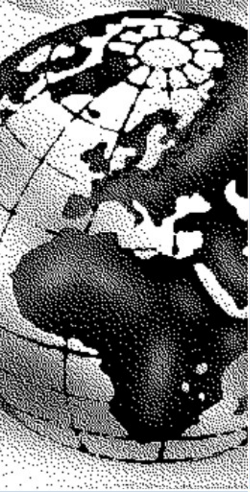

Steffen Blaschke

Structures and Dynamics of Autopoietic Organizations

Theory and Simulation

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Good science rests on self-proclaimed principles such as accuracy, precision, and rigor. These principles reduce error of all sorts (α, β, etc.) in the work of scientists; at the same time, they leave them with little room for passion in their work. The present work follows the principles of good science, of course. Nonetheless, it is deeply passionate about its subject of interest—organizations. On a more personal note than all the subtle and sometimes not so subtle hints of my own point of view on management science and organization theory, I want to acknowledge some of the people who in one way or another made a difference to my work.

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Rock & Roll.

Steffen Blaschke

Contents

List of Figures

List of Tables

1 Introduction

O body swayed to music, O brightening glance,
How can we know the dancer from the dance?

—William Butler Yeats, *Among School Children*, 1927

The closing question from Yeats' poem *Among School Children* incites a paradoxical answer. It is possible to observe the particular positions and movements of an individual dancer and thereby identify the performance as a specific dance, while it is impossible to observe the performance of the dance devoid of the positions and movements of the dancer. Still, any other dancer may well perform the same dance, and just therefore it is possible to distinguish the particular positions and movements that constitute a specific dance from any individual performance. "Such remarks indicate that we are aware of two ontologically distinct entities within one perceptual phenomenon," Gill (1975) highlights.

Knowing the dancer from the dance is neither purpose nor objective of the following contemplation. Nonetheless, the paradox that it is both possible and impossible to know the dancer from the dance is intriguing enough to introduces this work's genuine purpose and objective.

1.1 Purpose and Objective

The primary interest of this work rests with organizational knowledge and the associated concepts of organizational learning and memory, not the least because many argue that organizational knowledge is the main source of competitive advantage (e. g., Grant, 1996; Kogut & Zander, 1992; Nahapiet & Ghoshal, 1998; Nonaka, 1991, 1994; Prahalad & Hamel, 1990). The conceptual metaphors of organizational knowledge, organizational learning, and organizational memory enjoy a long-standing tradition in both management science and organization theory. "Indeed, they have simply become part of the taken-for-granted background in conversations of these topics, and now simply provide a point of departure for researchers to address their own assumptions," Easterby-Smith, Crossan, & Nicolini (2000, p. 748 f.) assert.

In general, metaphors allow for the understanding of one conceptual domain (source) in terms of another (target) (Lakoff & Johnson, 1980, p. 5), for example, organizations in terms of machines, organisms, brains, cultures, political systems, or psychic prisons (Morgan, 1986). The basic assumption of any such conceptual transfer is that the source and the target are two ontologically distinct entities that may or may not come within one perceptual phenomenon, not unlike the dancer and the dance. Hence, a clear-cut distinction between individuals and organizations is the prerequisite of organizational knowledge, learning, and memory.

The topics of knowledge, learning, and memory spawn an increasing amount of popular scientific literature. Bestselling titles such as *The New Organizational Wealth* (Sveiby, 1997), *Intellectual Capital* (Edvinsson & Malone, 1997), *Working Knowledge* (Davenport, 1993), *The Future of Knowledge* (Allee, 2003), and *The New Knowledge Management* (McElroy, 2003) present tools for measuring creativity, practical business rules for increasing prosperity, and step-by-step guides for sustaining competitive advantages. Their back flaps alone read like easy-bake recipes for organizational success. Davenport & Prusak (1998, front flap), for instance, lay claim to be the "definite overview of knowledge management, this influential book establishes the enduring vocabulary and concepts in the field." Although scientific in nature, this literature clearly lacks in rigor and therefore widely confuses individuals and organizations.

In large part, the scientific literature likewise denies organizations knowledge, learning, and memory of their own, nevertheless drawing heavily on the conceptual metaphors thereof. Carley (1992, p. 41) then writes, "there is no repository for knowledge in the organization other than personnel," and in a later work, "knowledge resides in the minds of the individuals in the organization, and it is also captured and stored in databases, procedural routines and organizational structure" (Carley & Hill, 2001, p. 68). Hedberg (1981, p. 3) states, "it is individuals who act and who learn from acting; organizations are the stages where acting takes place", and according to Argyris (1992, p. 8), "Organizations do not perform the actions that produce the learning. It is individuals acting as agents of organizations who produce the behavior that leads to learning."

