behaviour was valued by all three groups, with most items rated as 'important' or 'very important'. Despite professional behaviour being assessed as a core competency for both residents and medical students at the survey centre, psychiatry residents had the highest mean score in all items whereas medical students rated 'personal characteristics' and 'interaction with patients' as less important than the two other groups surveyed. 'Social responsibility' was rated as significantly more important by residents compared to both medical students and psychiatrists. A highly-regulated resident training environment (emphasising the importance of professionalism) and the idealism of new residents were postulated explanatory factors for these differences.

Choi et al. [18] investigated whether there was a relationship between medical students' views and convictions regarding professionalism and their use of substances, including nonmedical prescription stimulants, through a confidential survey sent to all medical students at a private medical university in the United States (46% response rate). Patterns of alcohol, marijuana and nonmedical prescription stimulant use were studied, as were stress levels and history of suicidal thoughts. Over one-third of respondents reported drinking to excess over the past month and 5% had used nonmedical prescription stimulants over the preceding year. A substantial proportion of students were unaware how to assist colleagues using stimulants. Students condoning substance use were significantly less likely to perceive it as an unprofessional behaviour worthy of treatment.

## 4 Methods for Assessing Professionalism in Psychiatry

Hodges et al. [19] observed several instances of behaviour consistent with professional misconduct towards simulated patients during a study evaluating a psychiatric OSCE for University of Toronto medical students. Concerning student performances included the aggressive restraint of a psychotic patient and receptiveness to a disinhibited manic patient's sexual overtures. The emotionally demanding nature of the OSCE material was postulated to have contributed to these behaviours emerging. The predictive validity of these occurrences was uncertain due to the preliminary nature of the research. Students involved were offered extensive feedback and debriefing but not disciplined in any way.

Roberts et al. [20] sent a 124-item written survey to 308 medical students (65% response rate) and 233 psychiatry residents (58% response rate) at the University of New Mexico School of Medicine to evaluate their views and preferences regarding professionalism and ethics education. Only 18% of respondents considered existing professionalism and ethics training to be adequate. A diverse range of initiatives in professionalism and ethics education were supported by respondents, more so by women than men and by residents than medical students. Clinically- and expert-oriented learning (such as ward rounds, demonstration by supervisors, patient contacts and case conferences), as well as clinically-focussed assessment methods, were preferred over didactic (e.g. lectures), unconventional (e.g. standardised patient interactions) or independent (e.g. web-based) learning approaches. By way of explaining this finding, the authors contrasted the meaningful immediacy of professionalism and ethics learning acquired through clinical encounters with the potentially detached nature of online learning [21–23].

Psychiatry residents at the University of Arkansas for Medical Sciences Department of Psychiatry were required to keep a work portfolio demonstrating their abilities in 13 skill areas identified by the department as essential for safe and proficient psychiatric practice. Jarvis et al. [24] examined whether the portfolio entries could also demonstrate resident performance in the general competency of professionalism as defined by the Accreditation Council for Graduate Medical Education (ACGME). Professionalism was reflected in 85% of the psychiatric skills. Skills in which there was a 'definite' reflection of professionalism included: crisis management, legal issues, professional communication, psychotherapy, treatment course, and working with teams and families. Skills in which there was 'some-definite' reflection of professionalism included: medical psychiatry and specific treatment modalities. Skills in which there was 'some' reflection of professionalism included: initial evaluation and diagnosis, neuropsychiatry, and teaching and presentation skills. Skills in which the reflection of professionalism was regarded as 'none' included: biopsychosocial formulation and self-directed learning.

Bennett et al. [25] conducted a 20-item survey among 120 directors of psychiatry clerkships and medical student education in the United States regarding the approaches used to identify, monitor and remediate unprofessional medical student behaviours. While the 57 respondents agreed that recognising unprofessional

behaviours was important, variable monitoring, remedial and disciplinary modalities were reported. Ninety-six percent of the clerkship programs evaluated professionalism and 70% reported taking action in response to unprofessional behaviours among one to three students annually. Unprofessional behaviours were seen as a potential impediment to medical student progress by 86% of directors and an emphasis was placed on student feedback. Mental health assessment was recommended in 76% of cases and severe or repetitive unprofessional behaviours were regarded as possible grounds for expulsion from medical school.

In a study conducted at the University of Cincinnati by Bennett et al. [26], tasks indicative of professionalism were performed significantly better in an end-of-course (fourth-year) competency examination by medical students who had previously undertaken a standardised patient examination during their third-year psychiatry rotation (246 out of 469 students). In particular, these students were deemed by both clinical examiners and standardised patients themselves to be more respectful of patients and to use comprehensible language and interact with them in a more professional manner. The competency exam was essentially an OSCE comprised of seven 15-min stations whereas the standardised patient examination that preceded it involved a 30-min videotaped interview with a standardised patient followed by a 2-h write-up of the case. While the write-up was the focus of assessment for most students, both the videotape and write-up were jointly reviewed by way of remediation by the student and clerkship director in the 10% of cases where performance was considered suboptimal (score of <80 out of 100).

Ballon and Skinner [27] sought to enhance the development of professionalism among trainees in an addiction psychiatry postgraduate core rotation by incorporating reflection techniques into their learning program: reflective journaling, regular reflection time (3 h per week), weekly reflection meetings with the education coordinator, preparation of a reflection paper and reading of reflection references. Trainees endorsed these reflection techniques as exceptionally useful in developing professional attitudes for effectively engaging and appropriately caring for people with addiction disorders. Greater use of reflective practices in psychiatric education was recommended by the authors as a way of fostering reflexive self-awareness as a key professional competence necessary for effective clinical practice, in challenging settings particularly.

In order to understand how medical students learn and grow during their 7-week psychiatry clerkship, West and Nierenberg [28] reviewed all student-patient-faculty encounters recorded by 173 students over 3 years on a web-based learning documentation system at Dartmouth Medical School. The system allowed students to document their progress in developing competency through beneficial learning situations in advanced communication skills, professionalism, personal and continuous learning and system-based practice. Professionalism issues challenged students most frequently: assessing their own strengths and weaknesses (13.4% of encounters), putting aside personal biases in delivering patient care (12.5%), placing patient interests first (12.1%), adhering to professional ethical standards (11.7%) and maintaining confidentiality (11.1%). Data thus obtained facilitated ongoing modification of the clerkship experience by the clerkship director.

In a follow up report to the studies by Jain et al. [15] and Jain et al. [16], Marrero et al. [29] reported on psychiatry residents' attitudes towards professionalism and ethics evaluation. Clinical supervision and clinically-based assessments involving direct observation of interactions with actual patients and clinicians were preferred over non-clinical (oral examinations, short-answer questions, essays) and simulation-based (standardised patient interactions) assessment methods.

Schillerstrom and Lutz [30] described absence patterns and compared academic performance among 433 third-year medical students with and without absences at The University of Texas Health Science Center at San Antonio. The study was conducted in the context of a policy being implemented to manage medical student attendance during the psychiatry rotation, allowing an absence of three days without consequence. Although students with $\geq 1$ absences had lower mean National Board of Medical Examiners psychiatry 'shelf' exam scores than those with no absences, no significant differences between groups were demonstrated in overall academic performance (including professionalism assessment). The authors thus concluded that the attendance management policy was effective.

## 5 Discussion

The literature suggests a considerable demand for more training in professionalism and ethics among doctors at all levels of learning within psychiatry. This is especially the case for medical students [12] and psychiatry trainees [12, 14–16]. Qualified psychiatrists also identified a need for ongoing instruction in this area, albeit to a lesser degree [13], suggesting it should be a focus for continuing professional development (CPD). There are several papers highlighting specific topics of importance in psychiatric professionalism—as identified by medical students, psychiatry trainees and psychiatrists—that can be used as a basis for curriculum development, teaching and programmatic assessment [12–17].

The literature regarding the assessment of professionalism in psychiatry specifically is very limited. A survey of psychiatry training directors regarding the detection and monitoring of *unprofessional* behaviour indicated that a variety of methods are used [25]. Absenteeism was not an accurate marker in this regard among medical students on their psychiatry rotation, as overall academic performance (including professionalism assessment) was not affected [30]. Information regarding the use of the following assessment tools is available.

### *5.1 Direct Observation of Clinical Practice*

This method, in which supervisors base their assessment of learners' professionalism on direct clinical observation, was a preferred method among medical students [20] and psychiatry trainees [20, 29] for the assessment of professionalism. There is

a dearth of psychiatry-specific evidence regarding how this approach should actually be used in practice. It is, however, a method that is potentially suitable for use at medical student, psychiatry trainee and consultant psychiatrist levels.

## 5.2 Examinations of Clinical Competency

Objective Structured Clinical Examination (OSCE) is the key modality for which psychiatry-specific evidence exists [19, 26]. Learners themselves may experience such methods less favourably than direct clinical encounters, as they are less lived, poignant and meaningful [20–23, 29]. While such methods may pose limitations in revealing unprofessional behaviour [29], Hodges et al. [19] reported that potential professional misconduct came to light in the course of a medical student OSCE that required counselling of the students involved. It is uncertain how effective OSCE would be in detecting unprofessional practice in more advanced learners (i.e. trainee psychiatrists) whose superior knowledge may allow them to conceal such tendencies. The use of an OSCE format as a teaching rather than assessment tool [31] has merit in CPD settings.

## 5.3 Reflective Practice

Trainees in addiction psychiatry endorsed reflective practice as exceptionally useful in managing patients with addiction disorders [27]. This method is suitable for use at medical student, psychiatry trainee and consultant psychiatrist levels as its longitudinal perspective is more informative than examination-based methods that are better suited to modular assessment.

## 5.4 Portfolio-Based Learning and Assessment

Jarvis et al. [24] demonstrated professionalism to be evident in 85% of the psychiatric skills documented by psychiatry trainees in a learning portfolio. Professionalism issues were also found to challenge students most often in a web-based learning documentation system [28]. As in the case of reflective practice (which may contribute to portfolio-based learning) portfolios are potentially useful at all levels of psychiatry training given their longitudinal nature and may be especially pertinent for psychiatrists who are not required to sit relicensing examinations.

In view of the paucity of evidence about the assessment of professionalism in psychiatry directly, educators must draw upon the literature regarding the assessment of professionalism in medicine as a whole in developing and implementing programmatic assessment of professionalism in psychiatry [32]. Ideally, imple-

mentation should be accompanied by research evaluating the discipline-specific effectiveness of the techniques employed.

## 6 A Guide to Implementing Programmatic Assessment of Professionalism in Psychiatry

A guide to implementing programmatic assessment of professionalism in psychiatry is provided below, based on a schema proposed by van der Vleuten et al. [3]. While the schema itself is not unique, this is the first time it has been applied to develop a detailed proposal for implementing programmatic assessment of psychiatric professionalism in particular.

### *6.1 Develop a Master Plan for Assessment*

Use of a competency framework for professionalism, such as that developed by the American Board of Internal Medicine in the United States [11], provides an overarching structure. Like other complex competencies, professionalism is fundamentally a behavioural characteristic that develops over time. Expert judgement of performance in real clinical situations and longitudinal assessments (e.g. portfolio) will be particularly important, but modular and standardised methods are all relevant. Sampling of multiple contexts by multiple assessors will address inherent subjectivity. Formative and summative assessment occurs on a continuum of low- to high-stakes decisions, where any individual assessment is a single data point and multiple data points are required for high-stakes (pass/fail) decisions [3]. In undergraduates, the master plan will focus primarily on a single psychiatry rotation, but professionalism can also be assessed elsewhere in the course, with data points from other disciplines contributing to a longitudinal picture. In postgraduate training, the masterplan should stretch across the duration of the program. A comparable three- to five-year professionalism learning and assessment cycle can be adopted to meet CPD and revalidation requirements.

### *6.2 Develop Examination Regulations That Promote Feedback Orientation*

Examination regulations should emphasise the low-stake (formative) nature of individual assessments, with credit points linked only to high-stakes (summative) decisions, to avoid students ignoring feedback and focussing only on passing tests [3, 8, 33]. A model currently used in postgraduate psychiatry training in

Australia, whereby several low-stakes workplace-based assessments—involving generous feedback opportunities—contribute to the attainment of an entrustable professional activity, is suitable for assessing professionalism [34]. A similar format could be adapted for use in undergraduate or CPD settings, although the content of activities and assessors may vary, e.g. low-stakes practice visits by colleagues can be used to provide psychiatrists with feedback on aspects of professionalism.

### *6.3 Adopt a Robust System for Collecting Information*

Use of an electronic portfolio (e-portfolio) is recommended to allow large amounts of information about professionalism, and other psychiatric competencies, to be gathered, handled and analysed over time, thereby allowing regular determination of whether learning goals relating to this competency are being met [3]. Incorporating professionalism focussed activities into e-portfolios that span entire postgraduate psychiatry training programs should be straightforward. An e-portfolio with a psychiatry professionalism component spanning all the clinical years of a medical course is advantageous in overcoming barriers posed by a time-limited psychiatry rotation to using an e-portfolio to its full potential. In a CPD or revalidation setting, the e-portfolio should reflect learning in and assessment of professionalism over a three- to five-year cycle and be oriented more towards peer-review (such as 360-degree appraisal) and self-reflection than examinations. However, the principles of low-stakes assessments (e.g. annual performance appraisal) informing high-stakes decisions (e.g. meeting revalidation requirements) should be adhered to.

### *6.4 Assure That Every Low-Stakes Assessment Provides Meaningful Feedback for Learning*

Effective programmatic assessment is founded on rich information. The main purpose of any individual data point is high-quality, credible feedback following a 'less-is-more' approach. While this requires resources, programmatic assessment will fail without it [3]. At a medical student or psychiatry trainee level, feedback from a supervisor or mentor is essential, but should be supplemented by patient, carer and multidisciplinary team member feedback. The benefits of practice visits in providing formative feedback in a CPD setting have already been touched upon. Expanding peer feedback and support among medical students and psychiatry trainees through feedback sessions moderated by a more senior colleague (to address junior learners' limited expertise in professionalism-related issues) is recommended. Peer feedback is also more resource efficient than other feedback modalities.

## 6.5 Provide Mentoring to Learners

Feedback as a basis for reflection and further discussion is needed for effective learning [35–37]. Mentoring allows a reflective dialogue to be effectively developed, whereby follow-up on feedback is stimulated. A mentor should be a regular staff member with knowledge of the curriculum, who can build a trusting relationship with the mentee and who should be removed from the decision-making process [3]. Mentorship represents an ideal forum for assisting learners to successfully negotiate the professionalism learning and assessment process. In the author's experience, however, only a subset of psychiatry trainees are likely to pursue mentorship and providing mentorship by psychiatrists to the many medical students who study psychiatry would likely be prohibitive. At a medical student level, professionalism teaching and assessment, including feedback and mentorship, should therefore be shared with colleagues in other disciplines, e.g. general practice. Setting up mentorship schemes for psychiatrists is recommended but identifying an adequate number of suitable mentors and matching them appropriately with mentees may be challenging.

## 6.6 Ensure Trustworthy Decision-Making

A highly trained assessment panel or committee can aggregate much information to make high-stakes (pass/fail) decisions that are credible and trustworthy, providing the information is accurate and reliable. Panel input by mentors and trainees should be facilitated (e.g. via a mentor's letter annotated by a trainee) but mentors should not make final pass/fail decisions [3]. Input by consumers, carers and other multidisciplinary team members should also be sought given the importance of these stakeholders in mental health settings. A need for such panels at undergraduate and postgraduate training levels is apparent. More rigorous appraisal of psychiatrists' CPD activities, including in the area of professionalism, as part of revalidation may see such panels having to be convened in the CPD setting.

## 6.7 Organise Intermediate Decision-Making Assessments

Intermediate assessments at regular intervals in a program of learning provide learners with feedback regarding progress and potential future high-stakes decisions, thereby adding credibility to the final decision and programmatic assessment as a whole [3]. Methods such as mini-Clinical Evaluation Exercises (mini-CEX) and OSCE are suitable in undergraduate and postgraduate training. Structured approaches to appraising real-world clinical skills are especially suited to

postgraduate-level training, e.g. by observing and evaluating a trainee's professionalism in managing a complex psychiatric patient with a highly distressed family. Such evaluations can be undertaken within the previously mentioned structure of workplace-based assessments leading to entrustable professional activities, with the latter representing the intermediate assessment [34]. Demonstrating that several professionalism targets have been met at an annual performance appraisal would represent an intermediate decision-making assessment at a CPD level (e.g. participating in annual 360-degree appraisal and documenting self-reflection in an e-portfolio). The performance appraisal should be conducted by a panel, given the rising stakes associated with it, and be informed by accurate, reliable data. Several intermediate assessments (i.e. performance appraisals) can be included in a three- to five-year CPD or revalidation cycle (pass/fail assessment).

## *6.8 Encourage and Facilitate Personalised Remediation*

Remediation should be personalised and stem from a learner's ongoing reflection about professionalism. It should be offered promptly when needed [38]. An experienced mentor should engage the learner in developing a remediation program [3]. Remediation of unprofessional behaviour may be particularly sensitive due to the implication or expectation that disciplinary action may be required in more severe cases. The stakes involved may increase with level of training and experience. Thinking carefully about how remedial and disciplinary activities are separated requires attention and a clear demarcation may not always be possible, e.g. where remediation is a requirement of disciplinary action undertaken by a registration body in response to reported unprofessional behaviour.

## *6.9 Monitor and Evaluate the Learning Effect of the Programme and Adapt*

Qualitative and quantitative data about the quality of the assessment program should be systematically gathered and applied to improve it [3]. Given the paucity of literature about professionalism assessment in psychiatry, feedback from all participants is essential for program refinement. For example, requiring professionalism issues to be addressed during practice visits is essential to start the programmatic assessment process but program evaluation by participants may lead to changes in the content or process of the visits being recommended. Collecting information about lessons learned and disseminating it through publications akin to those reviewed in this paper is recommended for advancing the field.

## 6.10 Use the Assessment Process Information for Curriculum Evaluation

The breadth of information collected during programmatic assessment is useful in evaluating the curriculum and teaching environment [3]. If assessment of professionalism regularly uncovers performance deficits, the curriculum content and teaching methods should be reviewed. As a starting point, however, it is recommended that educators involved in curriculum planning refer to the existing literature regarding topics of importance in psychiatric professionalism, as identified by medical students, psychiatry trainees and psychiatrists [12–17]. The extensive range of topics covered are useful for preparing materials to guide learning and assessment, e.g. development of OSCE scenarios or topics to focus on during self-reflection or practice visits.

## 6.11 Promote Continuous Interaction Between the Stakeholders

Programmatic assessment of professionalism in psychiatry is the responsibility of all organisations involved in training (e.g. university, health service and Specialist College) and the individuals that comprise them (e.g. trainees, supervisors, mentors, examiners and training directors). Appropriate communication between parties should be fostered while preserving confidentiality and objectivity [3]. As indicated in the preceding discussion regarding remediation, the converse of professionalism—unprofessional behaviour—is a particularly sensitive area and careful attention to how assessment information flows between stakeholders is needed, perhaps more so than for other competencies.

## 6.12 Develop a Strategy for Implementation

Modern education is moving away from modular teaching with summative assessment to constructivist learning theories in which learners are guided and supported to generate their own knowledge and skills. Programmatic assessment is more compatible with this perspective but represents a radical change in thinking and may fail (like many problem-based learning initiatives) if not properly implemented [3]. In the Australian context in which the author works, programmatic assessment has been adopted in both medical student education (at Monash University) and postgraduate psychiatry training (through the Royal Australian and New Zealand College of Psychiatrists) [39]. Robust processes for the teaching and programmatic assessment of professionalism at these levels thus already exist. Further attention

to ongoing professionalism education and assessment for psychiatrists may be warranted as well as ensuring that content in this competency domain is actually covered.

## 7 Conclusion

Observation of trends in postgraduate medical education in Australia suggests that programmatic assessment is being adopted as a preferred method of assessment. Programmatic assessment of professionalism is thus a topic that is likely to receive increasing attention over coming years. Within psychiatry, the specific evidence base for use of particular tools in assessing professionalism is very limited. However, used in conjunction with evidence regarding what psychiatrists at all levels of training consider to be important in professionalism education, as well as evidence about the usefulness of professionalism assessment tools from other medical disciplines, this evidence can inform implementation of programmatic assessment of this domain in undergraduate, postgraduate and CPD settings. Given the emergent nature of such assessment initiatives, they should be subjected to rigorous evaluation of their effectiveness. This paper is the first to provide a guide to applying the concept of programmatic assessment to psychiatric professionalism. Its recommendations are applicable to psychiatry educators, and medical educators more broadly, who seek to systematically evaluate professionalism across an entire training curriculum.

**Funding** No sources of funding were received for this work.

**Conflicts of Interest** The author reports no conflicts of interest and is alone responsible for the content and writing of this paper.

**Acknowledgement** The author would like to thank Dr Ian Presnell, Senior Lecturer, Faculty of Medicine, Nursing and Health Sciences, Monash University, for critically reviewing this manuscript.

## References

1. Schuwirth, L.W.T., and C.P.M. van der Vleuten. 2011. Programmatic Assessment: From Assessment of Learning to Assessment for Learning. *Medical Teacher* 33: 478–485. doi:10.3109/0142159X.2011.565828.
2. van der Vleuten, C.P.M., L.W.T. Schuwirth, E.W. Driessen, et al. 2012. A Model for Programmatic Assessment Fit for Purpose. *Medical Teacher* 34: 205–214. doi:10.3109/0142159X.2012.652239.
3. ———. 2015. Twelve Tips for Programmatic Assessment. *Medical Teacher* 37: 641–646. doi:10.3109/0142159X.2014.973388.

4. Prescott, L.E., J.J. Norcini, P. McKinlay, and J.S. Rennie. 2002. Facing the Challenges of Competency-Based Assessment of Postgraduate Dental Training: Longitudinal Evaluation of Performance (LEP). *Medical Education* 36: 92–97.
5. van der Vleuten, C.P.M., and L.W.T. Schuwirth. 2005. Assessing Professional Competence: From Methods to Programmes. *Medical Education* 39: 309–317.
6. Dannefer, E.F., and L.C. Henson. 2007. The Portfolio Approach to Competency-Based Assessment at the Cleveland Clinic Lerner College of Medicine. *Academic Medicine* 82: 493–502.
7. Fishleder, A.J., L.C. Henson, and A.L. Hull. 2007. Cleveland Clinic Lerner College of Medicine: An Innovative Approach to Medical Education and the Training of Physician Investigators. *Academic Medicine* 82: 390–396.
8. Bok, H.G., P.W. Teunissen, R.P. Favier, et al. 2013. Programmatic Assessment of Competency-Based Workplace Learning: When Theory Meets Practice. *BMC Medical Education* 13: 1.
9. Heeneman, S., A. Oudkerk Pool, L.W.T. Schuwirth, et al. 2015. The Impact of Programmatic Assessment on Student Learning: Theory Versus Practice. *Medical Education* 49: 487–498. doi:10.1111/medu.12645.
10. Arnold, L. 2002. Assessing Professional Behavior: Yesterday, Today, and Tomorrow. *Academic Medicine* 77: 502–515.
11. American Board of Internal Medicine (ABIM). 1994. *Project Professionalism*. Philadelphia, PA: American Board of Internal Medicine.
12. Roberts, L.W., T.D. Warner, K.A.G. Hammond, et al. 2005. Becoming a Good Doctor: Perceived Need for Ethics Training Focused on Practical and Professional Development Topics. *Academic Psychiatry* 29: 301–309.
13. Roberts, L.W., M.E. Johnson, C. Brems, and T.D. Warner. 2006. Preferences of Alaska and New Mexico Psychiatrists Regarding Professionalism and Ethics Training. *Academic Psychiatry* 30: 200–204.
14. Lapid, M., C. Moutier, L. Dunn, et al. 2009. Professionalism and Ethics Education on Relationships and Boundaries: Psychiatric Residents' Training Preferences. *Academic Psychiatry* 33: 461–469.
15. Jain, S., L.B. Dunn, C.H. Warner, and L.W. Roberts. 2011. Results of a Multisite Survey of U.S. Psychiatry Residents on Education in Professionalism and Ethics. *Academic Psychiatry* 35: 175–183.
16. Jain, S., M.I. Lapid, L.B. Dunn, and L.W. Roberts. 2011. Psychiatric Residents' Needs for Education About Informed Consent, Principles of Ethics and Professionalism, and Caring for Vulnerable Populations: Results of a Multisite Survey. *Academic Psychiatry* 35: 184–190.
17. Morreale, M.K., R. Balon, and C.L. Arfken. 2011. Survey of the Importance of Professional Behaviors Among Medical Students, Residents, and Attending Physicians. *Academic Psychiatry* 35: 191–195.
18. Choi, D., V. Tolova, E. Socha, and C.P. Samenow. 2013. Substance Use and Attitudes on Professional Conduct Among Medical Students: A Single-Institution Study. *Academic Psychiatry* 37: 191–195.
19. Hodges, B., G. Regehr, M. Hanson, and N. McNaughton. 1997. An Objective Structured Clinical Examination for Evaluating Psychiatric Clinical Clerks. *Academic Medicine* 72: 715–721.
20. Roberts, L.W., K.A.G. Hammond, C.M. Geppert, and T.D. Warner. 2004. The Positive Role of Professionalism and Ethics Training in Medical Education: A Comparison of Medical Student and Resident Perspectives. *Academic Psychiatry* 28: 170–182.
21. Hundert, E.M., F. Hafferty, and D. Christakis. 1996. Characteristics of the Informal Curriculum and Trainees' Ethical Choices. *Academic Medicine* 71: 624–642.
22. Szauter, K., and H.E. Turner. 2001. Using Students' Perceptions of Internal Medicine Teachers' Professionalism. *Academic Medicine* 76: 575–576.
23. Lichstein, P.R., and G. Young. 1996. "My Most Meaningful Patient." Reflective Learning on a General Medicine Service. *Journal of General Internal Medicine* 11: 406–409.

24. Jarvis, R.M., P.S. O'Sullivan, T. McClain, and J.A. Clardy. 2004. Can One Portfolio Measure the Six ACGME General Competencies? *Academic Psychiatry* 28: 190–196.
25. Bennett, A.J., B. Roman, L.M. Arnold, et al. 2005. Professionalism Deficits Among Medical Students: Models of Identification and Intervention. *Academic Psychiatry* 29: 426–432.
26. Bennett, A.J., L.M. Arnold, and J.A. Welge. 2006. Use of Standardized Patients During a Psychiatry Clerkship. *Academic Psychiatry* 30: 185–190.
27. Ballon, B.C., and W. Skinner. 2008. "Attitude is a Little Thing That Makes a Big Difference": Reflection Techniques for Addiction Psychiatry Training. *Academic Psychiatry* 32: 218–224.
28. West, D.A., and D.W. Nierenberg. 2009. Student Experiences with Competency Domains During a Psychiatry Clerkship. *Academic Psychiatry* 33: 204–211.
29. Marrero, I., M. Bell, L.B. Dunn, and L.W. Roberts. 2013. Assessing Professionalism and Ethics Knowledge and Skills: Preferences of Psychiatry Residents. *Academic Psychiatry* 37: 392–397.
30. Schillerstrom, J.E., and M. Lutz. 2013. Academic Performance in the Context of a "Three Excused Absences" Psychiatry Clerkship Policy. *Academic Psychiatry* 37: 171–174.
31. Chandra, P., S. Chaturvedi, and G. Desai. 2009. Objective Standardized Clinical Assessment with Feedback: Adapting the Objective Structured Clinical Examination for Postgraduate Psychiatry Training in India. *Indian Journal of Medical Sciences* 63: 235–243.
32. Swick, S., M.S. Hall, and E. Beresin. 2006. Assessing the ACGME Competencies in Psychiatry Training Programs. *Academic Psychiatry* 30: 330–351.
33. Harrison, C.J., K.D. Könings, A. Molyneux, et al. 2013. Web-Based Feedback After Summative Assessment: How Do Students Engage? *Medical Education* 47: 734–744.
34. The Royal Australian and New Zealand College of Psychiatrists. 2016. Workplace-Based Assessments (WBAs). https://www.ranzcp.org/Pre-Fellowship/2012-Fellowship-Program/Assessment-overview/Workplace-based-Assessments.aspx. Accessed 30 Aug 2016.
35. Ericsson, K.A. 2004. Deliberate Practice and the Acquisition and Maintenance of Expert Performance in Medicine and Related Domains. *Academic Medicine* 79: S70–S81.
36. Sargeant, J.M., K.V. Mann, C.P. van der Vleuten, and J.F. Metsemakers. 2009. Reflection: A Link Between Receiving and Using Assessment Feedback. *Advances in Health Sciences Education* 14: 399–410.
37. Driessen, E.W., J. van Tartwijk, M. Govaerts, et al. 2012. The Use of Programmatic Assessment in the Clinical Workplace: A Maastricht Case Report. *Medical Teacher* 34: 226–231.
38. Cohen, D., M. Rhydderch, and I. Cooper. 2014. Managing Remediation. In *Understanding Medical Education: Evidence, Theory and Practice*, ed. T. Swanwick, 2nd ed., 433–444. Chichester, West Sussex: John Wiley & Sons, Ltd.
39. The Royal Australian and New Zealand College of Psychiatrists. 2016. Assessment Overview. https://www.ranzcp.org/Pre-Fellowship/2012-Fellowship-Program/Assessment-overview.aspx. Accessed 10 July 2016.

# Opinion Mining for Educational Video Lectures

**Dimitrios Kravvaris and Katia Lida Kermanidis**

**Abstract** The search for relevant educational videos is a time consuming process for the users. Furthermore, the increasing demand for educational videos intensifies the problem and calls for the users to utilize whichever information is offered by the hosting web pages, and choose the most appropriate one. This research focuses on the classification of user views, based on the comments on educational videos, into positive or negative ones. The aim is to give users a picture of the positive and negative comments that have been recorded, so as to provide a qualitative view of the final selection at their disposal. The present paper's innovation is the automatic identification of the most important words of the verbal content of the video lectures and the filtering of the comments based on them, thus limiting the comments to the ones that have a substantial semantic connection with the video content.

**Keywords** Opinion mining • Education • Video lectures • Comments

## 1 Introduction

Educational videos constitute the most popular form of online education material today. The recent appearance of Massive Open Online Courses [1], which rely mainly on videos, as well as the tendency for data openness, have significantly increased the amount of educational videos available online for Internet users. Users must select videos which are the appropriate for them among a variety of videos on the same subject. This procedure is time consuming considering the time required to watch and to finally choose the best video for the user.

The videos are currently found mainly in shared-media communities such as YouTube. The pages containing the videos have some special features that mainly concern the number of views, whether the viewer liked or disliked the video, a short summary and the other users' comments on them. These characteristics can be exploited for the benefit of the users, in order for them to have a better view of the

D. Kravvaris (✉) • K.L. Kermanidis
Department of Informatics, Ionian University, Corfu, Greece
e-mail: jkravv@gmail.com



P. Vlamos (eds.), *GeNeDis 2016*, Advances in Experimental Medicine and Biology 989, DOI 10.1007/978-3-319-57348-9_20

videos at their disposal. Following the saying "Do not judge a book by its cover", we study the qualities of the web pages "covers" of the video, and the comments in particular. So users have at their disposal the view of other users who watched the corresponding video, and can exploit it in their decision to watch the video or not.

This work has two important contributions. The first concerns its scientific contribution in the field of educational data retrieval by studying the automatic classification of the opinion of users, into both positive and negative ones, based on the comments of users in educational video lectures. The second relates to the selection of the comments of the users, based on the verbal content of the video. The words with the highest keyness [2] are automatically extracted from the transcript of the educational videos and, based on these words, only the comments containing them are kept. So the categorization of the users' opinions into positive or negative ones only take into account the comments that are targeted to the content of the lecture and are of substantial importance.

The first part of the paper presents related work on the subject of opinion mining in the comments of the video. The second part presents the data of our experiment followed by an analytical methodology. Last but not least, it presents the experimental procedure, the results and finally it provides the conclusions.

## 2 Related Work

Our work reinforces the relevant previous work on the opinion mining comments on YouTube and offers a new approach to qualitative selection of reviews. The work called "EmoTube: A Sentiment Analysis Integrated Environment for Social Web Content" [3] introduced a tool called "EmoTube", which presents the summarization of users' opinions based on the comments on YouTube videos, depending on their geo-location. The comments used are pre-processed in a simple manner by removing common words, words not found in dictionaries, and punctuation marks. The final presentation of the results in a pie chart form, chosen by the authors, is an interesting approach. The research called "Opinion Mining on YouTube" [4] is a systematic approach to Opinion Mining by modelling classifiers for predicting the opinion polarity and the type of comment, and also proposing robust shallow syntactic structures for improving model adaptability. To automatically identify concept words of the video, the authors use words from the video title and description. Finally, the paper "Extracting Opinion Targets from Environmental Web Coverage and Social Media Streams" [5] compares two approaches for identifying potential opinion. The first approach combines statistical keyword analysis with sentiment classification and the second approach uses dependency parsing. In this case the YouTube comments are used to identify issues related to climate change. Our work, compared to related research, presents an interesting innovative aspect, which concerns the use of educational video lecture transcripts, where the content

is of significant importance. The transcripts are utilized in order to extract the terminology of each video lecture. Then the users' comments are filtered based on the extracted terms, keeping for the classification process only those which are strongly related to the content of the video lecture.

## 3 Data

Our experiment data has been collected from the largest shared-media provider i.e. YouTube [6]. In the web page that the video is hosted there are features from the creator of the video, e.g. title, summary, etc. There are also social characteristics from the registered YouTube users such as the views, likes, dislikes and comments.

1116 videos from 40 different subject areas were selected, as shown in Fig. 1 in the form of a word cloud. The more the video lectures the bigger the size of the word of the subject in the word cloud. All the videos under examination were selected on the condition that they included recorded users' comments. Having set a limit of 3000 comments per video lecture we collected more than 1.3 million comments. The process of collecting the social characteristics such as the likes, dislikes and comments of each video was implemented using the YouTube API [7].


**Fig. 1** Word cloud

## 4 Methodology

In the first phase, the automatic selection of the most important comments from the users takes place, and then using Rapidminer v5.3 [8] a model using supervised learning is built which is applied to those comments, classifying them as positive or negative.

### *4.1 Filtering the Comments*

In order to calculate the keyness of words, i.e. the frequency of a word in the text when compared with its frequency in a reference corpus [9], we used the AntConc version 3.4.3 software [10], which employs a Maximum Likelihood algorithm. The procedure of estimating the keyness of the words takes place for each video category separately. For example, in order to estimate the keyness of the words of a specific video lecture on mathematics, the word frequencies of the transcript of this video lecture are compared against the word frequencies from the transcript of other video lectures in the mathematics category.

### *4.2 Building the Model*

Our labeled data consisted of 500 positive and 500 negative sentences. Our data contain sentences labelled with positive or negative sentiment and comments from amazon.com, imdb.com and yelp.com [11]. We created a word vector from our data sets using TF-IDF [12], which reduces the weight of the terms that frequently occur and increases the weight of the terms that appear more rarely. For the best performance of the TF-IDF we pruned the terms that appear in more than 90% of the sentences.

In the second stage we created the final word vector list following the procedures of the Rapidminer presented below:

- Tokenize: Using the "non-letters" mode, it generates single word tokens from a comment.
- Filter stop words: Removes common English words such as "a", "and", "the" etc.
- Stem (Porter) [13]: Reduce words to their stem.
- Transform cases: Converts all words into lowercase.
- Filter Tokens: We took into consideration the words with maximum length up to 25 characters, avoiding that way multiple characters strings.

In the third stage a tenfold cross-validation procedure was set in order to assess the accuracy and validity of the model. The main dataset splits into ten subsamples: nine constitute the training set and, one the test set. The model uses initially the nine training sets for training and then the test set to evaluate its accuracy. The cross-validation process is then repeated 10 times.

In the fourth stage we select the classifier. According to relevant literature [14–16] there are several algorithms for binary classification, such as Logistic Regression, Support Vector Machines (SVM), the Naive Bayes classifier, the k-Nearest Neighbors algorithm, and Decision Tree learning. Our aim is to find the one that will achieve the highest accuracy value, which shows the number of correct classifications to the total number of classifications.

### *4.3 Applying the Model*

The users' comments are subjected to the same procedure as the positive/negative labeled data when building the model. Using the "Apply Model" operator of Rapidminer we combine the unlabeled user reviews on the model constructed. Rapidminer extracts the results in a table with the prediction of positive or negative for each comment.

Finally we calculate the percentage of positive and negative opinions (comments) of the users and display graphics in a pie graph to the user.

## 5 Experimental Procedure

Initially in the procedure of filtering the comments we estimate the keyness value of the words in the transcripts using AntConc, based on the Maximum Likelihood metric. Thus, for the transcript of a particular video lecture on "mathematics" we present in Table 1 the top ten words with the highest keyness value. When filtering, however, the comments of the users of the particular video lectures, we will use all the words with positive keyness. In the end, only the comments containing at least one of these words will be kept and will be used as input during the implementation of the classification model.

**Table 1** Keyness of the words

| Rank | Keyness | Keyword |
|---|---|---|
| 1 | 1.128 | Formula |
| 2 | 0.937 | Method |
| 3 | 0.874 | Determinant |
| 4 | 0.797 | Line |
| 5 | 0.702 | Prime |
| 6 | 0.694 | Coordinates |
| 7 | 0.690 | Field |
| 8 | 0.587 | Lambda |
| 9 | 0.583 | Theta |
| 10 | 0.512 | Region |

**Table 2** Accuracy of classifiers

| Classifier | Accuracy |
|---|---|
| Logistic Regression | 70.55% |
| Support Vector Machine Linear | 82.25% |
| Naive Bayes | 60.36% |
| k-Nearest Neighbors | 40.86% |
| Decision Tree | 71.66% |

**Table 3** Positive or negative prediction of comments

| File | Positive confidence | Negative confidence | Prediction |
|---|---|---|---|
| Comment1.txt | 0.900 | 0.100 | Positive |
| Comment2.txt | 0.115 | 0.885 | Negative |
| Comment3.txt | 0.530 | 0.470 | Positive |
| Comment4.txt | 0.433 | 0.567 | Negative |

In the model construction process, the classifiers were tested for their performance. We found, as shown in Table 2, that, in our case, the Linear SVM achieved the highest accuracy (82.25%). To avoid overfitting the parameter C, which determines the flexibility in separating the classes, was assigned a value of 1, leading to model with a good generalization ability. The application of this model on the users' comments showed that the confidence parameter clearly shows whether they are categorized as positive or negative, as shown in rows 2 and 3 of Table 3. There were cases, however, where the confidence was close to the limit between positive and negative as shown in rows 4 and 5 of Table 3. For this reason we created a safe zone for the classification of comments by setting a threshold of confidence that classified the comments as positive or negative to 0.6.

## 6 Results

The results of the experiment showed that the number of user comments decrease after the filtering, at a different rate, however, for each video lecture examined. There were 19 videos whose comments were totally removed in the end, and studying them we found that the comments did not concern the verbal content but other factors such as the volume of the speaker's voice, the format of the video, and other general comments.

Figure 2 below shows the positive and negative rates of the users' comments per video lecture. Of the 1116 total videos surveyed, 806 had more positive comments, 274 had more negative comments, 17 had an equal number of positive and negative comments, and 19 had no comments at all. Figure 3 shows the respective percentages of the quantitative parameters *like* (positive aspect) and *dislike* (negative aspect) for each video.

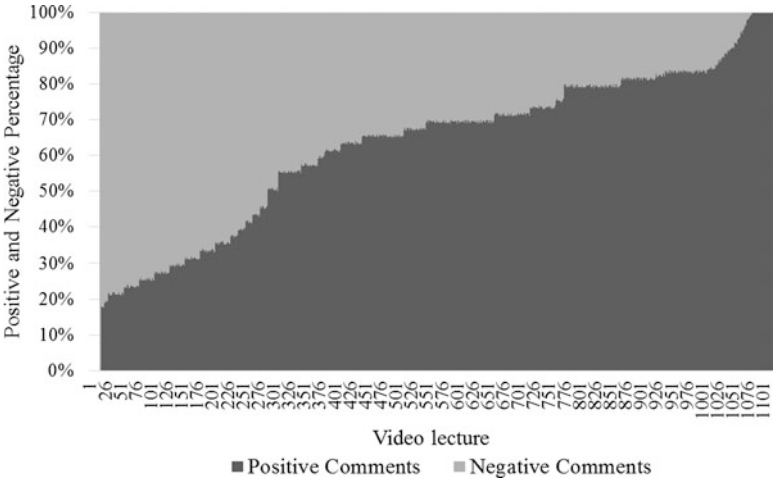


**Fig. 2** Positive and negative percentage of comments

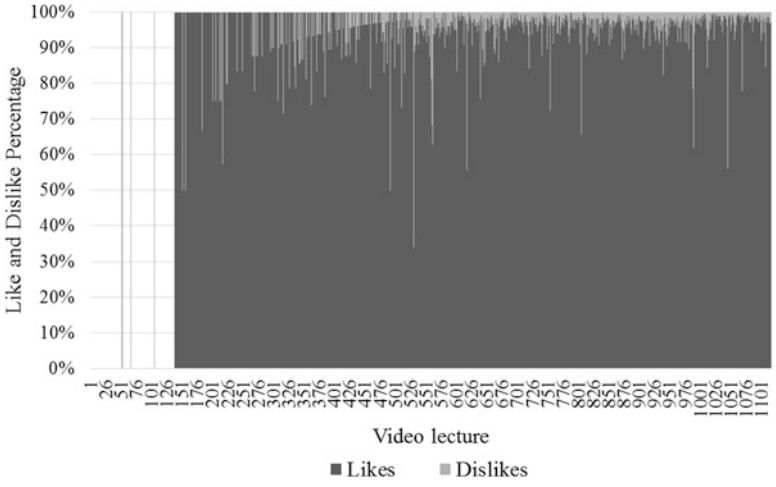


**Fig. 3** Positive and negative percentage of likes and dislikes

Comparing the two charts, we find out that there is a great difference in the rates recorded concerning the qualitative (comments) and quantitative (likes and dislikes) views of users. More specifically, it is clear that the quantitative approach gives high positive rates in video lectures reaching 96.22%, and there are few cases in which the dislikes outweigh the likes. On the other hand, the qualitative approach presents a more uniform distribution concerning the positive and negative comments with the positives reaching an average of 62.25%. This difference between our two approaches leads to the conclusion that the original perception that the user has about a video lecture through the likes and dislikes is partially misleading. Thus,

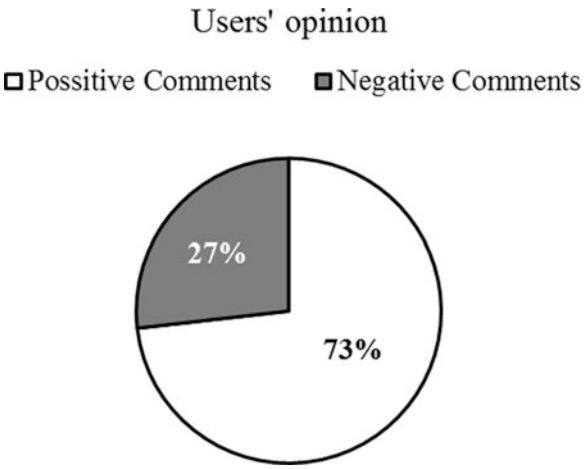


**Fig. 4** Presentation of users' opinion

it should be taken into consideration, and both approaches should be presented to the users. Furthermore, the high rates of likes will help the user to select the appropriate video lectures, since they would not exclude any of them. During our research we further found that in the quantitative approach 135 video were recorded without any likes and dislikes, although they were accompanied by users' comments. Respectively, in the qualitative approach, it was found that only 19 videos had all their comments removed, and there were no longer any recorded users' opinions. This reflects the significance of the existence of qualitative views of users, because they can offer a parallel and more meaningful view to the users for each video lecture.