Managerial practice (more or less) follows scientific theory. On the above assumption that organizational knowledge is little more than individual knowledge in an organizational setting, other literature advises business leaders to establish knowledge management systems (Hansen, Nohria, & Tierney, 1999; Poston & Speier, 2005; Thomas, Sussman, & Henderson, 2001; Watson & Hewett, 2006), for example. The promise is to efficiently and effectively capture, extract, and harvest individual knowledge for the benefit of the organization. Notwithstanding, information technology cannot deliver knowledge management all by itself (McDermott, 1999). An apparent trouble of managerial practice and ultimately organizational success (performance, survival, etc.) is thus the reliance on assumptions which may well be erroneous to begin with.

In remedy of these shortcomings, the genuine purpose and objective of this work is to develop a clear-cut distinction between (1) individuals and organizations, and between (2) individual and organizational knowledge, learning, and memory. Individuals and organizations lend themselves to theoretical scrutiny as two ontologically distinct entities despite being one perceptual phenomenon in practice. The distinction yields insights into knowledge, learning, and memory of both individuals and organizations as if the positions and movements that constitute a dance are observed devoid of the dancer, and vice versa. It provides the initial backdrop against which old and new questions in management science and organization theory are put, for example, “What is the effect of organizational structure on the knowledge of organizations?”, “How does personnel turnover and layoff affect organizational learning?”, and “Under which conditions are communities of practice beneficial to organizational memory?”

1.2 Scientific Contribution

The clear-cut distinction between individuals and organizations derives from social systems theory (Luhmann, 1984, 1995). Here, individuals and organizations are self-referential and self-producing or, in other words, autopoietic systems which recursively generate their networks of production through the interactions of previously produced components (Maturana & Varela, 1980, pp. 26–29). In case of individuals, these networks produce and reproduce consciousness; in case of organizations, they produce and reproduce communication (Luhmann, 1986). The autopoiesis of individuals and organizations furthermore separates them not only from their particular environment but from each other. Nonetheless, individuals and organizations are structurally coupled in that they incorporate observations of each other (Maturana & Varela 1980, p. 8; Orton & Weick 1990; Weick 1976) in their production and reproduction of consciousness and communication.

Autopoietic organization theory (Baecker, 1999, 2003; Bakken & Hernes, 2003; Seidl & Becker, 2006) adheres to the above definitions of individuals and organizations and already refines social systems theory (e. g., with respect to decision making, strategic management, organizational form and function). However, it lacks appropriate concepts of knowledge, learning, and memory. This work complements autopoietic organization theory in precisely this way. The core theoretical development comes at the level of basic research, then. In the following, organizational knowledge is derived as the cognitive structure of networks of communication, learning as the partial change, and memory as the connectivity thereof. Individual knowledge, learning, and memory are accordingly the cognitive structure of consciousness, its change, and its connectivity.

This work's theoretical core constitutes an advancement in management science and organization theory in itself. Still, autopoietic organization theory is only theory to begin with. There is nothing practical about it save for the alternative perspective on knowledge, learning, and memory it provides. Autopoietic organization theory already answers obvious questions such as "What is organizational knowledge?" (Tsoukas & Vladimirou, 2001), "What is organizational learning?" (Miller, 1996, p. 485), and "How is organizational memory different from individual memory?" (Walsh & Ungson, 1991, p. 60). However, it falls short of an explanation for the issue "Of what consequence is it for organizations that they are able to preserve knowledge of past events and bring it to bear on present decisions?" (again, Walsh & Ungson, 1991, p. 60).

Computational simulation is one way to inquire into complex issues (Luhmann, 1984, p. 275) which are hardly accessible to theoretical or empirical research. Knowledge, learning, and memory are such issues; theory describes them in easy enough terms, yet their practical workings are highly complex. Following the extension of autopoietic organization theory, this work operationalizes individuals and organizations as computational agents and their knowledge, learning, and memory as agent dynamics. Computational simulation of organizational structures and dynamics then answers the above questions—and more. For example, social systems theory claims that forgetting, rather than remembering, is the primary function of memory (Luhmann, 1996, p. 311). Findings from the simulation implicate that this may not be the general case after all.