For the final result of the percentage of the qualitative positive and negative comments of each video lecture under examination, we propose a presentation to the final user in the form of a pie graph [5], as shown below in Fig. 4. Furthermore, it is possible to present the words of the highest keyness value so that the user can also have at his disposal the keywords of a specific video lecture.

## 7 Conclusion

In the present paper we studied the selection of the comments of users of the video lectures based on the terms of the verbal content of the video. The automatic extraction of words with the highest keyness from the transcript of the educational videos showed that user comments, which are essential, can be identified and exploited to form an aggregated view of the users. In the opinion mining binary classification process, the SVM Linear algorithm reached the highest accuracy in relation to the others. The results of the classification highlighted a significant

issue concerning the case where the percentages of positive and negative comments are almost equal, so the correct classification can be doubted. In order to address this issue we introduced a threshold to classify the comment. The comparison of quantitative (likes, dislikes) and qualitative (comments) parameters showed that there is a divergence of opinions. The average percentage of positive views of the quantitative parameters is 96.22%, and classifies all the videos as positive, thus not allowing users to have a clear picture of the video lecture. The corresponding percentage of quality parameters, however, is 62.25%. Thus, the existence of the users' opinion, which is derived from the users' comments, and focuses on the verbal content of the video lecture, gives a qualitative view to the users on the video they want to watch.

## References


1. Siemens, G. 2013. Massive Open Online Courses: Innovation in Education. In *Open Educational Resources: Innovation, Research and Practice*, 5.
2. Scott, M., and C. Tribble. 2006. *Textual Patterns: Key Words and Corpus Analysis in Language Education*. Vol. 22. John Benjamins Publishing.
3. Polymerou, E., D. Chatzakou, and A. Vakali. 2014. Emotube: A Sentiment Analysis Integrated Environment for Social Web Content. Proceedings of the 4th International Conference on Web Intelligence, Mining and Semantics. ACM.
4. Severyn, A., A. Moschitti, O. Uryupina, et al. 2014. Opinion Mining on YouTube. *ACL* (1): 1252–1261.
5. Weichselbraun, A., A. Scharl, and S. Gindl. 2016. Extracting Opinion Targets from Environmental Web Coverage and Social Media Streams. 49th Hawaii International Conference on System Sciences, 1040–1048. IEEE.
6. Wattenhofer, M., R. Wattenhofer, and Z. Zhu. 2012. The YouTube Social Network. ICWSM, June 2012.
7. Padilla, A., and A. DeFields. 2009. *Beginning Zend Framework*. Apress.
8. Hofmann, M., and R. Klinkenberg. 2013. *RapidMiner: Data Mining Use Cases and Business Analytics Applications*. CRC Press.
9. Anthony, L. 2016. AntConc Tutorial. In AntConc Software web page from Waseda University. Available via http://www.laurenceanthony.net/software/antconc/releases/AntConc343/help.pdf. Accessed 10 Feb 2016.
10. ———. 2014. AntConc (Version 3.4.3) [Computer Software]. Tokyo, Japan. Available via http://www.laurenceanthony.net. Accessed 10 Feb 2016.
11. Kotzias, D., M. Denil, N. De Freitas, and P. Smyth. 2015. From Group to Individual Labels Using Deep Features. Proceedings of the 21st ACM SIGKDD International Conference on Knowledge Discovery and Data Mining, 597–606. ACM.
12. Ramos, J. 2003. Using TF-IDF to Determine Word Relevance in Document Queries. Proceedings of the First Instructional Conference on Machine Learning.
13. Willett, P. 2006. The Porter Stemming Algorithm: Then and Now. *Program* 40 (3): 219–223.
14. Kazemian, H.B., and S. Ahmed. 2015. Comparisons of Machine Learning Techniques for Detecting Malicious Webpages. *Expert Systems with Applications* 42 (3): 1166–1177.
15. Rashid, B., M.R. Arbabshirani, E. Damaraju, et al. 2016. Classification of Schizophrenia and Bipolar Patients Using Static and Dynamic Resting-State fMRI Brain Connectivity. *NeuroImage* 134: 645–657.
16. Thammasiri, D., D. Delen, P. Meesad, and N. Kasap. 2014. A Critical Assessment of Imbalanced Class Distribution Problem: The Case of Predicting Freshmen Student Attrition. *Expert Systems with Applications* 41 (2): 321–330.

# Cognitive Enhancement Using ICT and Its Ethical Implications

**Spyros Doukakis, Giannis Stamatellos, and Nektaria Glinou**

**Abstract** The utilization of digital tools aiming at the cognitive enhancement of students and adults, so that they can achieve better performance and professional or academic success, has increased in recent years. This paper focuses on ICT tools such as computer games, programming languages and educational software as means for cognitive enhancement and attempts to highlight their contributions. Issues of design and the limitations of digital tools are discussed. In the final section, the ethical implications of using educational ICT tools for cognitive enhancement from a virtue ethics perspective are presented.

**Keywords** ICT • Cognitive enhancement • Ethical implications • Education • Virtue ethics

## 1 Introduction

The cognitive enhancement of students and adults has always been a desideratum of formal and informal education. In this context, cognitive enhancement focuses on the improvement or strengthening of cognitive functions such as attention, memory, processing speed and problem solving [1]. In recent years, research in cognitive enhancement has gained more interest as it is not only related to cases of patients who suffer from some kind of dementia or demonstrate attention deficit disorder or have had a stroke etc., but it has broadened its spectrum to also include individuals without serious health issues, of all ages, with a view to the enhancement of their cognitive function so that they will have better performance and professional or academic success.

For cognitive enhancement to be achieved, different interventions are attempted and a variety of strategies are chosen, some of them generally acknowledged and documented in publications and others described as quite promising but not yet widely acknowledged [2]. Thus, there is an initial division between pharmaceutical

S. Doukakis (✉) • G. Stamatellos • N. Glinou
The American College of Greece, 6 Gravias Street, GR-153 42 Aghia Paraskevi, Athens, Greece
e-mail: sdoukakis@acg.edu



P. Vlamos (eds.), *GeNeDis 2016*, Advances in Experimental Medicine and Biology 989, DOI 10.1007/978-3-319-57348-9_21

and non-pharmaceutical enhancements. Pharmaceutical enhancements or biological cognitive enhancements (BCEs) involve pharmaceutical products and other technologies such as implants or configurations, magnetic stimulation and possibly modification of human embryos via genetic engineering [3]. Non-pharmaceutical enhancements include strategies such as nutrition, physical exercise and sleep and other more focused interventions such as meditation, mnemonic techniques, education through digital tools and brain stimulation [2]. The present study focuses on non-pharmaceutical enhancements, particularly on cognitive enhancement through education with the use of digital tools. First, a literature review on cognitive enhancement strategies through various types of digital tools will be presented. A closer look on the design of such tools and their limitations will follow. Next, ethical issues arising from the utilization of digital tools aiming at cognitive enhancement with special reference to a virtue ethics perspective of human selfhood and autonomy will be examined. The study concludes with suggestions for research approaches towards studying the education of students and adults on the use of digital tools aiming at their cognitive enhancement.

## 2 ICT and Cognitive Enhancement

The development of digital tools (from the construction of the first computer in 1942 to recent tablets and smartphones) provided researchers and experts with the opportunity to explore the possibilities of educational media. The launching of each new device (microcomputers, graphing calculators, tablets, smart phones etc.) is accompanied by a multitude of programs and software either for educational purposes or for the accommodation of professional and social needs, with the latter category often utilized for educational purposes as well.

According to literature [1], certain software programs aiming at cognitive enhancement have been developed. Software programs such as Brain Fitness Program, Cogmed QM, Braintrain Captain's Log and Cognifit have been developed by teams of specialists in the field, and researchers have studied their contribution to the cognitive enhancement of individuals. Participants in the studies were healthy adults (young and old), as well as patients with some form of dementia. A detailed analysis of the results derived from the aforementioned studies can be found in Jak et al. [1].

Moreover, electronic games that are believed to contribute to cognitive enhancement are available on the market. Traditional games of this kind are Tetris, as well as games that entail problem solving, puzzles, crosswords, etc. In their article, Jak et al. [1] analyze and discuss findings of research studies conducted with the use of electronic games such as Nintendo Big Brain, Rise of Nations, Medal of Honor, Tetris and Space Fortress.

In the field of education, research has focused on serious games, which are designed with a view to cognitive enhancement, skill development and greater engagement of the learners. According to Green and Bavelier [4], suitable for

cognitive enhancement are those games that have rich 3D possibilities, involve fast moving targets and require visual processing of the whole image of the game, contributing to the development of attention and improvement of speed as well as precision of decision-making.

In their critical analysis, Jak et al. [1] infer that there is a considerable number of programs (software and games) that have contributed to the improvement of educational methods in cognitive enhancement activities. However, they attest that only a limited number of studies have indicated improvements in people's daily lives or long-term improvements. Finally, they point out the methodological limitations of the existing research studies, concluding, nevertheless, that research findings show that software and games positively affect the individual's sense of personal development and raise his/her self-confidence. The latter conclusion is also supported by Green and Bavelier [4], who state that when serious games involve action, they improve perceptive skills, develop selective attention skills, contribute to cognitive enhancement and reinforce the skill of "learning how to learn"; however, further research is required to investigate their impact on daily life and the way gamification can contribute to young people's and adults' learning. Connolly et al. [5] corroborate this viewpoint and place emphasis on the activities, skills and functions that games must include in order for learners to achieve the expected learning outcomes.

Programming languages have also been suggested as tools for cognitive enhancement, aiming at algorithmic problem-solving, development of analytic thought and attention. In specific, the Logo programming language has been a tool for the cognitive development of students, which has enabled mathematical expression through programming [6]. Logo was transformed into the Scratch language by a group of scientists in the Lifelong Kindergarten Group at the Massachusetts Institute of Technology. Scratch is a visual programming language that can be utilized for the development of games, simulations and puzzles, thus contributing to brain stimulation and to interaction between users and the computer. Both Logo and Scratch are regarded as educational languages appropriate for children and adults. Moreover, studies on university students have shown that programming languages are among the tools for cognitive enhancement. According to a study by Georgouli and Sgouropoulou [7], writing programs in an object-oriented language contributes to cognitive enhancement. The researchers maintain that, apart from the programming language itself, important factors for cognitive enhancement and development of the students' social skills are group work, the blended learning model (which was employed in the study), and peer assessment. Recently, researchers have studied the use of environments of tangible programming with robot programming activities as a method of cognitive enhancement in patients with memory problems. According to Demetriadis et al. [8], these environments contribute to the enhancement of logic and analytical thought as well as visual-spatial skills.

In the next section educational software that has been integrated to a great extent in the education of students and adults are discussed. Early development of software related to science and mathematics aimed at the visualization, modeling and programming, and typically included activities in the form of drill and practice,

mainly offering a richer visual approach in comparison with the paper and pencil model. Over time, there has been development of software suitable for: (a) the dynamic management of objects and relations, (b) algebraic exploration, (c) exploration, simulation and processing of data and, finally, (d) modeling. These kinds of software are accompanied by proper theoretical contexts which emphasized the pedagogical expediency of their use and were often based on the learning theory of constructivism. Furthermore, they focus on the role that language and other mediation means play in teaching and learning on the basis of the principles of the socio-cultural theory [9], and situated learning [10] as a result of the activity, context and culture within which the process of learning and cognitive enhancement is taking place. Additionally, the role of scaffolding in cognitive enhancement is of particular importance, since these kinds of software and the accompanying activities are controlled by the learner, thus contributing to the construction and reconstruction of personal meanings.

In this context, educational software that could contribute to cognitive enhancement and skill development has been developed. Indicative examples of such software are GeoGebra and Maple for mathematics, as well as Modellus and Interactive Physics for the natural sciences. With the development of appropriate tasks, these software packages offer incentives and contribute to the strengthening of mental abilities, such as attention, memory, processing speed and problem-solving. In recent years, these kinds of software have been improved considerably and provide opportunities for increased motivation and cognitive enhancement through multiple representations. Besides, the results from their use regarding the performance and formal knowledge of the learners have been investigated [11–13].

As evident from the above, ICT is utilized to a great extent for the cognitive enhancement of individuals. However, the way and the context of utilization are important factors that can indicate their possible limitations on one hand and their possibilities on the other. In this context, there is an open discussion on issues of design and the limitations of ICT as tools for cognitive enhancement, as well as on ethical issues arising from their use. Both issues will be approached in the next sections.

## 3 Design and Limitations of Digital Tools

The increasing development of digital tools for educational purposes, as well as the development of digital tools for accommodating professional and social needs, which are nevertheless utilized to support educational processes, raises the question of their suitability for education and the cognitive enhancement of the learners. It is not necessary for all (educational) digital tools to possess those characteristics that could contribute to the cognitive enhancement of the learners and have a positive impact on attention, memory, processing speed and problem solving issues [14].

Furthermore, when developing digital tools along with the accompanying activities, it is essential to consider certain characteristics that have been found to

contribute to the learners' cognitive enhancement. Even the interface environment of a programming language can contribute to the learners' cognitive enhancement. According to Plerou et al. [15], the interface environment, the color and the existence of narration are all crucial during the development of such environment. In the case of digital tools that contribute to the learners' cognitive enhancement it is also important to take into consideration the principles involved in the evaluation of digital tools for educational purposes [16]. In specific, the axons of evaluation are:

- The content, as regards to both the existence of scientific validity and the absence of partiality.
- The suitability of digital tools with a view to the learners' cognitive enhancement and, more specifically, the presence of multiple representations, variety of applications from real life, utilization of simulations, improvement of traditional teaching approaches, opportunities for assessment and self-assessment, possibilities for individualized and differentiated support, etc.
- The degree of interaction with the user, which facilitates navigation and access to various parts of the application; the existence of various levels of difficulty where the flow is controlled by the user; instructions to the learner are clear; when the learner repeats the same part of the software, different questions appear and after a certain number of wrong answers the correct one is given.
- The structure and organization with a modular approach, table of contents, help to user when needed, possibilities of enrichment and extension of the learning process by the instructor; also, messages and texts are succinct, clear and comprehensible.
- Aesthetics, with reasonable use of fonts, colors and symbols, well organized windows compatible with the goals of the attempted cognitive enhancement.
- Technical adequacy for non-stop operation, compatibility with all operating systems and possibility for online use.
- The existence of a user's guide with technical guidelines, troubleshooting instructions and pedagogical instructions for its utilization.

Finally, since education is indispensably connected with research, it is essential that the related digital tools can be utilized as research tools. This will enable the researcher and the educator to determine the degree to which these tools contribute to cognitive enhancement as well as their limitations and possibilities. The ultimate goal will be to optimize possible benefits from their use and to enable the recording of their contribution to the learners' personal development on the basis of the context in which it is attempted.

## 4 Ethical Implications

The ethical implications of human enhancement have been discussed in a normative context in terms of human agency and with special reference to politics, society and

the law [2, 17]. An ethical debate is articulated in modern bioethical discussions [18], including both pharmaceuticals and non-pharmaceutical means of cognitive enhancement such as nutrition, physical exercise, sleep, meditation, mnemonic strategies, computer training, and brain stimulation [2]. However, a bioethics top-down analysis has been criticized in its "mere application of established principles a priori that are recognized as valid in all circumstances without regard to the specificity and situatedness of each intervention." [17]. Based on this criticism, both the Kantian categorical imperative and the utilitarian principle have been rejected [19]. The problem which has been identified is that different context-sensitive properties of human enhancement are not subject to a generalized and comprehensive ethical theory [17].

Considering the limitations of a top-down action-based ethical approach, the following argument could be suggested: since cognitive enhancement affects personal development and well-being through fostering secondary virtues such as the feeling of self-mastery and achievement, endurance, self-confidence and may confer self-knowledge [2], therefore a self-directed agent-based virtue ethics approach is relevant to the discussion of cognitive enhancement. Dresler et al. [2] state in their ethical analysis that "pharmaceutical or other enhancers are not intrinsically ethically dubious". However, in the light of a virtue ethics perspective, the use of cognitive enhancement could be reevaluated as "intrinsically dubious" as far as self-determination and human autonomy are concerned. Self-determination is primarily related to the decisions of the moral agent and the reasons to use cognitive enhancement are directly related to self-formation and the agent's personal improvement.

In particular, focusing on the use of ICT in computerized cognitive training, the potential to positively impact one's sense of social connectivity and self-efficacy is addressed [1]. Self-efficacy constitutes an important element in the ethical evaluation of cognitive enhancement using ICT in particular, and human enhancement in general, and also leads the discussion to a computer ethics context with a virtue ethics self-directed aspect. During the last decades, virtue ethics has been revived with a focus on human selfhood and character development, especially after the monumental work of Alasdair MacIntyre's *After Virtue* (first published 1981) [20]. Virtue ethics is also related to computer and cyber ethics discussions.

Frances Grodzinsky [21] emphasized the importance of virtue ethics in the information society and computer education. She argued that problem-solving in computer ethics cannot be strictly based on a Kantian duty-based deontological or a utilitarian consequence-based approach; a serious macro-ethical issue generated by ICT needs to be primarily evaluated from a micro-based perspective of the individual's moral agency [21, 22]. Virtue ethics develop students' personal ethics which later leads to professional ethics in ICT. Grodzinsky reevaluates the teaching methods of computer ethics courses in class in the ethics of Aristotle and Kant, considering however a relationship between virtue ethics and some elements of Kantianism in terms of human agency and autonomy [21, 23].

Human autonomy has been recognized as an intellectual virtue important for human agency and values; a natural desire to knowledge and autonomy underlies the competence of a self-determined and independent moral agent [24]. As Roberts

and Wood [24] put it, "the autonomous intellectual is such, not because he is an intellectually self-made man, but because he has actively and intelligently appropriated the regulators in his noetic structure.". Autonomy and self-determination is also important in education. According to Grodzinsky, virtue ethics provide a character-forming self-reflection that appears to be more applicable to students than an action-guiding rule-based agency; students see "the utilitarian or the deontologist as someone other than themselves, and there seems to be very little internalization of these action-based theories" [21].

Bearing in mind an ethical focus on 'being rather than doing', a character-based aspect in the use of ICT education is beneficial. ICT students are able to develop practical wisdom and moral excellence by being aware of the core values that undermine a computer ethics question. This is achieved by working on their personal identity, imagination and narrative [21]. Hermanns [23] further argued that virtue ethics should be approached from an individual human flourishing viewpoint with reference to moral values and behaviors in the ontology of a virtuous character and the development of virtuous habits. Moreover, Coleman [25] identifies a list of characteristics of computational agents that can be understood as virtues within a framework of virtue ethics. Coleman suggests that computer ethics could be conceived as a form of android ethics and the study of the morals of computational agents. As in the above critical discussion of an action-based ethical approach in the use of ICT, Coleman maintains that a construction of a moral computer should not be based on a deontological or consequential ethical approach, but more on an Aristotelian agent-based virtue ethics perspective.

In addition to the Aristotelian view, modern discussions of computer ethics education is also enlightened by a Platonic perspective of character development in relation to a more contemplative, or even metaphysical, self-directed theory of moral agency. More precisely, a Neoplatonic virtue ethics of intellectual autonomy and self-determination are relevant to cyber ethics and particularly a character-based moral agency applicable in computer education [22]. In this respect, a Platonic perspective of virtue ethics is central to the agent's cognitive enhancement as Plato's cardinal virtues of wisdom, justice, courage and self-control are the prerequisite and fundamental skills of character development and human excellence, goodness and knowledge. In this light, an Aristotelian virtue ethics perception is also relevant to the debates of human enhancement in terms of the political and personal achievement of eudaimonia through ethical *praxis*. Therefore, both the Aristotelian and the Platonic perspectives of virtue ethics underlie a political, social and psychological agent-based value that could be used as a guidance to the question of human enhancement not only in terms of self-efficacy at micro-level but also by extension in its socio-political ontology of moral agency at a macro-level. Thus, while a consequence-based utilitarian ethical theory promotes personal happiness and social utility by focusing on the consequences of moral action, and a duty-based Kantian or deontological ethical theory treats the moral agents as ends in themselves, it is suggested that the ethical debate of cognitive enhancement, and the wider issue of human enhancement, should be more effectively approached in the light of a virtue ethics discussion on human selfhood and autonomy.

## 5 Conclusion

The utilization of digital tools aiming at cognitive enhancement is an important approach towards supporting students and adults. Considering that today, in addition to computers, there are tablets and smartphones equipped with appropriate software and complementary activities available, it is useful to explore the ways those could contribute to cognitive enhancement. In addition, it seems that the ethical debate about cognitive enhancement should be moved from the level of action to the center of human selfhood, from a practical and empirical calculation of decision-making to the virtues of the person and the internal determinations, conscious decisions and the will of the moral agent. Finally, it seems that an important factor of cognitive enhancement could be the socio-cultural context in which it is attempted. The above issues are yet to be explored in future research studies.

## References

1. Jak, A.J., A.M. Seelye, and S.M. Jurick. 2013. Crosswords to Computers: A Critical Review of Popular Approaches to Cognitive Enhancement. *Neuropsychology Review* 23 (1): 13–26.
2. Dresler, M., A. Sandberg, K. Ohla, C. Bublitz, C. Trenado, A. Mroczko-Wasowicz, S. Kühn, and D. Repantis. 2013. Non-pharmacological Cognitive Enhancement. *Neuropharmacology* 64: 529–543. doi:10.1016/j.neuropharm.2012.07.002.
3. Buchanan, A. 2011. Cognitive Enhancement and Education. *Theory and Research in Education* 9 (2): 145–162. doi:10.1177/1477878511409623.
4. Green, C.S., and D. Bavelier. 2015. Action Video Game Training for Cognitive Enhancement. *Current Opinion in Behavioral Sciences* 4: 103–108. Available at: http://linkinghub.elsevier.com/retrieve/pii/S2352154615000613.
5. Connolly, T.M., et al. 2012. A Systematic Literature Review of Empirical Evidence on Computer Games and Serious Games. *Computers & Education* 59 (2): 661–686. doi:10.1016/j.compedu.2012.03.004.
6. Papert, S. 1980. *MindStorms, Children, Computers and Powerful Ideas*. New York: Basic Books.
7. Georgouli, K., and C. Sgouropoulou. 2013. Collaborative Peer-Evaluation Learning Results in Higher Education Programming-Based Courses. ICBL2013 – International Conference on Interactive Computer Aided Blended Learning, 309–314.
8. Demetriadis, S., V. Giannouli, and T. Sapounidis. 2015. Robot Programming and Tangible Interfaces for Cognitive Training. In *Handbook of Research on Innovations in the Diagnosis and Treatment of Dementia*.
9. Vygotsky, L.S. 1962. In *Thought and Language*, ed. E. Hanfmann and G. Vakar. Cambridge, MA: The MIT Press.
10. Lave, J., and E. Wenger. 1991. *Situated Learning. Legitimate Peripheral Participation*. Cambridge: University of Cambridge Press.
11. Doukakis, S., and N. Matzakos. 2013. Training Prospective Engineering Educators in the Use of GeoGebra for Simulation Construction. 12th International Conference on Information Technology Based Higher Education and Training (ITHET), 1–5. Antalya, Turkey: IEEE. Available at: http://ieeexplore.ieee.org/document/6671048/?arnumber=6671048.

12. Gómez-Chacón, I.M., I.M. Romero Albaladejo, and M. del Mar García López. 2016. Zigzagging in Geometrical Reasoning in Technological Collaborative Environments: A Mathematical Working Space-Framed Study Concerning Cognition and Affect. *ZDM-The International Journal on Mathematics Education*. Available at: http://link.springer.com/10.1007/s11858-016-0755-2.
13. Takaci, D., G. Stankov, and I. Milanovic. 2015. Efficiency of Learning Environment Using GeoGebra When Calculus Contents Are Learned in Collaborative Groups. *Computers and Education* 82: 421–431.
14. Hubert-Wallander, B., C.S. Green, and D. Bavelier. 2011. Stretching the Limits of Visual Attention: The Case of Action Video Games. *Wiley Interdisciplinary Reviews: Cognitive Science* 2 (2): 222–230.
15. Plerou, A., P. Vlamos, and P. Kourouthanasis. 2014. Screening Dyscalculia and Algorithmic Thinking Difficulties. 1st International Conference on New Developments in Science and Technology Education.
16. Zibidis, D., M. Chionidou-Moskofoglou, and S. Doukakis. 2011. Primary Teachers' Embedding Educational Software of Mathematics in Their Teaching Practices. *International Journal of Teaching and Case Studies* 3 (2/3/4): 216–227.
17. Battaglia, F., and A. Carnevale. 2014. Epistemological and Moral Problems with Human Enhancement. *Humana.Mente Journal of Philosophical Studies* (26): III–XXI.
18. Racine, E., et al. 2014. The Value and Pitfalls of Speculation About Science and Technology in Bioethics: The Case of Cognitive Enhancement. *Medicine, Health Care and Philosophy* 17 (3): 325–337.
19. Nida-Rümelin, J. 2007. Human Biotechnology as an Ethical and Social Challenge. In *Humanbiotechnology as Social Challenge*, ed. N. Knoepffler, D. Schipanski, and S.L. Sorgner, 129–135. Aldershot, Burlington: Ashgate Publishing.
20. MacIntyre, A. 1984. *After Virtue*. 2nd ed. Notre Dame: Univ. of Notre Dame Press.
21. Grodzinsky, F. 2001. The Practitioner from Within: Revisiting the Virtues. In *Readings in Cyberethics*, ed. A.R. Spinello and T.H. Tavani, 580–591. Jones and Bartlett Publishers.
22. Stamatellos, G. 2011. Computer Ethics and Neoplatonic Virtue: A Reconsideration of Cyber Ethics in the Light of Plotinus' Ethical Theory. *International Journal of Cyber Ethics in Education* 1 (1): 1–11.
23. Hermanns, S. 2007. How Virtuous is the Virtual? Perspectives on New Media. Quality of Life and Virtue Ethics, *CEPE* 2007 July 12–14, University of San Diego, USA.
24. Roberts, C.R., and W.J. Wood. 2007. *Intellectual Virtues: An Essay in Regulative Epistemology*. Oxford: Oxford University Press.
25. Coleman, K.G. 2001. Android Arete: Toward a Virtue Ethic for Computational Agents. *Ethics and Information Technology* 3 (4): 247–265.

# Smart Health Caring Home: A Systematic Review of Smart Home Care for Elders and Chronic Disease Patients

**Marina Moraitou, Adamantia Pateli, and Sotiris Fotiou**

**Abstract** As access to health care is important to people's health especially for vulnerable groups that need nursing for a long period of time, new studies in the human sciences argue that the health of the population depend less on the quality of the health care, or on the amount of spending that goes into health care, and more heavily on the quality of everyday life. Smart home applications are designed to "sense" and monitor the health conditions of its residents through the use of a wide range of technological components (motion sensors, video cameras, wearable devices etc.), and web-based services that support their wish to stay at home. In this work, we provide a review of the main technological, psychosocial/ethical and economic challenges that the implementation of a Smart Health Caring Home raises.

**Keywords** Smart environments • Smart home • Smart care • Elderly people • People with chronic disease/disabilities • Monitoring • Assistance • Care • Sensors • Actuators • Echnological • Psychosocial • Economic challenges • Independent living • Quality of life

## 1 Introduction

Based on estimation for the evolution of demographics, life expectancy is predicted to increase resulting in population aging [1]. As the great majority of elderly people are living alone, they treat their home as a refuge, in which they try to cope with highly risk situations, such as falls, sensory impairment, diminished mobility, isolation, and medication management. Aiming to a society with healthy citizens, we seek solutions that will improve the quality of their lives and allow them to stay safe at home. Recent developments in information and communication technologies related to computer networks, embedded systems and artificial intelligence have made the vision of building a smart home environment technologically feasible.

M. Moraitou (✉) • A. Pateli • S. Fotiou
Department of Informatics, Ionian University, Corfu, Greece
e-mail: moraitoum@gmail.com; pateli@ionio.gr; fotiousotirios@yahoo.gr



P. Vlamos (eds.), *GeNeDis 2016*, Advances in Experimental Medicine and Biology 989, DOI 10.1007/978-3-319-57348-9_22

Smart environment is a physical world interwoven with invisible sensors, actuators, displays, and computational elements. These computing elements are generally embedded seamlessly in everyday objects and networked to each other and beyond (the internet, usually) [1]. The term "Smart health caring homes" address to a residence equipped with technology that facilitates monitoring and remote sensing of residents and/or promotes independence and increases residents' quality of life. The technology is integrated into the infrastructure of the residence and does not in principle require training of or operation by the resident, distinguishing thereby smart home applications from stand-alone units that can be used in the home setting and need to be operated by the end-user (e.g., blood pressure cuffs, videophones, etc.).With the intention to enhance users' independence, SHCH projects utilize a wide range of applications serving different users' needs [2]:

- *Physiological monitoring*. Collection and analysis of data pertaining to physiological measurements such as vital signs of pulse, respiration, temperature, and blood pressure, as well as blood sugar level, bladder and bowel output.
- *Functional monitoring/Emergency detection and response*. Collection and analysis of data pertaining to functional measurements such as general activity level, motion, gait, meal intake, and other activities-of-daily-living. Emergency detection is enabled through the collection of data that indicate abnormal or critical situations (such as falls).
- *Safety monitoring and assistance*. Collection and analysis of data pertaining to measurements that detect environmental hazards such as fire or gas leak. Safety assistance includes functions such as automatic turning on off bathroom lights when getting out of bed, facilitating safety by reducing trips and falls. Location technologies aimed at safety also fit into this type.
- *Security monitoring and assistance*. Measurements that detect human threats such as intruders. Assistance includes responses to identified threats.
- *Social interaction monitoring and assistance*. Collection and analysis of data pertaining to social interactions such as phone calls, visitors, and participation in activities. Social interaction assistance includes technologies that facilitate social interaction, such as video-based components that support video mediated communication with friends and loved ones, virtual participation in group activities etc.
- *Cognitive and sensory assistance*. Cognitive assistance technologies include those of automated or self-initiated reminders and other cognitive aids, such as medication reminder and management tools and lost key locators, for users with identified memory deficits. They also include task instruction technologies, such as verbal instructions in using an appliance. Sensory assistance includes technologies that aid users with sensory deficits, such as eyesight, hearing, and touching problems.

In this paper, we provide a review of the main issues that must be addressed during the implementation of a SHCH project. Based on this review, the main research streams could be divided into: technological, psychosocial and economic challenges. Following, we present the main findings of prior studies and outline avenues for future research in the area of SHCH environments.

## 2 SHCH Challenges

### *2.1 Technological Challenges*

Taking into consideration the recent advances in networking technologies, such as devices' miniaturization and increase of computational power in pervasive and ubiquitous computing, it can be easily deducted that recent technological maturity gave a significant impetus to smart environments research. SHCH's design requires the combination of research from different disciplines, such as computer networks, embedded systems and artificial intelligence, ubiquitous and mobile computing, robotics, middleware, agent-based software, sensor networks and multimedia computing. SHCH are complex heterogeneous environments comprising a Home Automation System that contains a set of home electric and electronic appliances that fulfil several functions (e.g. washing and cooking machines, heaters and more advanced "smart" devices [3] like smart floors, etc.), a Control System that combines human with software-based control using information provided by sensors and the instructions sent to actuators in order to achieve one or more high-level goals or functions and a Home Automation Network that assures all technological components, including Home Automation System and Control System, can exchange status and control information [4]. Figure 1 presents an

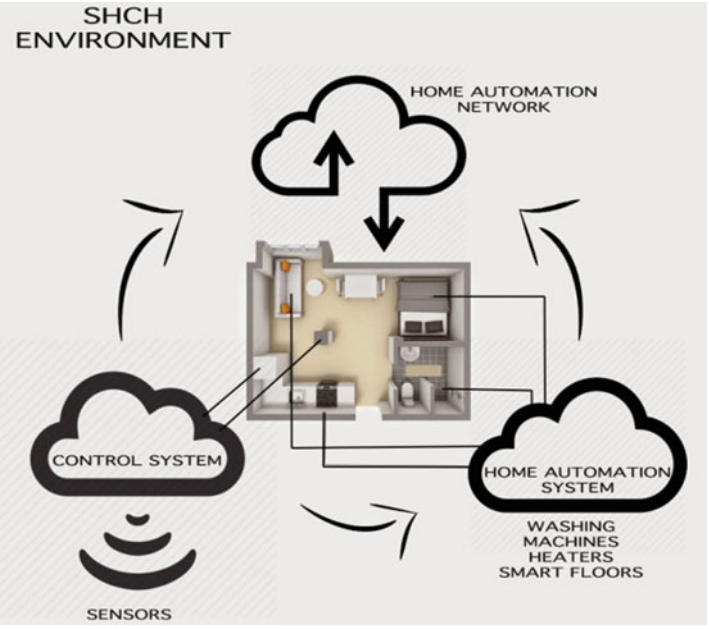


**Fig. 1** Smart health care home architecture

indicative SHCH architecture by identifying the main components of the network and the way in which they communicate.

Perception of the environment is a bottom-up process. Sensors monitor the environment using physical components and make information available through the communication layer. The database stores this information while other information components process the raw information into more useful knowledge (e.g., action models, patterns). New information is presented to the decision making algorithms (top layer) upon request or by prior arrangement. Action execution flows top-down. The decision action is communicated to the services layers (information and communication) which record the action and communicates it to the physical components. The physical layer performs the action with the help of actuators or device controllers, thus changing the state of the world and triggering a new perception. In order to implement a secure and functional smart health care home environment, it is required to assure secure exchange of clinical data between different systems or data sources. To facilitate the appropriate collection, transmission, processing and interpretation of information, a semantically sound and technically feasible set of standards is also demanded. These standards include clinical, vocabulary, messages, workflow, and technical standards [5].

- *Clinical standards*, such as guidelines indicating evidence-based care, must be clearly reflected in the domain knowledge included in programs for disease management and wellness.
- *Vocabulary standards* pertain to terminologies in different formats and usually developed for specific purposes, such as clinical documentation, comparison of data, or statistical reporting.
- *Standards for messages address* the issue of interoperability and focus on the electronic exchange of information within or between health information systems. Health Level Seven (HL7) is such an example, which provides standards for the exchange, management, and integration of data that support clinical patient care and the management, delivery, and evaluation of health care services [6]. Such an interoperability standard is essential when it comes to exchange of data between a home-based application and the electronic medical record of a clinical facility. Current HL7 v3 message models, e.g., for patient care, do allow for the patient to be "author of health information," thus respecting self-care responsibilities.
- *Workflow standards* describe the tasks and processes of the care plan, involved stakeholders and timeline, required interactions, and transactions. For example, at home care, there is a detailed care plan that dictates the number of home care visits, their goals, who conducts them (registered nurse, nursing aid, social worker, etc.), and rules for specific processes (e.g., capturing of vital signs).
- *Technical standards* address infrastructure, networking, and security issues. Particularly relevant for disease management applications are the Internet protocol (TCP/IP) for the infrastructure and Extensible Markup Language (XML) for the technical expression of messages.

The interoperability between different entities among software or hardware applications at home care and disease management demands also the use of common communication protocols [7]. These protocols can be classified into: (1) proprietary protocols, owned by private companies and not disclosed to the public, (2) public protocols, usually maintained by company or consortium, but public to public, (3) standard protocols that are recognized by standardization bodies. Some of the most famous communication protocols are IEEE 802.15.4/Zig-Bee, EIB/KNX ISO/IEC 14543-3, IEEE 802.11/Wi-Fi. The integration and the interoperability of heterogeneous smart devices is achieved by an intermediary software layer called middleware that is responsible for (1) interfacing with device drivers (2) providing interoperability using standardized interfaces and protocols. The most commonly used standards for the development of the middleware are Open Services Gateway initiative (OSGi) [8], Foundation for Intelligent Physical Agents (FIPA) [9] and Web Standards (WS) [10]. Concluding the above technological challenges, it becomes obvious that the SHCH project must be simple, robust and easy to configure with zero errors, taking into concern that the targeted users are from different psychological/social/mental/physical disability status and a failure of the system could cost one's life.

## *2.2 Psychosocial and Ethical Challenges*

Living your everyday life using the aforementioned technology introduces psychosocial and ethical issues concerning the usability, accessibility, privacy, security, autonomy of the home and mainly the lack of human touch. Usability of the SHCH is of critical importance as it is related to the accessibility of users to the new technology and leads to rapid learning, good skill retention, and low error rates. End-users should be able to communicate with each other, find information, and navigate the software and hardware with ease [11]. A large segment of home care patients are elders and in some cases have functional limitations due to aging, or their diagnosis, or both. A functional limitation describes a "reduced sensory, cognitive or motor capability associated with human aging, temporary injury, or permanent disability that prevents a person from communicating, working, playing or simply functioning in an environment where other people in the population can function" [12]. Thus, system designers should be aware of all limitations (e.g. many users may not have high-speed internet infrastructure in their home), in order to create fully operational, accessible, usable, rigorous, low cost SHCH environments that are not addressed to a small portion of citizens [13].

A further ethical issue pertains to call for an examination of how privacy, confidentiality and security of transmitted and exchanged clinical data are protected as regard to individuals' health information. These concerns indicate that technology and ethics may not always co-exist harmoniously. Privacy issues sometimes have been identified as a potential barrier to acceptance of assistive health information technologies [14–16]. Privacy is composed of: (a) informational privacy which

refers to the desire to control the sharing of personal information with others and may be violated when health devices reveal more information than the user desires, and (b) physical privacy which is related to both the degree to which one is physically accessible to others and the accessibility of one's personal space or territory and may be violated when health technology impinges on the user's control of such access. Regulation concepts towards privacy demand transparency, informed consent, confidentiality, purposefulness, privacy, dignity, information management, usability, user control, and the coordination of responsibilities and actions within a clearly-defined framework for action. Berlo from introduces the 3-Ps (Perspectives, Principles, and Paradigms) approach which introduce the necessity of defining older people's perspectives about the new technology. Principles of autonomy, beneficence, non-maleficence and justice are applied, and the paradigms or contextual situations are referenced [17]. Zwijsen et al. also point out that "people are, or should be, independent and self-determinant" [15].

A different concern that raises with the introduction of SHCH in our life is the fact that they create functional dependency of users turning them to less autonomous individuals. [18] It also supports systems that enhance the medicalization of the home or set new functional attributes as a consequence of non-portability or limited power supply which may restrict users to shortened distance or time away from home. Additionally it is likely that SHCH may demand on time and effort associated with using the new technology, for example, in learning how to use it and for its maintenance. Such demands will be greater for users who are inexperienced with technology (which include some elderly). Thoughts have been also associated with the robustness of the equipment, including its perceived reliability and effectiveness. Concerns about inaccurate measurement (e.g. vital signs) which may be directly impacted by the technology, itself, or by how familiar its human operators are in using it [19]. Moreover, medical data of all SHCHs should be collected into a single database, which will belong to public health organizations.

SHCH interventions have the potential to bridge geographic distances and allow the anonymity that might be desired for a specific medical condition. However, such applications might be lacking the sense of touch and inter-human close contact that occurs in face-to-face meetings. SHCH patients may fear technology replacing in-person interaction with their health care providers or affecting friendships and other relationships [16, 20]. Family caregivers may be afraid that this will mean greater burden of providing care, since they should also be responsible for SHCH's sustainability. Finally, great anxiety have been revealed about the sustainability of SHCH and the possibility that a call/information message might have no human response or assistance. Other fears concerns their ability to assure the system's affordability [15, 16] and efficiency in a long time horizon [21].

### *2.3 Economic Challenges*

SHCH emerged from the parallel need of reducing national public health costs and elders people's requirement to stay and receive treatment and health care support at home [22]. At first sight, living at a SHCH environment could bridge geographic distance and increase access to care. However, going deeply into costing the infrastructure required, it might result in eventually reducing access to care, as its use actually increases the cost of the care. As a result the study of economic challenges are of major importance. A SHCH must be cost-effective from the viewpoint of both patients and society. In other words, the investment in technology for medical purposes would represent a realistic ratio (e.g. less than 10%) of the total home investment. An evaluation of the cost effectiveness of SHCH demands a correlation of incremental costs and health benefits.

An available device that function as standalone unit can often be purchased at a relatively low cost and used by a patient with a chronic disease to monitor his state at home. Furthermore, SHCH reimburses the costs of the technologies due to virtual visits and remote monitoring [23], moving away from payment for services to paying for outcomes [24]. From the other side, the health device is part of an information technology application, allowing the transmission of monitoring data through Internet to a central server, which burden the cost several times. From the hospital perspective of view, the costs associated with the construction of a new building to house the call center, and the hiring of new technical staff must also be included into the analysis. Given the limited resources of the health care system and the challenges that home care agencies face, it is possible that a subset of home care patients will finally have access to the SHCH services.

Apart from the direct costs (program administration, IT delivery, training and maintenance, health care costs, and patient-borne costs pertaining to disease management), cost analysis should also include societal, health care system, third-party, and patient/family perspectives. These indirect costs include patients or caregiver's productivity losses, providers' traveling time to the patients and other more qualitative sources of costs.

The majority of published economic studies on SHCH are not pure economic evaluations, so they cannot assist in determining whether a treatment is justifiable based on the incurred costs and benefits. Polisena et al. have concluded that the use of SHCH system reduced the costs of health care provision, due to the need for fewer contacts with health care providers, meaning reduced frequency of access to other services but not necessarily a reduced need for these services [25]. This highlights the significance of inclusion of clinical outcomes (disease markers or patient's quality of life) in economic evaluations. The clinical outcomes are part of the cost-effectiveness, or cost-utility analysis and can highlight the potential long-term impact of the SHCH. The cost-effectiveness analysis needs to include data on clinical outcomes associated with a particular disease or condition studied, such as event rates and deaths. Such research requires for long term period to demonstrate differences in long-term clinical outcomes, and hence should adopt a longitudinal

pattern. An economic evaluation should also include a sensitivity analysis to determine the robustness of the study findings based on the assumptions made. Last but not least, time and energy that could be saved using SHCH properly of patients, nurses, doctors, and family or voluntary careers should also be included. The benefits most often mentioned are reduced anxiety, reduced hospital admissions, reduced length of stay in hospitals, earlier discharges from hospitals, delayed entry into nursing homes, and reduced need for nursing care at home [26]. As quite a few researchers suggest [25, 27–31], SHCH has the potential to reduce costs, but its impact from a societal perspective remains uncertain until higher quality studies become available.

## 3 Conclusions

Combining the wish of elder people or people with chronic disease/disabilities to receive care at home with the ever increasing maturity of smart technologies, the vision of SHCH starts becoming a reality. This paper provides a review of the main technological, psychosocial/ethical and economic challenges that SHCH projects have to meet so as to support and promote patients' quality of life while remaining at home. Figure 2 summarizes the main challenges, as they have been concluded from our systematic review of the SHCH current research.

Evaluating the technological area needed for SHCH, it is evident that there is active research with great progress in network infrastructures, communication protocols, sensors, middleware, and SHCH components' interoperability. This

| Type of Challenges | Challenges | Studies |
|---|---|---|
| Technological | • Device Size<br>• Common Communication Protocols<br>• Middleware Standards<br>• System Robustness<br>• Interoperability between SHCH parts (software and hardware) | [3],[4],[5],[6],[7], [8],[9],[10] |
| PsychoSocial & Ethical | • Privacy<br>• Security<br>• Autonomy<br>• Accessibility<br>• Usability | [11],[12],[13],[14], [15],[16],[17], [18],[19],[20],[22] |
| Economic | • Reduce public health costs<br>• Reduce private costs<br>• Cost effectiveness analysis<br>• Sensitivity analysis<br>• Incremental costs vs. health benefits | [23],[24],[25],[26], [27],[28],[29],[30], [31],[32] |

**Fig. 2** SHCH main research issues and challenges

highlights the emerging role of SHCHs and the fact that they are becoming smarter. However, there are many ongoing challenges that researchers in this area continue to face such as the ability to handle multiple inhabitants in a single environment, the need for user-centered projects, the decrease of the infrastructure cost and the extent of the environment. We identified that, apart from the design and implementation of applications, it is of vital importance that issues concerning usability, accessibility, privacy, security of collected data, autonomy, formed consent, medicalizations of home and human touch must be declared, so as not to jeopardize the well-being of their inhabitants. Concerning the economic effectiveness, while such projects have the potential to reduce costs, further economic evaluation studies taking into consideration the perspectives of all stakeholders involved in the SHCH ecosystem (technology providers, patients, hospitals and doctors) for calculating costs versus benefits in a long time horizon are required.