1.3 Content and Structure

A critical review of the relevant literature in management science and organization theory introduces knowledge, learning, and memory from the rational, natural, and open systems perspective on organizations. Bureaucracy theory, scientific management, administration theory, and administrative behavior (Section 2.1) are the now classic theories that establish a general understanding of management science and organization theory early on. Human relations, cooperative systems, theories X, Y, and Z, and organizational learning (Section 2.2) depart from these roots only to focus on organizational characteristics in greater detail. Cybernetics, contingency theory, sensemaking, and knowledge management (Section 2.3) broaden the perspective on knowledge, learning, and memory once again. In summary, the literature review points to the development potential of these theories (Section 2.4).

Taken-for-granted concepts are of great value for any scientific community. They present a starting point for further research. Notwithstanding, paradigm shifts constitute times for reconsideration (Kuhn, 1970, pp. 66–76). Social systems theory is a prime candidate to ask old questions in hope of new answers as well as to address previously uncontested issues. It is a constructivist theory at heart and therefore presents a paradigm shift with respect to the rational, natural, and open systems perspective on organizations. As a grand theory, it provides fundamental concepts of individuals and organizations in terms of psychic and social systems (Section 3.1). An introduction to these autopoietic systems and their environment, their operations and observations, as well as communication, consciousness, expectation, and decision precedes the core theoretical development of this work. Section 3.2 extends autopoietic organization theory with respect to organizational knowledge, organizational learning, and organizational memory. The theoretical development draws heavily on the social systems perspective on organizations. First and foremost, it highlights the clear-cut distinction between individuals and organizations, and thus their knowledge, learning, and memory.

Autopoietic organization theory presents a necessary first step in conducting scientific research by means of computational simulation, namely, the deductive development of a theory or model. In addition, simulation requires two more steps which are the implementation of the theory or model in an experimental design, and the inductive analysis of the simulation results (Axelrod, 1997). An excursion into simulation as scientific endeavor (Section 4.1) and a brief historical account of social science simulation (Section 4.2) provide the basis for further application of this scientific methodology. In summary, the purposes and limitations of social science simulation are elaborated on (Sections 4.3 and 4.4).

The implementation of the core theoretical development in an experimental design brings the solution to the problem of complexity (i. e., that knowledge, learning, and memory are too complex phenomena to study in just theoretical or empirical fashion) a considerable step closer. To that effect, Section 5.1 operationalizes social and psychic systems as computational agents in their respective environment. Section 5.2 then establishes knowledge and decision, learning and unlearning, and remembering and forgetting as agent dynamics. The combination of agent types and dynamics allows for computational simulation of organizational structures and dynamics. The simulation findings (Section 5.3) confirm the proximity of autopoietic organization theory to other research in management science and (other) organization theory, in general. The simulation furthermore inquires into the issues of personnel turnover and layoff. Finally, it sheds new light on an ongoing discord in theories of communities of practice as it ventures into the question which type of community may serve organizations best, a gatekeeper, a random, or an expert community of practice.

The sixth and final chapter concludes this work in summary, implications for theory and practice, and an outlook of future research to be done.

2 Organizations as Rational, Natural, and Open Systems

The importance of organizations in modern society is an inevitable fact. They are "the principal mechanism by which, in a highly differentiated society, it is possible to 'get things done,' to achieve goals beyond the reach of the individual" (Parsons, 1960, p. 41). Already in ancient civilizations, organizations play an import role in society. Greek and Roman empires, for example, had institutions for public administration or tax collection. And while these empires came and went, some organizations such as the Catholic Church are still present today (cf. Kieser, 1989). However, the modern organization is a relatively young phenomenon. Scott remarks,

> Even though organizations are now ubiquitous, their development has been sufficiently gradual and uncontroversial that they have emerged during the past few centuries almost unnoticed. The spread of public bureaucracies into every sector and the displacement of the family business by the corporation "constitutes a revolution" in social structure, but one little remarked until recently. (Scott, 1998, p. 4)

Organizations in the form that we know and address them today emerge during the 19th century, a period of economic growth fueled by the industrial revolution. A corresponding science of organizations as a recognized and independent academic discipline does not come into being until the late 1950s when earlier efforts of individual researchers form a coherent theoretical basis.