## References


1. Astaras, A., L. Hadas, C. James, A. Katasonov, D. Ruschin, and P.D. Bamidis. 2015. Unobtrusive Smart Environments for Independent Living and the Role of Mixed Methods in Elderly Healthcare Delivery: The USEFIL Approach. In *Handbook of Research on Innovations in the Diagnosis and Treatment of Dementia*, 290–305. Hershey: IGI Global.
2. Demiris, G., and B.K. Hensel. 2008. Technologies for an Aging Society: A Systematic Review of "Smart Home" Applications. *IMIA Yearbook of Medical Informatics*: 33–40.
3. Fortino, G., A. Guerrieri, and W. Russo. 2012. Agent-Oriented Smart Objects Development. IEEE 16th International Conference on Computer Supported Cooperative Work in Design (CSCWD'2012).
4. Poland, M.P., C.D. Nugent, H. Wang, and L. Chen. 2009. Smart Home Research: Projects and Issues. *International Journal of Ambient Computing and Intelligence* 1 (4): 32–45.
5. Goossen, W. 2003. Templates: An Organizing Framework to Link Evidence, Terminology and Information Models in the Nursing Profession. Proceedings of the Eighth International Congress in Nursing Informatics. Rio de Janeiro, Brazil.
6. Aditya, B.S., J.C. Sharma, S.C. Allen, and M. Vassallo. 2003. Predictors of a Nursing Home Placement from a Non-acute Geriatric Hospital. *Clinical Rehabilitation* 17 (1): 108–113.
7. Gomez, C., and J. Paradells. 2010. Wireless Home Automation Networks: A Survey of Architectures and Tecnologies. *IEEE Communications Magazine* 48 (6): 92–101.
8. [Online]. Available: http://www.osgi.org/Specifications/HomePage.
9. [Online]. Available: http://www.fipa.org.
10. [Online]. Available: http://www.w3.org/.
11. Preece, J. 2000. *Online Communities: Designing Usability, Supporting Sociability*. Chichester, UK: John Wiley and Sons.
12. E. I. A. a. t. E. I. Foundation. 1996. Resource Guide for Accessible Design of Consumer Electronics: Linking Product Design to the Needs of People with Functional Limitations, A. j. v. o. t. E. I. A. a. t. E. I. Foundation, Ed. Arlington, VA: Telecommunications Industry Association.
13. Demiris, G., M.S. Finkelstein, and M.S. Speedie. 2001. Considerations for the Design of a Web-Based Clinical Monitoring and Educational System for Elderly Patients. *Journal of the American Medical Informatics Association* 8 (5): 468–472.
14. Leino-Kilpi, H., M. Valimaki, and T. Dassen. 2001. Privacy: A Review of the Literature. *International Journal of Nursing Studies* 38 (6): 663–671.

15. Demiris, G., M. Rantz, and M. Aud. 2004. Older Adults' Attitudes Towards and Perceptions of "Smart Home" Technologies: A Pilot Study. *Medical Informatics and the Internet in Medicine* 29 (2): 87–94.
16. Bauer, K. 2001. Home-Based Telemedicine: A Survey of Ethical Issues. *Cambridge Quarterly of Healthcare Ethics* 10: 137–146.
17. Van Berlo, A. 2002. Smart Home Technology: Have Older People Paved the Way? *Gerontechnology* 2: 77–87.
18. Abascal, J. Ambient Intelligence for People with Disabilities and Elderly People.
19. Stauch, G., K. Schweppe, and K. Kayser. 2000. Diagnostic Errors in Interactive Telepathology. *Analytical Cellular Pathology* 21: 201–206.
20. Magnusson, L., and E. Hanson. 2003. Ethical Issues Arising from a Research, Technology and Development Project to Support Frail Older People and Their Family Carers at Home. *Health and Social Care in the Community* 11 (5): 431–439.
21. Thobaben, M. 2005. Telehomecare. *Home Health Care Management & Practice* 17 (6): 487–488.
22. Tang, P., and T. Venables. 2006. 'Smart' Homes and Telecare for. *Journal of Telemedicine and Telecare* 6 (1): 8–14.
23. Harris, S.B., B.L. Gottlieb, and S. Weiner. 2005. Regulating Broadband. *Communications Lawyer* 23: 1–10.
24. Hyler, S.E., and D.P. Gangure. 2004. Practitioner's Corner: Legal and Ethical Challenges in Telepsychiatry. *Journal of Psychiatric Practice* 10: 272–276.
25. Polisena, J., D. Coyle, K. Coyle, and S. McGill. 2009. Home Telehealth for Chronic Disease Management: A Systematic Review and an Analysis of Economic Evaluations. *International Journal of Technology Assessment in Health Care* 25 (3): 339–349.
26. Sixsmith, A. 2000. An Evaluation of an Intelligent Home. *Journal of Telemedicine and Telecare* 6: 63–72.
27. Vimarlund, V. 2005. Economic Analyses for ICT in Elderly Healthcare: Questions and Challenges. *Health Informatics Journal* 11 (4): 309–321.
28. Aanesen, M., A.T. Lotherington, and F. Olsen. 2011. Smarter Elder Care? A Cost-Effectiveness Analysis of Implementing Technology in Elder Care. *Health Informatics Journal* 17 (3): 161–172.
29. Ekeland, A.G., A. Bowes, and S. Flottorpc. 2010. Effectiveness of Telemedicine: A Systematic Review of Reviews. *International Journal of Medical Informatics* 79: 736–771.
30. Graybill, E.M., P. McMeekin, and J. Wildman. 2014. Can Aging in Place Be Cost Effective? A Systematic Review. *PLoS One* 9 (7).
31. Akiyama, M., and B.-K. Yoo. 2016. A Systematic Review of the Economic Evaluation of Telemedicine in Japan. *Journal of Preventive Medicine and Public Health* 49: 183–196.
32. Zwijsen, S.A., A.R. Niemeijer, and C. Hertogh. 2011. Ethics of Using Assistive Technology in the Care for Community-Dwelling Elderly People: An Overview of the Literature. *Aging & Mental Health* 15: 419–427.

# SSEv: A New Small Samples Evaluator Based on Modified Survival Curves

**Styliani Geronikolou and Stelios Zimeras**

**Abstract** Rare diseases, either of genetic or epigenetic origin, either proliferative or degenerative, are hard to be studied credibly, because of sparse prevalence, thus, small sampling. In addition, biological or translational experimentation either with animal models, or in vitro studies share small sampling-often due to lack of financial support or due to mannered and costly techniques. Pilot or feasibility studies been performed, before expensive clinical trials are decided, focus on small samples. Small Samples Evaluator (SSEv) is a useful tool based on a modification of survival curves. The technique can be applied to repeated measures, as well as to case-control or cross-sectional designed studies. A web-based application of SSEv is created and presented herein. The application is freely accessible at: https://ssev.eu.

**Keywords** Rare diseases • Small samples statistical analysis • Survival analysis modification • Translational epidemiology • Credibility

## 1 Introduction

More than 4800 out of 6000 rare diseases, affecting 2–30,000,000 peoples in the EU, are genetic. Almost half of them affect children, thus, are of great research interest. Rare diseases, either of genetic or epigenetic origin either proliferative or degenerative are hard to be studied because of sparse prevalence, thus, small sampling. Investigators of basic sciences, clinical or translational researchers, as well as epidemiologists of rare diseases face the same problem: small sampling or small prevalence. Biological as well as translational experimentation either with animal models, or in vitro studies share small sampling-often due to lack

S. Geronikolou (✉)
Biomedical Research Foundation of the Academy of Athens, 4 Soranou Efessiou Street, 11527, Athens, Greece
e-mail: sgeronik@gmail.com; sgeronik@bioacademy.gr

S. Zimeras (✉)
University of the Aegean, 83200, Karlovassi, Samos, Greece
e-mail: zimste@aegean.gr



P. Vlamos (eds.), *GeNeDis 2016*, Advances in Experimental Medicine and Biology 989, DOI 10.1007/978-3-319-57348-9_23

of financial support or due to mannered and costly techniques, or participants' disability/unwillingness to follow up a study design.

In small sized studies, validity/statistical power problems arise [1]. Various techniques have been proposed for small samples: i.e. non parametric tests, simulation for sample enlarging before calculation [2], effect sizes corrections [3–5], or even simple t-test [6] etc.

## 2 Small Samples Evaluator Method

In epidemiology, survival analysis is a common method widely applied in mortality as well as in determination of pregnancy (fertility) rates [7], drug efficacy; [8, 9].

We propose, hereby, a new technique been borrowed from the survival analysis, modifying the time of events as the values (for rare diseases or sparse data) or mean values (when block of data are available i.e. insect cultures, cell cultures, polycentric epidemiological studies) of data differences between the compared groups. Based on that assumption, the convergence of the final results is more rapid. Thus, according to this modified hazards analysis for Mean Data (i.e. Group A) set probability of scoring greater than a specific value $\alpha$ is given by Pr[mean Data Group A $\geq \alpha$]. This probability can easily be obtained from the graph and for the two comparison groups: case vs control. For that calculation, the long-rank test is used to find significant differences between comparing groups. According to curve comparison analysis, significance may be obtained. To overcome the problem with the small sample variation the Lipsey & Wilson correction to Hedge's statistics formula is proposed [10]. As the g tends close to 0 ($g \to 0$), the comparison between the survival curves is getting larger (non-signoficant differences, no variability). As the g tends to be large ($g \to \infty$), the comparison betweeen the survival curves is getting smaller (significant differences, variability).

We validated the method in given and published biological data [10]. In the first five sets of experiments, we had separated the insects into two groups: (a) the Exposed group (cordless phone) and (b) the Unexposed group using GSM 1880 MHz mobile phone field. In the second five set of experiments we had separated the insects into two groups: (a) the Exposed group (mobile phone) and (b) the Unexposed group using GSM 900 MHz mobile phone field. The results of the experimental repetitions are presented in Tables 1 and 2.

Figure 1 illustrates the results of the hazards analysis of survival functions considering Mean Ovicity in vials among the two groups (mobile/cordless phones and control group). According to this modified hazards analysis for Mean Ovicity in vials the probability of scoring GSM 1880 MHz mobile phone (or GSM 900 MHz mobile phone) greater than a specific value $\alpha$ is given by Pr[mean Ovicity in vials $\geq \alpha$]. This probability can easily be obtained from the graph and for the two comparison groups (cordless phones vs control and mobile phones vs controls). For that calculation the long-rank test is used to find significant differences between comparing groups. According to curve comparison analysis, there was significant

**Table 1** Experimental results from cultures radiated with cordless phone (1880 MHz)

| Experiment | Culture radiated with cordless phone<br>Mean ovicity in vials (egg nr) | Control<br>Mean ovicity in vials (egg nr) |
|---|---|---|
| 1 | 9.7 | 12.25 |
| 2 | 9.6 | 13.1 |
| 3 | 12.4 | 12.4 |
| 4 | 11.9 | 12.1 |
| 5 | 9.3 | 12.4 |
| Mean ± St.dev Total | 10.58 ± 1.45 | 12.45 ± 0.384 |

Data are expressed as mean ± SD

**Table 2** Experimental results from cultures radiated with second generation mobile phone (900 MHz)

| Experiment | Culture radiated with mobile phone<br>Mean ovicity in vials (egg nr) | Control<br>Mean ovicity in vials (egg nr) |
|---|---|---|
| 1 | 9.05 | 13.5 |
| 2 | 7.8 | 11.4 |
| 3 | 7.95 | 12.4 |
| 4 | 9.1 | 12.8 |
| 5 | 8.7 | 12 |
| Mean ± St.dev Total | 8.52 ± 0.60 | 12.42 ± 0.794 |

Data are expressed as mean ± SD

difference among the types of the phones for the Mean Ovicity in vials (egg nr) considering the cordless phones ($p = 0.049$) and the mobile phones ($p = 0.002$).

After the modified survival analysis the long-rank test, there was significant difference among the types of the phones for the Mean Ovicity in vials (egg nr) considering the cordless phones ($p = 0.048$) and the mobile phones ($p = 0.002$). For Mean Ovicity in vials (egg nr) the probability of scoring 1880 MHz portable phone (or 900 MHz mobile phone) greater than a specific value $\alpha$ is given by pr[mean Ovicity in vials $\geq \alpha$]. This probability can easily be obtained from the graph and for the two comparison groups (cordless phones vs control and mobile phones vs controls). The results absolutely agree with the ones published in Geronikolou et al. [10].

## 3 Small Samples Evaluator (SSEv) Web Based Application

The web-based application of SSEv is a useful tool for small samples statistical analysis. The application is freely accessible at: https://ssev.eu. It can generate credible results and figure curves small user-provided data sets. This server enables users to analyze their data and generate curves for valid estimation of their

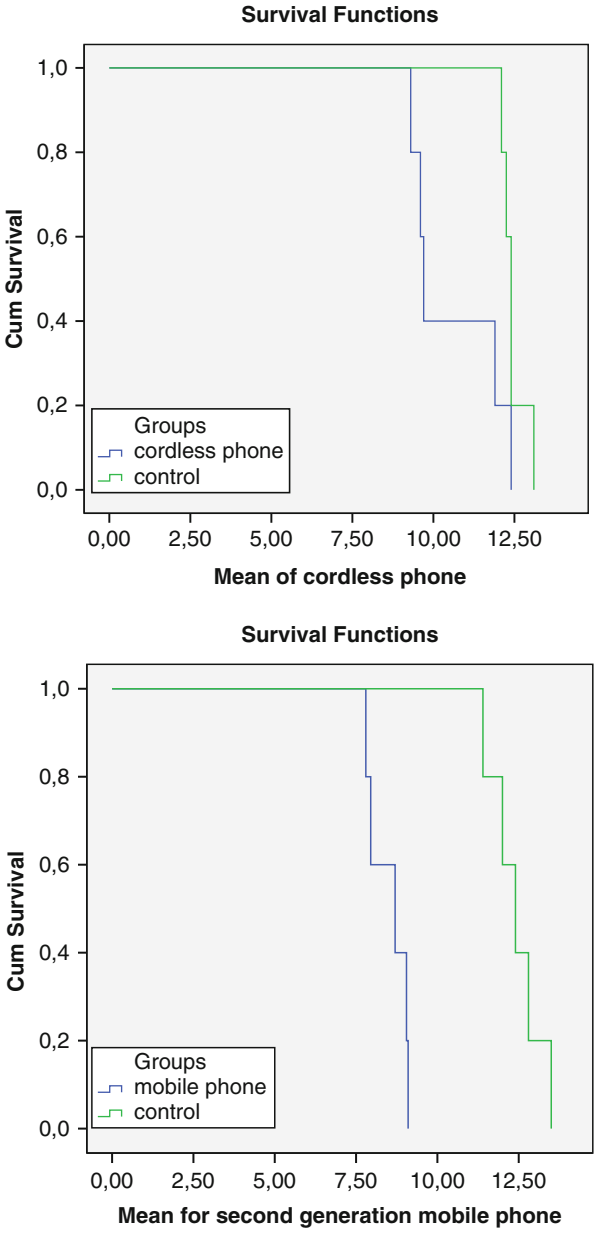


**Fig. 1** Kaplan-Meier estimates of the survival functions for GSM 1880 MHz mobile phone and GSM 900 MHz mobile phone under Mean Ovicity in vials (egg nr) and control group

comparing groups differences. Additionally, it provides users probability calculation to empower their result. Furthermore, the corrected for small samples Hedge's g is also provided by this web application.

## 4 Discussion

Reporting and interpreting credible results, avoiding bias due to small samples might be of ethical and bioethical importance affecting patients and families real life, researchers daily practice ease etc. Here, issues such as quality of study design, representation of the sample and, mainly, power issues after the statistical method arise [1]. Publishing is another phase, where statistical power proven by large sampling is impossible in the above cases, whereas, innovative early studies, pilot or feasibility studies are often discouraged or declined [11].

Non-parametric methods are also called distribution-free tests and rank methods, thus, feasible for small samples. For the simplest parametric tests there are corresponding non-parametric tests (Mann–Whitney test, Wilcoxon, etc), while non parametric tests are used for testing hypotheses rather than estimation. They are less informative–comparing to parametric tests, using ranks rather than original values. Simulation solution enlarges the sample for typical power sake, but refrain the dynamic of the sample, lacking representiveness. Our solution calculates differences, illustrates convergences providing probability of the resulting effect to occur in real life, thus, more informative.

## 5 Conclusion

Our proposed modification of survival analysis (SSEv) is a tool that rapidly evaluates the differences between two small sampled groups, calculating probabilities to empower the results. The convergence of the curves illustrate the differences between the compared groups. The tool is feasible for cross-sectional and case-control studies, as well as repeated measures. It may prove to be helpful for translational, biological researchers as well as clinicians.

**Conflict of Interest** We see no conflict of interest. This work and server construction had no financial support.

**Acknowledgements** We thank Dr. I Michalopoulos for helping us constructing the website.

## References


1. Button, K.S., J.P. Ioannidis, C. Mokrysz, B.A. Nosek, J. Flint, E.S. Robinson, and M.R. Munafo. 2013. Power Failure: Why Small Sample Size Undermines the Reliability of Neuroscience. *Nature Reviews. Neuroscience* 14 (5): 365–376. doi:10.1038/nrn3475.
2. Paraskevopoulou, M.D., I.S. Vlachos, E. Athanasiadis, and G. Spyrou. 2013. BiDaS: A Web-Based Monte Carlo BioData Simulator Based on Sequence/Feature Characteristics. *Nucleic Acids Research* 41 (Web Server Issue): W582–W586. doi:10.1093/nar/gkt420.
3. Durlak, J.A. 2009. How to Select, Calculate, and Interpret Effect Sizes. *Journal of Pediatric Psychology* 16: 1–12.
4. Hedges, L.V., and I. Olkin. 1985. *Statistical Methods for Meta-Analysis*. New York: Academic Press.
5. Lipsey, M.W., and D.B. Wilson. 2001. *Practical Meta-Analysis*. Thousand Oaks, CA: Sage.
6. de Winter, J.C.F. 2013. Using the Student's t-Test with Extremely Small Sample Sizes. *Practical Assessment, Research and Evaluation* 18 (10) ISSN-1531-7714.
7. Mu, Q., and R.J. Fehring. 2014. Efficacy of Achieving Pregnancy with Fertility-Focused Intercourse. *MCN: American Journal of Maternal Child Nursing* 39 (1): 35–40. doi:10.1097/NMC.0b013e3182a76b88.
8. Espinosa Bosch, M., R. Asensi Diez, S. Garcia Agudo, and A. Clopes Estela. 2016. Nintedanib in Combination with Docetaxel for Second-Line Treatment of Advanced Non-small-cell Lung Cancer; GENESIS-SEFH Drug Evaluation Report. *Farmacia Hospitalaria* 40 (4): 316–327. doi:10.7399/fh.2016.40.4.10455.
9. Karim, M.E., J. Petkau, P. Gustafson, R.W. Platt, and H. Tremlett. 2016. Comparison of Statistical Approaches Dealing with Time-Dependent Confounding in Drug Effectiveness Studies. *Statistical Methods in Medical Research*. doi:10.1177/0962280216668554.
10. Geronikolou, S., S. Zimeras, C.H. Davos, I. Michalopoulos, and S. Tsitomeneas. 2014. Diverse Radiofrequency Sensitivity and Radiofrequency Effects of Mobile or Cordless Phone Near Fields Exposure in *Drosophila melanogaster*. *PLoS One* 9 (11): e112139. doi:10.1371/journal.pone.0112139.
11. Bacchetti, P., S.G. Deeks, and J.M. McCune. 2011. Breaking Free of Sample Size Dogma to Perform Innovative Translational Research. *Science Translational Medicine* 3 (87): 87ps24. doi:10.1126/scitranslmed.3001628.

# Efficient Health Information Management Based on Patient-Generated Digital Data

**Maria M. Psiha**

**Abstract** Technology has been a growing part of healthcare for decades. The patient experience is going digital, and consumers are leading the way by accessing EHRs and using digital tools, such as wearables and apps, to manage their health. Patient-generated health data (PGHD) are health-related data created, recorded, or gathered by or from patients (or family members or other caregivers) to help address a health concern. PGHD may have several reported patient engagement and empowerment benefits, but lingering issues may prohibit providers from actually using patients' data. In this paper we review the main recent PGHD uses, challenges and opportunities.

**Keywords** EHR • Patient-generated health data • Healthcare management • Challenges • Patient engagement

## 1 Introduction

Rapid advances in mobile and cloud technology, wearable sensors, and data analytics, combined with nearly universal access to cellular services, are shifting the way healthcare is both delivered and received [1]. Until recently, patients who have played a mostly passive role in their own care are familiar with great advances in imaging devices, advanced surgical technology, sophisticated heart rate monitors, and more recently, electronic patient management systems and clinical workflow systems, which are being utilized daily in health systems, hospitals and clinics. The challenge now focuses on technologies being used by patients outside of the clinical setting. These technological achievements can solidify active patients' role in the future of medicine and care.

Patient-Generated Health Data (PGHD) is becoming extremely significant in the operational efficiency of health systems. According to a National eHealth Collaborative Technical Expert Panel, PGHD is health-related, data-created, recorded,

M.M. Psiha (✉)
Department of Informatics, Ionian University, Corfu, 49100, Greece
e-mail: psiha@ionio.gr; marypsiha@hotmail.com



P. Vlamos (eds.), *GeNeDis 2016*, Advances in Experimental Medicine and Biology 989, DOI 10.1007/978-3-319-57348-9_24

gathered or inferred by or from patients, family, personal caregivers or designees to help address a health concern [2]. Data from wearables, clinical in-home devices and consumer applications are powering personalized approaches to remote monitoring, telemedicine, preventative wellness and analytics. Sensors and manually entered data by the patient allow these new technologies to collect and store real-time events, not only helping patients to better understand their personal wellbeing, but also arming practitioners with a more complete patient profile and the ability to be proactive in their care. Physicians can now monitor the effectiveness of treatments, respond to alerts, follow-up and offer advice, without the patient having to physically go into their office [1].

According to a 2015 survey, 68% of American adults owned a smartphone, up from 35% in 2011. Additionally, the older demographic—and currently the highest number of healthcare users—is actively engaged with smart technology. In fact, 58% of 50–64 year olds and 30% of 65+ year olds owned a smartphone in 2015 [3] (Fig. 1). This means that, as the use of oldest mobile technologies declines and the proliferation of smart technology increases, users have come to expect the ability to access information anytime, and from anywhere [1]. Now, patients are looking to access to their own data and expect digital interactions with their healthcare provider. A 2014 FICO survey revealed that 80% of people would like the option to use their smartphones to interact with healthcare providers [4]. These same researchers also found that 76% of people worldwide would like a digital reminder for their medical appointments, and 69% would like to be able to arrange appointments and receive prompts to take their medication.

To meet the aforementioned demands, the healthcare industry has had to adapt to the digital boom, ultimately changing the healthcare practitioner-patient relationship. Now, electronic medical records, health apps, and wearable technology have made it easier for both patients and practitioners to monitor and respond to PGHD. In fact, the use of health apps has doubled in the past 2 years, shifting from 16% in 2014 to 33% in 2016 among consumers who use technology to manage their health, and 3 out of 4 patients followed their doctor's recommendation to wear a health app [5] (Fig. 2). The personal health device market is expected to grow to more than 70 million devices sold by 2018, which will improve the availability and affordability of wearable devices for health [6]. The International Data Corporation reports that worldwide shipments of wearable devices, including devices like Fitbit and Google Glass, will reach 110 million by the end of 2016, a 38.2% growth over the previous year. By 2020, the forecast for devices shipped is expected to double [7].

## 2 From Electronic Health Record to PGHD

A trusted organization is typically the national or regional entity that provides infrastructures for offering data storage and access services. At the EU level these services are called Personal Health Record (PHR) and Electronic Health

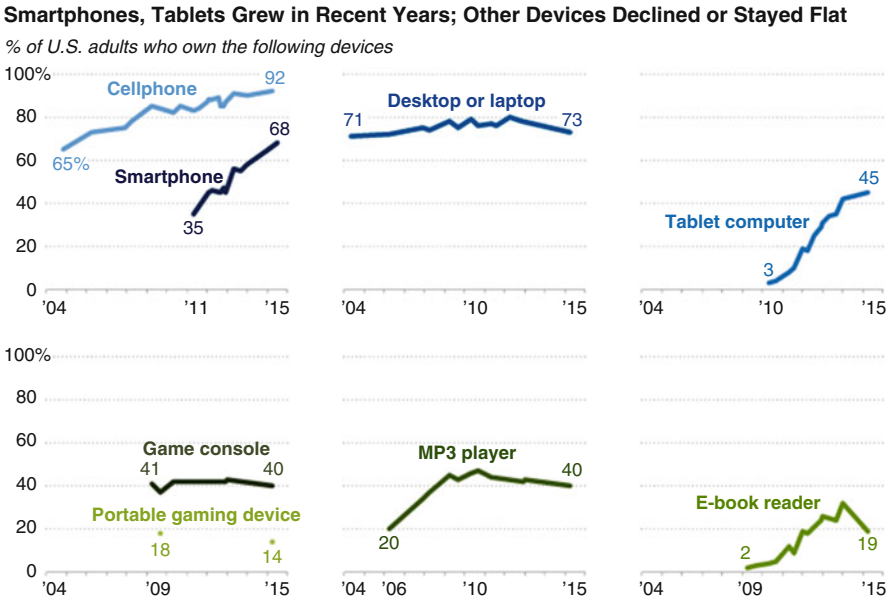


**Fig. 1** Smart technology growth 2004–2015. Adapted from Anderson [3]

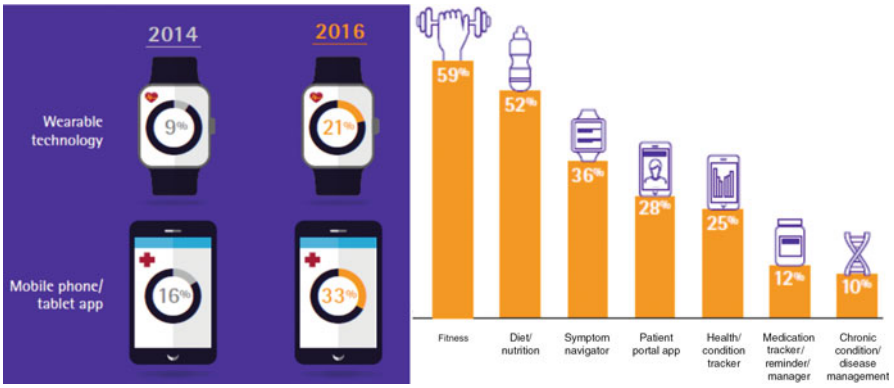


**Fig. 2** Use of health apps and wearables has doubled in the past 2 years among health technology users. The most popular health apps are Fitness and Diet/Nutrition. Adapted from Accenture Consulting [5]

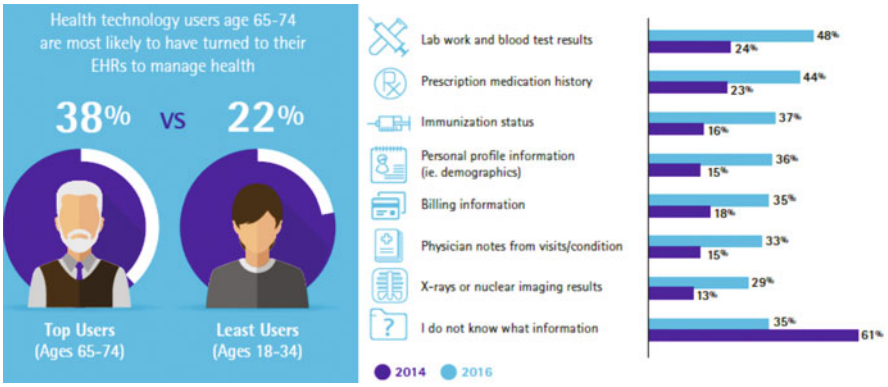


**Fig. 3** Consumers know more about what data they can access in their EHR. Adapted from Accenture Consulting [5]

Records (EHR). The ePSOS[1] infrastructure, developed with support of the EC Competitiveness and Innovation Programme (CIP), provides service and semantic interworking capabilities between national PHR/EHR.

Based on recent studies, and contrary to popular belief, age isn't a deterrent for shifting to digital healthcare. In fact, 38% of users aged 65–74 are most likely to use their EHR to review their health information (Fig. 3). Compared to two years ago, healthcare consumers know more about what data they can access in their EHR. In 2016, 65% with EHRs said they know what data they have access to in their EHR vs. 39% in 2014. However, 35% still don't know what information they can access (Fig. 3) [5].

Patients' access to their own EHR is a controversial issue. Many care professionals are concerned about negative effects deriving from patients reading their record information without support from clinicians [8]. Patients on the other hand often think their concerns are outweighed by the benefits. Specifically, most (92%) patients believe they should have full access to their records, while only 18% of physicians share this belief. Interestingly, about half (49%) of patients believe they should have full access (Fig. 4) [5]. According to the Accenture survey most US doctors (82%) want patients to actively participate in their own healthcare by updating their electronic health records. However, only a third of physicians surveyed (31%) believe their patients should have access to their full health record. These findings were consistent among 3700 doctors surveyed by Accenture in eight countries: Australia, Canada, England, France, Germany, Singapore, Spain and the United States [9]. The vast majority of US doctors also believe that patients should be able to update some or all of the standard information in their health record, including demographics (95%), family medical history (88%), medications (86%)

[1] http://www.epsos.eu/.

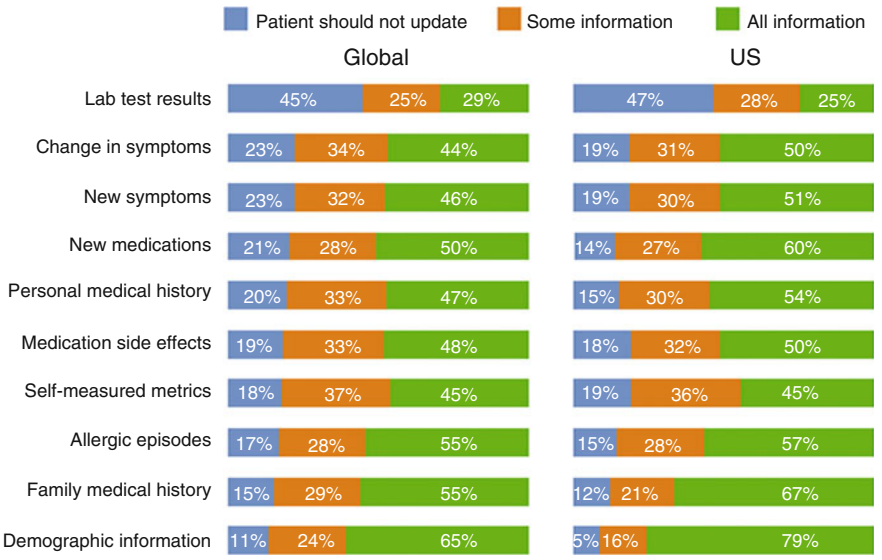


**Fig. 4** Information patients should be able to update in electronic health record. Adapted from Accenture Doctors Survey [9]

and allergies (85%). And, many doctors (81%) even believe that patients should be able to add some clinical updates to their record, such as new symptoms and self-measured metrics, including blood pressure and glucose levels. Meanwhile, nearly half of US doctors (47%) believe patients should not be able to update their lab test results.

There are technical challenges associated with accessing and integrating PGHD, but these are no longer the hurdles preventing digital health adoption. These kinds of healthcare innovations open doors to data and information that those in the healthcare industry have never had before. The practitioner-patient relationship becomes less about gathering data and more about interpreting what the patient-generated data means for the care of that individual, in the context of their life.

## 3 Applications and Challenges

Whereas much progress has been made in collecting data from clinical care teams via EHRs, there is still a critical gap in capture of information from patients/caregivers. PGHD integrated into EHRs could address this important gap and make this information available for clinical care, research, and quality improvement.

PGHD provides an unparalleled opportunity to monitor and track a patient's longitudinal cancer experience, to engage patients as partners in their care, and to make advancements toward a true learning health care system for cancer care [10]. Examples of biometric PGHD that have promise for cancer care include heart rate, temperature, weight, blood pressure, pulse oximetry, physical activity and intensity, caloric expenditure, and sleep duration and quality.

Additionally, diabetes patients have to always keep their blood glucose under control, because higher glucose levels can lead to severe complications (e.g., retinopathy, neuropathy), while lower might cause coma and even death. Thus, patients should measure glucose a few times a day for the rest of their lives. Analyzing patients' glucose measurements along with other PGHD, caregivers are able to help individuals stick to their normal numbers and avoid serious health deterioration.

In the past, electrocardiograms (ECG) could only be administered by a physician in a clinical setting, providing a snapshot of the patient's cardiac responses for that one moment in time, in a situation that does not reflect their real life [1]. Now, there are smartphone apps that let the patient take a single-lead ECG and transmit that information to their physician. Moreover, the data can be integrated into electronic health records and the patient can input personal notes e.g. time of day or an activity that could have accounted for the issue, such as caffeine or stress-induced spikes. Although this type of reporting is not a replacement for an in-depth assessment and a full 12-lead ECG, it is being used to monitor things like atrial fibrillation while the patient is not in the office.

Accenture Federal Services announced a 2-year consulting contract with the ONC to help the federal government create a framework for collecting and using patient generated health data in both research and clinical care. Accenture executives told MobiHealthNews that this framework is an important first step toward creating standards that would make patient generated health data more interoperable [5].[2]

Of course, disruption does not occur without challenges. While PGHD is being leveraged in many areas of healthcare today, it is still in the relatively early stages. There are several challenges to unlocking the potential for PGHD that need to be addressed including provider concerns, workflow issues, standardization of PGHD and interoperability of devices/sensors, security and privacy issues, and lack of the necessary HER functionalities and software innovations [10] (Fig. 5).

A common concern is that patient-generated data is a fleeting trend and that the use of digital technology will eventually fall off. However, in a recent interview, Fitbit CEO James Park addressed this concern explaining that "we noted that out of 18 million new registered device users added in 2015, 72% were still active users at year end." [12]. The truth is that as technology continues to advance, becomes cheaper, faster and much more accessible to a broader range of patients and providers, it naturally becomes woven into the everyday fabric of our lives.

[2] http://www.mobihealthnews.com/content/onc-taps-accenture-create-patient-generated-health-data-framework.

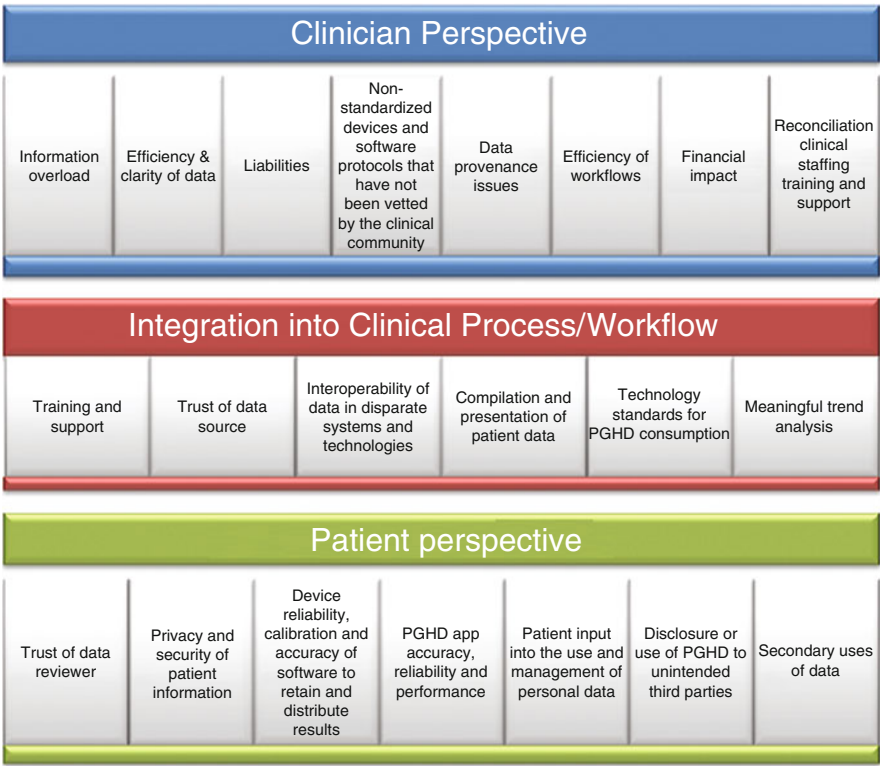


**Fig. 5** Challenges to use of patient-generated health data. Adapted from HIMSS Industry Briefing [11]

Lack of industry-wide standards for both PGHD and interoperability of devices is a growing concern within the information technology community [10]. A further significant gap is the lack of comprehensive Web accessible databases of anonymous PGHD, encoded with well-established data and metadata standards [13, 14]. Such data provide numerical parameters for use in computational models. This need was expressed in §3.2.3 of the Virtual Physiological Human (VPH) STEP Roadmap [15].

The privacy and security of PGHD is also a challenge and potential barrier to operationalizing PGHD. It is common knowledge that effective data protection is vital for building trust in e-Health. It is also a key driver for its successful cross-border deployment, in which harmonization of rules concerning cross border exchange of health data is essential [16]. In January 2012, the European Commission Adapted a proposal for a regulation setting out a general EU framework

for data protection[3] with a view to modernizing current data protection rules and strengthening their harmonization. The e-Health Task Force report and the responses to the public consultation for the e-Health Action Plan H2020 both point to a strong interest in discussing the concept of 'ownership' and control of data while providing more clarity on the conditions for accessing and re-using health data for research and public health purposes and the flow of such data across health and care systems, if suitably protected [16]. Data protection issues also need to be addressed in respect to the use of cloud computing infrastructures and services for health and wellbeing data processing. E-Health and wellbeing ICT initiatives should integrate the principle of privacy by design and by default as well as make use of Privacy Enhancing Technologies (PET's), as foreseen in the proposed Data Protection Regulation. The latter contains new principles which will allow the deployment of trustworthy tools e.g. the principle that controllers will be accountable for their data processing, carry out data protection impact assessments and comply with strengthened security requirements.[4]

Another fear is that patient-generated data will replace traditional examinations and medical expertise, ultimately diminishing the role of the healthcare provider. In reality, the ability to collect real-time data supplements the expertise doctors have, shifting where they focus their efforts, not replacing their medical knowledge [1]. Access to data and the ability to customize the patient experience is a differentiator, not a substitute, for the healthcare provider.

## 4 Conclusion

The next step of research community in human physiology modelling was the development of VPH Framework which is a methodological and technological framework that, once established, will enable collaborative investigation of the human body as a single complex system. In other words, a VPH info structure facilitating complex integrative modeling of human physiology and pathophysiology, in ways that make it immediately accessible and fruitful for personalized, predictive and integrative health care. Specifically, the Physiome and VPH initiatives strive to build a digital representation of an in silico human from molecular to organism level [17]. One of the main steams of H2020 research funding includes the creation of Digital Patient. The Digital Patient is intended to be a framework of information technologies that enable a more integrative, predictive, personalized, and patient-centric medicine. In order to integrate such concepts into healthcare, industry professionals tout the usefulness of PGHD, which not only gives providers a window into patient wellness

[3]Commission proposal for a regulation on the protection of individuals with regard to the processing of personal data and on the free movement of such data: http://ec.europa.eu/justice/dataprotection/document/review2012/com_2012_11_en.pdf.

[4]http://ec.europa.eu/justice/data-protection/article-29/index_en.htm.

when away from the doctor's office, but gives patients a stake in their own care, fostering patient engagement.

PGHD can be a valuable tool to improve the patient experience of care; reduce the overall cost of healthcare; and achieve and maintain a healthier population. Healthcare's access and use of PGHD has the power to disrupt the entire sector and move healthcare toward preventive diagnosis and predictive treatment. Patients have taken the first step to adopt the devices, companies have provided access to the data, and leaders are providing the evidence to support ROI of PGHD. Information collected directly from patients is important; the process must be user-friendly, trustworthy, and secure, with minimal disruption to the healthcare organization. Now is the time to build on this momentum to create ubiquitous adoption and integration of PGHD that can accelerate the management and delivery of value-based care.

## References


1. McIntyre, Chris. 2014. Clinical Benefits of Patient-Generated Health Data, available at: http://www.hearingreview.com/2016/07/clinical-benefits-patient-generated-health-data/.
2. HIMSS. 2013. National eHealth Collaborative Technical Expert Panel Final Report, available at: http://www.himss.org/ResourceLibrary/genResourceDetailPDF.aspx?ItemNumber=28740.
3. Anderson, M. 2015. Technology Device Ownership: 2015. Pew Research Center, available at: http://www.pewinternet.org/2015/10/29/technology-device-ownership-2015.
4. FICO. 2014. FICO Global Survey: 80% of Smartphone Users Interested in Health Care Alerts, available at: http://www.fico.com/en/newsroom/fico-global-survey-80-of–smartphone-users-interested-in-health-care-alerts-06-18-2014.
5. Accenture Consulting. 2016. Patients Want a Heavy Dose of Digital, available at: https://www.accenture.com/t20160226T105643__w__/us-en/_acnmedia/PDF-6/Accenture-Patients-Want-A-Heavy-Dose-of-Digital-Infographic.pdf%20-%20zoom=50.
6. Consumer Electronics Association White Paper. 2014. *Connected Health and Wellness Market*. Baltimore, MD: Consumer Electronics Association.
7. Heath, S. 2016. What Keeps Providers from Using Patient-Generated Health Data? Patient Engagement HIT, available at: http://patientengagementhit.com/news/what-keeps-providers-from-using-patient-generated-health-data.
8. Scandurra, I., A. Jansson, M.L. Forsberg-Fransson, and T. Ålander. 2015. Is 'Patient's Online Access to Health Records' a Good Reform? – Opinions from Swedish Healthcare Professionals Differ. *ScienceDirect, Procedia Computer Science* 64: 964–968.
9. Accenture Doctors Survey. 2012. Patient Access to Electronic Health Records: What Does the Doctor Order?, available at: https://www.accenture.com/us-en/insight-patient-access-electronic-health-records-summary.
10. Chung, A.E., and E.M. Basch. 2015. Potential and Challenges of Patient-Generated Health Data for High-Quality Cancer Care, American Society of Clinical Oncology, Special Series: Quality Care Symposium.
11. HIMSS Industry Briefing. 2014. The Value of Patient-Generated Health Data (PGHD).
12. Fitbit, Comstock J. 2016. CEO Hints at Expanding Healthcare Strategy, FDA-Cleared Devices. Mobi Health News. May 5, 2016. Available at: http://mobihealthnews.com/content/fitbit-ceo-hints-expanding-healthcare-strategy-fda-cleared-devices.
13. Schlogl, A. 2009. An Overview on Data Formats for Biomedical Signals. Proceedings of the World Congress on Medical Physics and Biomedical Engineering, vol. 25 (4), 1557–1560. Berlin, Germany: Springer.

14. Testi, D., P. Quadrani, and M. Viceconti. 2010. PhysiomeSpace: Digital Library Service for Biomedical Data. *Philosophical Transactions of the Royal Society A* 368: 2853–2861.
15. Hunter, P., T. Chapman, P.V. Coveney, B. de Bono, V. Diaz, J. Fenner, A.F. Frangi, et al. 2013. A Vision and Strategy for the Virtual Physiological Human: 2012 Update. *Interface Focus* 3 (2): 20130004.
16. eHealth Action Plan 2012–2020. 2012. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, Brussels, COM(2012) 736.
17. VPH NoE. 2012. A Vision and Strategy for the Virtual Physiological Human. NoE Newsletter, available at: http://www.vph-noe.eu/vph-repository/cat_view/13-newsletter-archives.