This modern organization theory contains two streams of classical influences (Hatch, 1997). The sociological stream is represented by scholars such as Emile Durkheim, Max Weber, and Karl Marx. It focuses on the general role of formal organizations within society and the broader influences of industrialization on work and the worker. Weber's (1964) sociological analysis of bureaucracy, in particular, finds resonance in later works of organization theorists. The other stream comprises early works on administrations and management by Frederick Taylor (1911) and Henri Fayol (1969), Chester Barnard's (1972) acceptance theory of authority, and the economic theory of the firm (Coase, 1937). It focuses mostly on the practical problems faced by managers of industrial organizations. For more comprehensive reviews of the history of organization theory, see March (1965, pp. iv–xvi), Pfeffer (1982, pp. 23–33), and Hatch (1997, pp. 27–34).

The classical influences on modern organization theory trace back to these few sources. Naturally, the number of analytical approaches to organizations has grown over the past decades. As within all scientific fields, some theories are thoroughly developed (e. g., decision making in organizations) and have branched off into special-interest sub-disciplines (executive decision-support systems, knowledge management, etc.), while others (e. g., machine metaphors of organizations) have been rendered obsolete by paradigm shifts (Kuhn, 1970). Introductory texts to organization theory (e. g., Hatch, 1997; March, 1965; Perrow, 1986; Pfeffer, 1982; Scott, 1998; Shafritz & Ott, 2001) (for introductions in German, cf. Frese, 2000; Kieser & Kubicek, 1992; Schreyögg, 2000) commonly review both. The predominantly accepted theories of core concepts such as the environment of organizations, strategy and goals, technology, social and physical structure, and culture (Hatch, 1997) are contrasted with lesser known or outdated theories. In like manner, Scott (1998) identifies three general perspectives that have shaped the general understanding of organizations. His classification of organization theories in rational, natural, and open systems approaches offers a valuable framework for the analysis of organizational core concepts. The aforementioned classical streams of research, for example, find themselves mostly within the rational systems perspective. The remainder of this chapter examines selected theories from each of the three perspectives with respect to their conceptualizations of knowledge, learning, and memory in and of organizations. This literature review introduces the prevalent opinions held by leading scholars in management science and organization theory. It also offers a preface to the paradigmatic value of systems thinking. The chapter closes with a subsuming critique of organizational theories within the rational, natural, and open systems perspectives.

2.1 Organizations as Rational Systems

From a rational systems perspective, organizations are mechanistic means to achieve specified ends. They are well-designed machines in need of maintenance and tuning for optimal performance. Consequently, rationality with regard to the machine metaphor is defined in a narrow technical or functional sense. It refers to the optimized implementation of goals, not the goals themselves. “Indeed, it is perfectly possible to pursue irrational or foolish goals by rational means" (Scott, 1998, p. 33). A formal organizational structure, industrial specialization, and detailed job descriptions are but a few features of organizations seen as rational systems.

There are two defining characteristics that contribute to the rationality of organizational action (Scott, 1998, pp. 34–37). First, goal specificity provides the necessary criteria for decision making in organizations. A hierarchical structure ensures the top-down translation of ambiguous goals which guide strategic choices to programmatic decisions on the operational level. Thus, goals determine general resource allocation as well as detailed manufacturing procedures. The second characteristic is formalization. It refers directly to structure, that is to say, the precise and explicit rules governing organizational activity. Formalization includes, for example, the specified chain of command, the arrangement of functional departments, and individual roles in group relations. It is these two characteristics that rational systems theorists use to distinguish between organizations and other types of collectives.

The rational systems approach dates back to the works of Max Weber, Frederick Taylor, and Henri Fayol. While the first author is mainly concerned with the organizational structure, the latter two are clearly preoccupied with the management of organizations. Nevertheless, their efforts mark the foundation of organization theory at large; therefore, they are discussed in detail. Moreover, Herbert Simon's work on decision making in organization introduces the modern era in rational systems thinking.

2.1.1 Bureaucracy Theory

The German economist and social historian Max Weber (1864–1920) decisively influences organization theory through his analysis of administrative structures (for a detailed account of the life and work of Weber, cf. Bendix, 1960). The central aspect of his theoretical framework is the idea of authority (*Herrschaft*). He identifies three types thereof, namely, traditional, rational-legal, and charismatic authority (Weber, 1968, p. 215 ff.). Traditional authority rests on the established belief in the sanctity of traditions. Gerontocracy, patriarchalism, and patrimonialism are the most elementary forms of traditional domination. Rational-legal authority is based on the legality of enacted rules and the right of those elevated to power under it. The bureaucratic administration is the purest type of exercise of legal dominance. Charismatic authority resides in the devotion to the exceptional sanctity, heroism, or exemplary character of an individual person and in the normative rules embodied by him. Communities or communal relationships rooted in charismatic leadership exist only "in natu nascendi" (Weber, 1968, p. 246, sic). That is to say, they remain stable but in the long run become either traditionalized or rationalized.