# Long-Term Survival of Women with Breast Cancer. Overview Supportive Care Needs Assessment Instruments

**Parthenopi Ktistaki, Nephely Alevra, and Maria Voulgari**

**Abstract** *Introduction*: Worldwide, breast cancer is the fifth leading cause of cancer death (after lung, stomach, liver and colon cancer), while among women it is first on the list. The incidence of breast cancer has made a dramatic increase since 1970 which is partly interpreted by the modern western life standards. The expected risk of breast cancer throughout a lifespan of an average is 1 in 11 women. The five-year survival rates for breast cancer are at 80% if it has not spread, and only at 40% for the metastatic type of cancer.

The concept of survival comes from the US, where there is an active promotion of self-help difficulties coping strategies. Surviving from cancer may be a mixed experience. Survivors of cancer often say they are still running a full and meaningful life after experiencing a threatening disease. Others may find it difficult to handle the feeling that they have no right to be alive, which is probably related to the guilt of survival after the war. Although the survival potential for some is a satisfactory fee, others may be looking for improvement, change, or to adapt their life and struggle with the late effects of cancer after stopping the treatment.

In recent years it has been observed that survival of women with breast cancer has increased significantly because of current antineoplastic therapeutic interventions. The definition of support needs derives from the one of supportive care considering that there is no theoretical framework or specific definition at the moment. "Supportive care is defined as the care which helps the individual and his/her family to deal with the experience of cancer and cover their bodily, emotional, psychological, social, mental and practical needs, as well as their need of information. It includes the period before the final diagnosis, during the diagnosis and the treatments or during the ongoing disease with recurrences and the survivors of the disease."

*Purpose*: The purpose of this review is to describe the tools used in research to measure and evaluate supportive care needs during long-term survival of women with breast cancer.

P. Ktistaki (✉) • N. Alevra • M. Voulgari
Department of Nursing, Faculty of Human Movement and Quality of Life Sciences, University of Peloponnese, P.C. 23100, Sparta, Greece
e-mail: pktistaki@yahoo.gr; nephely.alevra@gmail.com; mariavoulgari92@gmail.com



P. Vlamos (eds.), *GeNeDis 2016*, Advances in Experimental Medicine and Biology 989, DOI 10.1007/978-3-319-57348-9_25

*Method*: An electronic search of articles was held in the PubMed database for the period from 2005 up to 2015. The terms used in the search were "breast cancer", "quality of life", "long-term survivorship" and "supportive care needs". The entry criteria of the articles were to be breast cancer diagnosis, written in English, quantitative methodology and include patients with at least a five-year survival. The sorting of articles were based on the inclusion and exclusion criteria according to the MOOSE Checklist systematic review. With the criteria set out, the articles incurred are a total of 249 from which 47 were excluded according to their title, 28 as they were articles of other types of cancer, 61 had direct objective the description of drugs, treatments and their cost, 5 did not study supportive care needs, 49 did not have direct research questions, 4 did not relate to the period of 10 years, and 6 were not associated with a five-year survival. From a total of 249 articles 43 met the inclusion criteria and 23 were finally included. These 23 articles were studied thoroughly by two independent researchers in order to record the analytical tools used by individual researchers to measure the supportive care needs.

*Results*: There were several different methodological approaches identified, particularly in the way of recruiting and determining the patient research sample and complete questionnaires. Altogether 82 different tools were used to measure the support needs. Supportive care needs are divided into organic, psychological, socio-economic and spirituality. The commonly studied supportive care needs are related to mobility/functionality (39.8%), psychological well-being (37.3%), mainly depression, sexuality (14.5%), fatigue (7.2%) and spirituality (4.8%) of the surviving women. Some tools were discovered that studied bodily needs (47.6%), psychological needs (36.6%), a combination of the two (3.7%), socioeconomic needs (8.5%) and mental needs (1.2%). Tools such as Center for Epidemiologic Studies—Depression Scale (17.4%), Physical Component Scale (13%) and Beck Depression Inventory (13%) are included in the most commonly used ones.

*Conclusions*: The supportive care needs of breast cancer women during long-term survivorship are slightly explored, comparing to antineoplasmatic treatment period supportive care needs. This is probably due to the subjective nature of the concept examined. Approximately every scientific team worked on the study of supportive care needs on two or three different dimensions. More frequently examined are Physical and Psychological Care Needs. Gap is observed in exploring the social/economical and spiritual supportive care needs of women with breast cancer survivors as well as practical needs.

**Keywords** Breast cancer • Supportive care needs • Long-term survivorship • Survival

## References

1. WHO. 2006. *Fact Sheet No. 297: Cancer*. Geneva: World Health Organization.
2. Corner, J., and Christopher Bailey. 2008. *Cancer Nursing Care in Context*. Hoboken, NJ: Blackwell Publishing Limited.

3. Park, B.W., and S.Y. Hwang. 2012. Unmet Needs of Breast Cancer Patients Relative to Survival Duration. *Yonsei Medical Journal* 53 (1): 118–125. doi:10.3349/ymj.2012.53.1.118.
4. Nair, M., and I. Peate. 2009. *Fundamentals of Applied Pathophysiology. An Essential Guide for Nursing Students*. United Kingdom: John Wiley & Sons.
5. Konstantinidis, T.I., and A. Philalithis. 2014. Supportive Care Needs of Advanced Cancer Patients. The Nursing Perspective. *Archives of Hellenic Medicine* 31 (4): 412–422.
6. Bradley, C.J., and A. Wilk. 2014. Racial Differences in Quality of Life and Employment Outcomes in Insured Women with Breast Cancer. *Journal of Cancer Survivorship* 8 (1): 49–59. doi:10.1007/s11764-013-0316-4. Epub 2013 Oct 16.
7. Wonghongkul, T., N. Dechaprom, L. Phumivichuvate, and S. Losawatkul. 2006. Uncertainty Appraisal Coping and Quality of Life in Breast Cancer Survivors. *Cancer Nursing* 29 (3): 250–257.
8. Carver, C.S., R.G. Smith, V.M. Petronis, and M.H. Antoni. 2006. Quality of Life Among Long-Term Survivors of Breast Cancer: Different Types of Antecedents Predict Different Classes of Outcomes. *Psychooncology* 15 (9): 749–758.
9. Carpenter, J.S., A.M. Storniolo, S. Johns, P.O. Monahan, F. Azzouz, J.L. Elam, C.S. Johnson, and R.C. Shelton. 2007. Randomized, Double-Blind, Placebo-Controlled Crossover Trials of Venlafaxine for Hot Flashes After Breast Cancer. *The Oncologist* 12 (1): 124–135.
10. Parker, P.A., A. Youssef, S. Walker, K. Basen-Engquist, L. Cohen, E.R. Gritz, Q.X. Wei, and G.L. Robb. 2007. Short-Term and Long-Term Psychosocial Adjustment and Quality of Life in Women Undergoing Different Surgical Procedures for Breast Cancer. *Annals of Surgical Oncology* 14 (11): 3078–3089. Epub 2007 Jun 16.
11. Paskett, E.D., J.E. Herndon 2nd, J.M. Day, N.N. Stark, E.P. Winer, S.S. Grubbs, M.D. Pavy, C.L. Shapiro, M.A. List, M.L. Hensley, M.A. Naughton, A.B. Kornblith, K.R. Habin, G.F. Fleming, M.A. Bittoni, and Cancer and Leukemia Group B. 2008. Applying a Conceptual Model for Examining Health-Related Quality of Life in Long-Term Breast Cancer Survivors: CALGB Study 79804. *Psychooncology* 17 (11): 1108–1120. doi:10.1002/pon.1329.
12. Littman, A.J., M.T. Tang, and M.A. Rossing. 2010. Longitudinal Study of Recreational Physical Activity in Breast Cancer Survivors. *Journal of Cancer Survivorship* 4 (2): 119–127. doi:10.1007/s11764-009-0113-2. Epub 2010 Feb 24.
13. Brain, E.G., C. Mertens, V. Girre, F. Rousseau, E. Blot, S. Abadie, L. Uwer, E. Bourbouloux, I. Van Praagh-Doreau, L. Mourey, S. Kirscher, B. Laguerre, E. Fourme, S. Luneau, J. Genève, and M. Debled. 2011. Impact of Liposomal Doxorubicin-Based Adjuvant Chemotherapy on Autonomy in Women Over 70 with Hormone-Receptor-Negative Breast Carcinoma: A French Geriatric Oncology Group (GERICO) Phase II Multicentre Trial. *Critical Reviews in Oncology/Hematology* 80 (1): 160–170. doi:10.1016/j.critrevonc.2010.10.003. Epub 2010 Oct 28.
14. Ganz, P.A., L. Kwan, A.L. Stanton, J.E. Bower, and T.R. Belin. 2011. Physical and Psychosocial Recovery in the Year After Primary Treatment of Breast Cancer. *Journal of Clinical Oncology* 29 (9): 1101–1109. doi:10.1200/JCO.2010.28.8043. Epub 2011 Feb 7.
15. Askoxylakis, V., A.D. Jensen, M.F. Häfner, L. Fetzner, F. Sterzing, J. Heil, C. Sohn, J. Hüsing, U. Tiefenbacher, F. Wenz, J. Debus, and H. Hof. 2011. Simultaneous Integrated Boost for Adjuvant Treatment of Breast Cancer—Intensity Modulated vs. Conventional Radiotherapy: The IMRT-MC2 Trial. *BMC Cancer* 11: 249. doi:10.1186/1471-2407-11-249.
16. Ma, H., C.L. Carpenter, J. Sullivan-Halley, and L. Bernstein. 2011. The Roles of Herbal Remedies in Survival and Quality of Life Among Long-Term Breast Cancer Survivors—Results of a Prospective Study. *BMC Cancer* 11: 222. doi:10.1186/1471-2407-11-222.
17. Taleghani, F., J. Karimain, S. Babazadeh, F. Mokarian, M. Tabatabaiyan, M.A. Samimi, and M.R. Aminian. 2012. The Effect of Combined Aerobic and Resistance Exercises on Quality of Life of Women Surviving Breast Cancer. *Iranian Journal of Nursing and Midwifery Research* 17 (1): 47–51.
18. Pumo, V., G. Milone, M. Iacono, S.R. Giuliano, A. Di Mari, C. Lopiano, S. Bordonaro, and P. Tralongo. 2012. Psychological and Sexual Disorders in Long-Term Breast Cancer Survivors. *Cancer Management and Research* 4: 61–65. doi:10.2147/CMAR.S28547. Epub 2012 Feb 24.

19. Short, C.E., E.L. James, A. Girgis, P. McElduff, and R.C. Plotnikoff. 2012. Move More for Life: The Protocol for a Randomised Efficacy Trial of a Tailored-Print Physical Activity Intervention for Post-Treatment Breast Cancer Survivors. *BMC Cancer* 12: 172. doi:10.1186/1471-2407-12-172.
20. Hui, D., M. De La Cruz, M. Mori, Parsons Ha, Jh. Kwon, I. Torres Vigil, et al. 2013. Concepts and Definitions for "Supportive Care","Best Supportive Care", "Palliative Care", and "Hospice Care" in the Published Literature, Dictionaries, and Textbooks. *Support Care Cancer* 21: 659–685.
21. Courneya, K.S., J.K. Vallance, S.N. Culos-Reed, M.L. McNeely, G.J. Bell, J.R. Mackey, Y. Yasui, Y. Yuan, C.E. Matthews, D.C. Lau, D. Cook, and C.M. Friedenreich. 2012. The Alberta Moving Beyond Breast Cancer (AMBER) Cohort Study: A Prospective Study of Physical Activity and Health-Related Fitness in Breast Cancer Survivors. *BMC Cancer* 12: 525. doi:10.1186/1471-2407-12-525.
22. Tian, Y., P.E. Schofield, K. Gough, and G.B. Mann. 2013. Profile and Predictors of Long-Term Morbidity in Breast Cancer Survivors. *Annals of Surgical Oncology* 20 (11): 3453–3460. doi:10.1245/s10434-013-3004-8. Epub 2013 May 24.
23. Hwang, S.Y., S.J. Chang, and B.W. Park. 2013. Does Chemotherapy Really Affect the Quality of Life of Women with Breast Cancer? *Journal of Breast Cancer* 16 (2): 229–235. doi:10.4048/jbc.2013.16.2.229. Epub 2013 Jun 28.
24. Hsu, T., M. Ennis, N. Hood, M. Graham, and P.J. Goodwin. 2013. Quality of Life in Long-Term Breast Cancer Survivors. *Journal of Clinical Oncology* 31 (28): 3540–3548. doi:10.1200/JCO.2012.48.1903. Epub 2013 Aug 26.
25. Lee, C.K., V.J. Gebski, A.S. Coates, A.S. Veillard, V. Harvey, M.H. Tattersall, M.J. Byrne, B. Brigham, J. Forbes, R.J. Simes, and Australia and New Zealand Breast Cancer Trials Group (ANZBCTG). 2013. Trade-Offs in Quality of Life and Survival with Chemotherapy for Advanced Breast Cancer: Mature Results of a Randomized Trial Comparing Single-Agent Mitoxantrone with Combination Cyclophosphamide, Methotrexate, 5-Fluorouracil and Prednisone. *SpringerPlus* 2: 391. doi:10.1186/2193-1801-2-391. eCollection 2013.
26. von Blanckenburg, P., F. Schuricht, U.S. Albert, W. Rief, and Y. Nestoriuc. 2013. Optimizing Expectations to Prevent Side Effects and Enhance Quality of Life in Breast Cancer Patients Undergoing Endocrine Therapy: Study Protocol of a Randomized Controlled Trial. *BMC Cancer* 13: 426. doi:10.1186/1471-2407-13-426.
27. Spector, D., A.M. Deal, K.D. Amos, H. Yang, and C.L. Battaglini. 2014. A Pilot Study of a Home-Based Motivational Exercise Program for African American Breast Cancer Survivors: Clinical and Quality-of-Life Outcomes. *Integrative Cancer Therapies* 13 (2): 121–132. doi:10.1177/1534735413503546. Epub 2013 Oct 7.
28. Champion, V.L., L.I. Wagner, P.O. Monahan, J. Daggy, L. Smith, A. Cohee, K.W. Ziner, J.E. Haase, K.D. Miller, K. Pradhan, F.W. Unverzagt, D. Cella, B. Ansari, and G.W. Sledge Jr. 2014. Comparison of Younger and Older Breast Cancer Survivors and Age-Matched Controls on Specific and Overall Quality of Life Domains. *Cancer* 120 (15): 2237–2246. doi:10.1002/cncr.28737. Epub 2014 May 28.

# Safe Use of Defibrillators: A Case Study in Greek Registered Nurses

**John Stathoulis, Maria Tsironi, Nikolaos Konofaos, Sofia Zyga, Alexandros Michopoulos, Helen Bakola, and George Panoutsopoulos**

**Abstract** International literature reveals the deficit of nurses' knowledge on the defibrillator and the need to implement continuing education training courses relative to clinical issues.

The purpose of this study was the evaluation of Greek registered nurses' knowledge on the safe use of the defibrillator before and after a 2-h workshop. Anonymous self-administered validated questionnaire consisted of two parts was used to collect the data, after the written consent of the participants. The sample consisted of 65 participants (12 men and 53 women) and the output data were analyzed with SPSS v. 19.0 (SPSS Inc., Chicago, IL). The quantitative variables are expressed as mean values (SD) or as median values (interquartile range = IQR) while the qualitative variables are expressed as absolute and relative frequencies. For the comparison of the proportions of the correct answers before and after the intervention, McNemar tests were used. A knowledge score was computed for every participant from all correct answers and converted to a scale from 0 to 100 (where 0 = none correct answer and 100 = all answers were correct). Paired Student's t-tests were used for the comparison of the knowledge score before and after the intervention. All reported p values are two-tailed and the statistical significance was set at $p < 0.05$. The mean knowledge score increased significantly from 66.7% to 91.3% after the intervention. The study showed that the implementation of educational programs contributes positively to update registered nurses' knowledge on clinical issues, which cannot be replenished only through undergraduate education and experience.

**Keywords** Defibrillators • Nurses • Safety procedures • Nursing education • Clinical engineering

J. Stathoulis (✉) • M. Tsironi • S. Zyga • A. Michopoulos • H. Bakola • G. Panoutsopoulos
Department of Nursing, Faculty of Human Movement and Quality of Life Sciences, University of Peloponnese, Sparta, Greece
e-mail: johnstathoulis@yahoo.gr; jstath@hol.gr

N. Konofaos
Department of Informatics, Aristotle University of Thessaloniki, Thessaloniki, Greece



P. Vlamos (eds.), *GeNeDis 2016*, Advances in Experimental Medicine and Biology 989, DOI 10.1007/978-3-319-57348-9_26

## 1 Introduction

The safe use of the defibrillators in everyday clinical practice is related to patient and staff safety along with the quality of the provided patient healthcare. The international literature reveals the deficit of nurses' knowledge on the defibrillators and the need to implement continuing education training courses relative to clinical issues, such us performing safety and performance tests of the devices along with the correct evaluation of patient's cardiac arrhythmias.

## 2 Material and Methods

The purpose of this study was the evaluation of Greek registered nurses' knowledge on the safe use of defibrillators before and after an educational intervention and in our case during a hands-on workshop. For the purposes of the study, an anonymous self-administered questionnaire was used to collect the data, which was constructed and validated for the purpose of the study and consisted of two parts: the first contained demographical questions and the second part consisted of 22 questions (True of False type) investigating registered nurses' knowledge on the principles of defibrillators' safe use and operation along with the discrimination of basic cardiac arrhythmias.

Before conducting the specific study, permission from the Hellenic Data Protection Authority was requested and obtained. In the application form, the purpose and form of the study and how the output data will be used were mentioned ensuring the anonymity of participants and the confidentiality of results. This study followed all the fundamental principles of research. Specifically, all the information about the participants was completely anonymous and confidential. Commitment given that the information and the extracted data will be used solely for the purposes of this study.

## 3 Results

Quantitative variables are expressed as mean values (SD) or as median values (interquartile range = IQR). Qualitative variables are expressed as absolute and relative frequencies. For the comparison of the proportions of the correct answers before and after the intervention, Mc Nemar tests were used. A knowledge score was computed for every participant from all correct answers and converted to a scale from 0 to 100 (0 = none correct answer and 100 = all answers were correct). Paired Student's t-tests were used for the comparison of the knowledge score before and after the intervention. All reported p values are two-tailed and the statistical significance was set at $p < 0.05$ while for the statistical analysis of the output data, SPSS v. 19.0 (SPSS Inc., Chicago, IL) was used.

Sample consisted of 65 participants (12 men and 53 women). Our sample is a sample of convenience and as in all studies conducted in Nurses in Greece; the

majority of participants were women. Our sample was collected within a hands-on workshop and consisted of Nurses of many different disciplines and workplaces derived from hospitals throughout the entire Greek region. Sample characteristics are presented in Table 1.

The proportion of correct answers before and after the intervention, along with the knowledge score is shown in Table 2. A significant increase in the proportion of correct answers was after the intervention for all questions except for 4, 11, 15, 17, 18.

The mean knowledge score (Fig. 1) increased significantly from 66.7% to 91.3% after the intervention.

**Table 1** Sample characteristics

| | N (%) |
|---|---|
| Sex | |
| Men | 12 (18.5) |
| Women | 53 (81.5) |
| Age | |
| 20–29 | 10 (15.4) |
| 30–39 | 31 (47.7) |
| 40–49 | 21 (32.3) |
| 50–59 | 3 (4.6) |
| Family status | |
| Unmarried | 23 (35.4) |
| Married | 37 (56.9) |
| Divorced | 4 (6.2) |
| Widowed | 1 (1.5) |
| Number of children, median (IQR) | 1 (0–2) |
| Educational status | |
| Technological education registered nurses | 51 (78.5) |
| University education registered nurses | 4 (6.2) |
| MSc | 9 (13.8) |
| PhD | 1 (1.5) |
| Nurse specialty | 22 (33.8) |
| Second degree | 10 (15.4) |
| Degree in English | 65 (100.0) |
| Hospital location | |
| Athens | 8 (12.3) |
| Thessaloniki | 2 (3.1) |
| Other prefecture | 55 (84.6) |
| Job position | |
| Head nurse | 4 (6.2) |
| Shift manager | 8 (12.3) |
| Registered nurse | 52 (80.0) |
| Other | 1 (1.5) |

(continued)

**Table 1** (continued)

| | N (%) |
|---|---|
| Professional status | |
| State employee | 62 (95.4) |
| Private law employee | 1 (1.5) |
| Contact employee | 2 (3.1) |
| Overall experience as registered nurse | |
| 0–4 years | 10 (15.4) |
| 5–9 years | 18 (27.7) |
| 10–14 years | 15 (23.1) |
| 15–19 years | 3 (4.6) |
| >20 years | 19 (29.2) |
| Working experience in present nursing department | |
| 0–4 years | 21 (32.3) |
| 5–9 years | 25 (38.5) |
| 10–14 years | 7 (10.8) |
| >15 years | 12 (18.5) |

**Table 2** Proportion of correct answers before and after the intervention

| | Correct answers | | |
|---|---|---|---|
| | Before | After | |
| Question | N (%) | N (%) | P Mc Nemar test |
| 1 | 37 (56.9) | 60 (92.3) | **<0.001** |
| 2 | 50 (76.9) | 64 (98.5) | **<0.001** |
| 3 | 34 (52.3) | 62 (95.4) | **<0.001** |
| 4 | 60 (92.3) | 64 (98.5) | 0.125 |
| 5 | 31 (47.7) | 58 (89.2) | **<0.001** |
| 6 | 37 (56.9) | 56 (86.2) | **<0.001** |
| 7 | 40 (61.5) | 58 (89.2) | **<0.001** |
| 8 | 38 (58.5) | 62 (95.4) | **<0.001** |
| 9 | 40 (61.5) | 53 (81.5) | **0.015** |
| 10 | 31 (47.7) | 54 (83.1) | **<0.001** |
| 11 | 46 (70.8) | 53 (81.5) | 0.210 |
| 12 | 35 (53.8) | 60 (92.3) | **<0.001** |
| 13 | 38 (58.5) | 61 (93.8) | **<0.001** |
| 14 | 45 (69.2) | 61 (93.8) | **0.001** |
| 15 | 54 (83.1) | 58 (89.2) | 0.388 |
| 16 | 39 (60.0) | 53 (81.5) | **0.014** |
| 17 | 48 (73.8) | 55 (84.6) | 0.167 |
| 18 | 51 (78.5) | 58 (89.2) | 0.167 |
| 19 | 52 (80.0) | 63 (96.9) | **0.003** |
| 20 | 40 (61.5) | 63 (96.9) | **<0.001** |
| 21 | 54 (83.1) | 65 (100.0) | **0.001** |
| 22 | 54 (83.1) | 65 (100.0) | **0.001** |
| Knowledge score (%), mean (SD) | 66.7 (16.2) | 91.3 (10.3) | **<0.001**[a] |

[a]Paired t-test

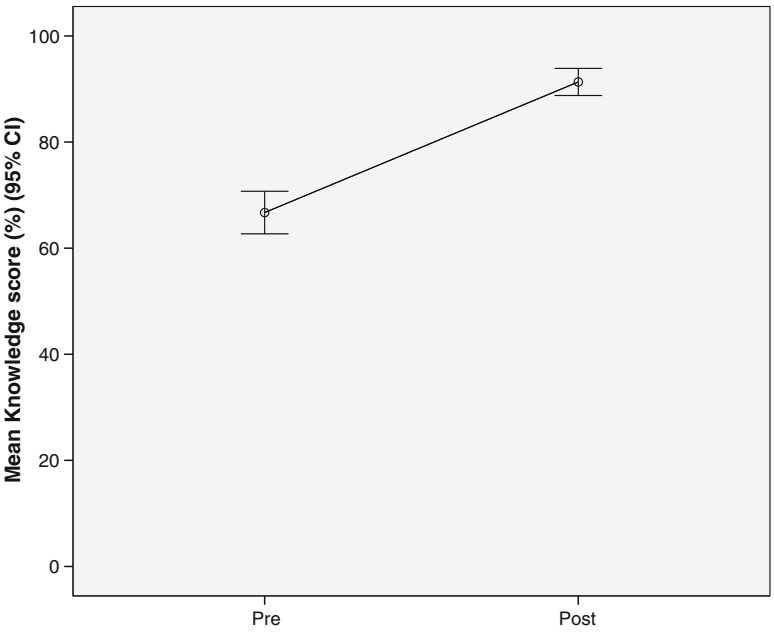


**Fig. 1** Mean knowledge score before and after the intervention

## 4 Conclusions

Clinical nurses' knowledge on the Defibrillators along with the knowledge of the biophysics' principles and electricity mechanisms mainly based on experience, aim at the avoidance of adverse invents, similar to these reported by other relative international studies. Identification of knowledge deficits concerning defibrillators must be researchers' primary goal, and these were mainly associated with principles of defibrillators' functions and safe use. Implementation of continuing education programs (lectures, hands-on training workshops and video presentations) is expected to positively contribute to the promotion of knowledge obtained from basic education and clinical experience.

# Quality of Life in Elderly Cancer Patients Undergoing Chemotherapy

**Maria Lavdaniti, Sofia Zyga, Eugenia Vlachou, and Despina Sapountzi-Krepia**

**Abstract** *Introduction*: As life expectancy increases, it is expected that 60% of all cases of cancer will be detected in elderly patients in the next two decades. Cancer treatment for older persons is complicated by a number of factors, thus negatively affecting patients' quality of life.

*Purpose*: The purpose of this study is to investigate quality of life in elderly cancer patients undergoing chemotherapy.

*Material and Method*: This study was descriptive and non-experimental. It was conducted in one large hospital in a major city of Northern Greece. The sample was convenience comprising 53 elderly cancer patients undergoing cycle 3 chemotherapy. The data was collected using the Functional Assessment of Cancer Therapy scale and included questions related to demographic and clinical characteristics.

*Results*: The majority of participants were men ($n = 27$, 50.9%) who were married ($n = 32$, 79.5%). Their mean age was 70.07 ± 3.60. Almost half of the sample ($n = 30$, 56.6%) had colon cancer. There was a statistical significant difference between men and women pertaining to physical wellbeing ($p = 0.004$) and overall quality of life ($p < 0.001$). When comparing each subscale with the patients' marital status it was found that there was a statistical difference with respect to social/family wellbeing ($p = 0.029$), functional wellbeing ($p = 0.09$) and overall quality of life ($p < 0.001$). Moreover, the type of cancer affected overall quality of life ($p < 0.001$) and social/family wellbeing ($p = 0.029$).

M. Lavdaniti (✉)
Nursing Department, Research Laboratory "Care in Adult Cancer Patients", Alexander Technological Educational Institute of Thessaloniki, P.O. Box 141, GR-574 00, Thessaloniki, Greece
e-mail: maria_lavdaniti@yahoo.gr

S. Zyga
Department of Nursing, Faculty of Human Movement and Quality of Life Sciences, University of Peloponnese, Sparta, Greece

E. Vlachou
Nursing Department, Technological Educational Institute of Athens, Egaleo, Greece

D. Sapountzi-Krepia
Nursing Department, Frederick University of Nicosia, Nicosia, Cyprus



P. Vlamos (eds.), *GeNeDis 2016*, Advances in Experimental Medicine and Biology 989, DOI 10.1007/978-3-319-57348-9_27

*Conclusions*: These findings call attention to quality of life and its related factors in elderly cancer patients. It is highly recommended to envisage measures for improving quality of life in this group of cancer patients.

**Keywords** Elderly • Cancer • Quality of life • Chemotherapy

## 1 Introduction

Cancer is the second leading cause of death worldwide. One of the high risk factor for cancer is advancing age [1]. As life expectancy increases, is expected that the number of older persons with cancer will increase. Nowadays, 60% of all cancers involve patients over 65 years and this percentage will increase to 70% by to 2030 [2].

Advanced age is associated with a decline in a function of organ system so the administration of antineoplasmatic drugs (chemotherapy) is accompanied with a number of complications [3]. Generally, cancer treatment for older persons is complicated by a number of factors, thus negatively affecting patients' quality of life.

There is evidence about quality of life in elderly patients undergoing chemotherapy. These patients had advanced cancer [4] prostate cancer [5] and breast cancer [6]. The results of these studies have shown that quality of life is affected by chemotherapy. Although, in Greece the population is getting older, little is known about quality of life in elderly cancer patients undergoing chemotherapy.

## 2 Purpose

The purpose of this study is to investigate quality of life in elderly cancer patients undergoing chemotherapy.

## 3 Material-Method

### *3.1 Sample and Setting*

This study was descriptive and non-experimental. It was conducted in a large hospital in a major Greek city. The sample was convenience comprising 53 elderly cancer patients undergoing cycle 3 chemotherapy on an outpatient basis.

### *3.2 Procedure*

The hospital's Research Committee gave its approval for the study. All potential participants were approached by a member of a research team and introduced to the aim of the study. A confidential letter was distributed to these potential participants to inform them about the study and participants' rights. Confidential statements were then collected from the patients who agreed to participate, following which they were given the questionnaire.

### *3.3 Instruments*

Subjects were assessed for their quality of life using the Functional Assessment of Cancer Therapy-General (FACT-G) scale. This is a 27-item scale and is comprised of four subscales: physical well-being (seven items), social/family well-being (seven items), emotional well-being (six items) and functional well-being (seven items). The items are rated on a 5-point Likert scale ranging from 0 = "not at all" to 5 = "very much". The FACT-G is scored by summing the individual scale scores. Higher total scores indicate better quality of life. Also, the questionnaire contained demographic and clinical characteristics [7].

### *3.4 Data Analysis*

The data analysis was performed using the statistical software package SPSS 21.0 for Windows. Descriptive statistics were used in order to analyze the demographic data. The variables are not normally distributed, so nonparametric tests were used.

## 4 Results

The mean age of patients was 70.07 ± 3.60 years. The majority of participants were men (n = 27, 50.9%) and were married (n = 42, 79.2%). A percentage of 64.2% (n = 34) were primary school graduates and all of them were retired. Almost half of the sample (n = 30, 56.6%) had colon cancer. The mean scores of the FACT-G subscales were: 8.41 ± 5.46 for physical well-being, 24.75 ± 3.75 for social/family well being, 6.56 ± 2.93 for emotional well-being and 13.11 ± 5.79 for functional well-being.

A statistically significant correlation was observed between the subscale of physical well being and age ($r = 0.272$, $p = 0.049$), gender ($r = 0.360$, $p = 0.008$), educational status ($r = -0.529$, $p < 0.001$). It was found a statistically significant correlation between social/family well being and age ($r = 0.935$, $p < 0.001$).

Furthermore, emotional well being subscale was correlated with family status ($r = -0.409$, $p = 0.002$), educational status ($r = -0.321$, $p = 0.001$) and type of cancer ($r = -0.440$. $p = 0.001$). Finally, functional well being subscale was correlated well with age ($r = 0.281$, $p = 0.042$), family status ($r = 0.439$, $p = 0.001$) and emotional status ($r = 0.541$, $p < 0.0001$).

## 5 Discussion

The study assessed quality of life in Greek elderly cancer patients receiving adjuvant chemotherapy. It contributes to the growing body of evidence regarding quality of life and provides an important foundation for Greek oncology nurses, because describing the phenomenon is a fundamental step toward appropriate interventions.

Elderly cancer patients in the study sample generally experienced low levels of quality of life. This is consistent with other studies [4, 6].

The study also found that age, gender, educational status, family status and type of cancer influence quality of life. These findings are not absolutely comparable with the results of a study which examined the pattern of quality of life during adjuvant chemotherapy [6] or another study evaluated and compared the health-related quality of life (HRQOL) of patients aged ≥65 with aged <65 during and after chemotherapy [8]. The findings of the present study could be attributed to a small sample size that did not have enough power to detect any such differences.

In addition, the present research revealed that quality of life is affected by chemotherapy in elderly cancer patients. Also the study found that many domains of quality of life are influenced by treatment so "a good quality of life should be a primary goal in the treatment of elderly patients with cancer" [9].

Furthermore, it should be stressed that the assessment of health-related QOL in elderly patients with cancer is a controversial area of research, because there are some methodological problems such as higher frequency of illiteracy, difficulty to understand the questionnaires, existence of comorbidities, use of instruments not validated in the elderly population. There is a great need for further research dedicated to elderly cancer patients with no methodological problems.

There are some limitations which should be discussed. One of them is the use of a convenience sample, and the fact that the data collection was conducted in one hospital in a major Greek city. Another significant limitation is the fact that the researchers did not study patients' clinical characteristics (e.g. stage of cancer, chemotherapy regimen, etc.) and thus it is difficult to correlate quality of life with them.

## 6 Conclusions

These findings call attention to quality of life and its related factors in elderly cancer patients. It is highly recommended to envisage measures for improving quality of life in this group of cancer patients.

## References


1. Berger, N.A., P. Savvides, S.M. Koroukian, E.F. Kahana, G.T. Deimling, J.H. Rose, K.F. Bowman, and R.H. Miller. 2006. Cancer in the Elderly. *Transactions of the American Clinical and Climatological Association* 117: 147–155.
2. Doni, L., A. Perin, L. Manzione, V. Gebbia, R. Mattioli, G.B. Speranza, L. Latini, A. Iop, O. Bertetto, F. Ferraù, P. Pugliese, P. Tralongo, A. Zaniboni, and F. Di Costanzo. 2011. The Impact of Anemia on Quality of Life and Hospitalisation in Elderly Cancer Patients Undergoing Chemotherapy. *Critical Reviews in Oncology/Hematology* 77 (1): 70–77. doi:10.1016/j.critrevonc.2010.04.002. Epub 2010 May 18.
3. Balducci, L., and M. Extermann. 2000. Management of Cancer in the Older Person: A Practical Approach. *The Oncologist* 5 (3): 224–237.
4. Li, Q., Y. Lin, Y. Qiu, B. Gao, and Y. Xu. 2014. The Assessment of Health-Related Quality of Life and Related Factors in Chinese Elderly Patients Undergoing Chemotherapy for Advanced Cancer: A Cross-Sectional Study. *European Journal of Oncology Nursing* 18 (4): 425–435. doi:10.1016/j.ejon.2014.03.005. Epub 2014 Apr 8.
5. Manokumar, T., S. Aziz, H. Breunis, S.F. Rizvi, A.M. Joshua, I.F. Tannock, and S.M. Alibhai. 2016. A Prospective Study Examining Elder-Relevant Outcomes in Older Adults with Prostate Cancer Undergoing Treatment with Chemotherapy or Abiraterone. *Journal of Geriatric Oncology* 7 (2): 81–89. doi:10.1016/j.jgo.2016.01.003. Epub 2016 Feb 4.
6. Leinert, E., S. Singer, W. Janni, N. Harbeck, T. Weissenbacher, B. Rack, D. Augustin, A. Wischnik, M. Kiechle, J. Ettl, V. Fink, L. Schwentner, and M. Eichler. 2016. The Impact of Age on Quality of Life in Breast Cancer Patients Receiving Adjuvant Chemotherapy: A Comparative Analysis from the Prospective Multicenter Randomized ADEBAR Trial. *Clinical Breast Cancer*. pii: S1526-8209(16)30372-X. [Epub ahead of print]. doi:10.1016/j.clbc.2016.10.008.
7. Fairclough, D.L., and D.F. Cella. 1996. Functional Assessment of Cancer Therapy (FACT-G): Non-response to Individual Questions. *Quality of Life Research* 5: 321–329.
8. Park, S., I.R. Kim, K.K. Baek, S.J. Lee, W.J. Chang, C.H. Maeng, J.Y. Hong, M.K. Choi, Y.S. Kim, J.M. Sun, J.S. Ahn, K. Park, J. Jo, S.H. Jung, and M.J. Ahn. 2013. Prospective Analysis of Quality of Life in Elderly Patients Treated with Adjuvant Chemotherapy for Non-small-cell Lung Cancer. *Annals of Oncology* 24 (6): 1630–1639. doi:10.1093/annonc/mds649.
9. Di Maio, M., and F. Perrone. 2003. Quality of Life in Elderly Patients with Cancer. *Health Quality of Life Outcomes* 1: 44.

# Quality of Life in Elderly Bladder Cancer Patients Following a Cystectomy

**Maria Lavdaniti and Sofia Zyga**

**Abstract** *Introduction*: Bladder cancer is the ninth most common cancer worldwide. The most common treatment for invasive cancer is radical cystectomy and urinary diversion (ileal conduit, continent urinary reservoir, orthotopic neobladder). In elderly patients, the standards methods of urinary diversion have been the ileal conduit and ureterocutaneostomy. Quality of life is an important consideration for patients with urinary diversion.

*Purpose*: The purpose of the present study was to review the literature on quality of life in elderly patients with bladder cancer following a cystectomy and urinary diversion.

*Material and Method*: A literature review was conducted using the electronic databases PubMed and Google scholar covering the period of time from 2006 to 2016. The following key words were entered: "quality of life", "bladder cancer", "elderly" "cystectomy" and a combination thereof. The exclusion criteria for the articles were languages other than English.

*Results*: It was found that various questionnaires were used. Some instruments measure QoL in general, whereas others are more specific with respect to the unique ways in which urinary diversion can impact patients' lives. Furthermore, some findings are contradictory, with certain results indicating that there is no statistically significant difference between quality of life parameters when comparing patients with a neobladder to those with an ileal conduit. In another study, patients who underwent orthotopic neobladder reconstruction reported significantly better physical functioning, role functioning, social functioning and QoL in general throughout the first postoperative months compared to patients who had ileal conduit formation.

M. Lavdaniti (✉)
Nursing Department, Research Laboratory "Care in Adult Cancer Patients",
Alexander Technological Educational Institute of Thessaloniki, P.O. Box 141,
GR-574 00, Thessaloniki, Greece
e-mail: maria_lavdaniti@yahoo.gr

S. Zyga
Department of Nursing, Faculty of Human Movement and Quality of Life Sciences,
University of Peloponnese, Sparta, Greece



P. Vlamos (eds.), *GeNeDis 2016*, Advances in Experimental Medicine
and Biology 989, DOI 10.1007/978-3-319-57348-9_28

*Conclusions*: All types of treatment have a number of advantages and disadvantages, the details of which should be explained to elderly patients thoroughly. This calls for comprehensive counseling sessions during which the patient and health professional discuss all relevant considerations.

**Keywords** Quality of life • Bladder cancer • cystectomy

## 1 Introduction

Bladder cancer is the ninth most common cancer worldwide. The most common treatment for high-grade bladder cancer (invasive cancer) is radical cystectomy with extended lymphadenectomy and urinary diversion, which includes ileal conduit, continent urinary reservoir and orthotopic neobladder [1]. In elderly patients, the most often used methods of urinary diversion have been the ileal conduit and ureterocutaneostomy [2].

There are many advantages and disadvantages of orthotopic neobladder and ileal conduit urinary diversions. Orthotopic neobladder may disturb quality of life in elderly patients because there is a risk of nocturnal incontinence and a need for strick postoperative bladder training regime. On the other hand, ileal conduit urinary diversions, may cause some problems, such as the difficulty of self-pouching, but there are fewer complications, there isn't a need for bladder retraining and there not risk of stomal complications [1, 2].

Quality of life is defined as "an individual perception of their position in life in the context of the culture and value systems in which they live and in relation to their goals, expectations, standards and concerns." Quality of life is an important consideration for patients with cystectomy due to its impact on patients' satisfaction with body image and urinary, sexual and social functioning [3].

## 2 Purpose

The purpose of the present study was to review the literature on quality of life in elderly patients with bladder cancer following a cystectomy and urinary diversion.

## 3 Material-Method

A literature review was conducted using the electronic databases PubMed and Google scholar covering the period of time from 2006 to 2016. The following key words were entered: "quality of life," "bladder cancer," "elderly" "cystectomy" and a combination thereof. The exclusion criteria for the articles were languages other than English.

## 4 Results

There is a growing body of evidence related to quality of life after radical cystectomy in elderly and younger patients.

Some findings of the studies are contradictory especially these compared quality of life between patients who underwent different surgical procedure.

In one comparative study, researchers investigated quality of life in elderly patients who underwent ideal conduit, ureterocutaneostomy or orthotopic urinary reservoir. Patients in three different groups reported good quality of life but they had different demands and expectations from their surgical procedure. The researchers argued that more efforts should be made in order to explain to elderly patients the advantages and disadvantages of each method [2].

Similarly, in another study was found the same level for all aspects of quality of life in patients who received orthotopic neobladder or received ileal conduit. The authors suggested that the orthotopic neobladder could be suitable for elderly patients [4].

In a recent published study Longo et al. [5] compare patients underwent ileal conduit diversion and patients underwent single stoma cutaneous ureterostomy. The patients with ileal conduit diversion had higher operating times, estimated blood loss, need for intensive care unit stay and length of hospital stay than the others. They concluded that a single stoma is a method without many complications and without significant impairment of quality of life in elderly patients.

Siddiqui and Izawa [6] in their detailed review suggested that ideal conduit after radical cystectomy is the better choice for most elderly patients and this group of patients reported acceptable levels of quality of life.

Furthermore it was found that in the studies used different instruments for measuring quality of life but the most frequently used tools was the EORTC QLQ-C30 and FACT-BL [2, 4]. Undoubtedly, there is a need for further research in this group of patients and future studies should attempt to incorporate larger samples, longer term follow up and validated disease specific HRQOL instruments.

## 5 Conclusions

All types of treatment have a number of advantages and disadvantages, the details of which should be explained to elderly patients thoroughly. This calls for comprehensive counseling sessions during which the patient and health professional discuss all relevant considerations.

## References

1. Chang, D.T., and N. Lawrentschuk. 2015. Orthotopic Neobladder Reconstruction. *Urology Annals* 7 (1): 1–7. doi:10.4103/0974-7796.148553.
2. Saika, T., R. Arata, T. Tsushima, Y. Nasu, B. Suyama, K. Takeda, S. Ebara, D. Manabe, T. Kobayashi, R. Tanimoto, H. Kumon, and Okayama Urological Research Group. 2007. Health-Related Quality of Life After Radical Cystectomy for Bladder Cancer in Elderly Patients with an Ileal Conduit, Ureterocutaneostomy, or Orthotopic Urinary Reservoir: A Comparative Questionnaire Survey. *Acta Medica Okayama* 61 (4): 199–203.
3. Ali, A.S., M.C. Hayes, B. Birch, T. Dudderidge, and B.K. Somani. 2015. Health Related Quality of Life (HRQoL) After Cystectomy: Comparison Between Orthotopic Neobladder and Ileal Conduit Diversion. *European Journal of Surgical Oncology* 41 (3): 295–299.
4. Sogni, F., M. Brausi, B. Frea, C. Martinengo, F. Faggiano, A. Tizzani, and P. Gontero. 2008. Morbidity and Quality of Life in Elderly Patients Receiving Ileal Conduit or Orthotopic Neobladder After Radical Cystectomy for Invasive Bladder Cancer. *Urology* 71 (5): 919–923.
5. Longo, N., C. Imbimbo, F. Fusco, V. Ficarra, F. Mangiapia, G. Di Lorenzo, M. Creta, V. Imperatore, and V. Mirone. 2016. Complications and Quality of Life in Elderly Patients with Several Comorbidities Undergoing Cutaneous Ureterostomy with Single Stoma or Ileal Conduit After Radical Cystectomy. *BJU International* 118 (4): 521–526. doi:10.1111/bju.13462. Epub 2016 Apr 4.
6. Siddiqui, K.M., and J.I. Izawa. 2016. Ileal Conduit: Standard Urinary Diversion for Elderly Patients Undergoing Radical Cystectomy. *World Journal of Urology* 34 (1): 19–24. doi:10.1007/s00345-015-1706-1. Epub 2015 Oct 16.