Weber (1968, p. 223) asserts that the "bureaucratic type of administrative organization [is] capable of attaining the highest degree of efficiency and is in this sense formally the most rational known means of exercising authority." Rationality describes the idea of correct calculation of the propositions involved in bureaucracy and refers to procedures where impersonality and expert knowledge are necessary (Albrow, 1970). At this, bureaucracy is defined as a particular type of administrative structure which follows the principle of hierarchy. It has to be noted that this definition excludes the head of the organization (whether president, dictator, or owner) as well as the common laborer. Theoretical analyses from this perspective then focus primarily on the existence of organizational structures, and only to a lesser extent on the function thereof.

Weber's analysis of administrative structures must be seen in a larger historical context. His listing of structural characteristics of bureaucracy differentiates this rational system from earlier forms; it does not put forth criteria to enhance the bureaucratic organization itself. Within these structures, authority consists in a sphere of legal competence and is distributed via a system of promotion according to seniority, achievement, or both. The assumption is that organizational tenure is positively related to (technical) experience. Learning takes place strictly on the job. Knowledge in this context is reflected by each individual's status in the hierarchy of offices, because the higher a person stands within the chain of command, the more qualified he had to be in the first place to have been appointed by superiors. Memory is likewise personal. The administrative officers "acquire through the conduct of office a special knowledge of facts and have available a store of documentary material peculiar to themselves" (Weber, 1968, p. 225).

The idea of authority attributes competence only to the administrative staff. "Bureaucratic administration means fundamentally domination through knowledge," Weber (1968, p. 225) writes. But not only the rational-legal type of authority emphasizes individual knowledge; in like matter, organizations based on traditional and charismatic beliefs assign superior skills to their leaders. As expressed above, the key difference between the various organizational types is the legitimacy of authority and consequently their structural design. In terms of knowledgeable action, however, another distinguishing mark is the specification of knowledge held by individuals. Traditional and charismatic authority incorporates wisdom of elders, saints, or heroes, whereas bureaucracy focuses on technical knowledge independent of birth privileges or heroic deeds. This latter expertise (*Fachwissen*) is solely ascribed to administrative personnel; organizations possess no knowledge per se. In conclusion, the rationalization process as practical application of knowledge to achieve a desired end is exactly what constitutes the superiority of the bureaucratic administration over any other organizational form.

While there is controversy over some aspects of Weber's conceptions and arguments, his work nevertheless remains influential. For example, even in times when studies on organizational design tend to center on processes and networks, support for the efficiency of hierarchies persists (Leavitt, 2003); other scholars re-conceptualize Weber's own critique of the imprisonment of humanity in the iron cage of bureaucracy (Barker, 1993; DiMaggio & Powell, 1983); and lately there are discussions of Weber's impact on issues in the information age (Greenwood & Lawrence, 2005).

2.1.2 Scientific Management

The scientific management approach received its most important inputs from the American engineer Frederick Taylor (1856–1915) in the late 19th and early 20th century (for biographic details on Taylor, cf. Copley (1923) and Kakar (1970)). Scientific management aims to increase productivity by means of rationalization of processes and subsequently through standardization of practices. The starting point is always the scientific experiment whereby necessary activities in manual labor as well as administrative tasks are identified and evaluated. Taylor's (1911, p. 65) time-motion studies in the "science of shoveling" are certainly the most prominent examples. Moreover, the experimental findings are related to four programmatic principles of management (Taylor, 1911, p. 36): (1) The development of a true science of work, (2) the scientific selection and progressive development of the worker, (3) the bringing together of the science of work and the scientifically selected and trained workers, and (4) the constant and intimate cooperation of management and workers.

A True Science of Work. Taylor's true science of work points to the contradiction between managers and workers in terms of the amount of work to be done. Managers have no knowledge about the output of a suitable worker under optimal conditions. Workers, in turn, never really know what is expected of them. Scientific investigation remedies these shortcomings, eventually leading to the definition of standards and best practices. Workers then receive a premium pay depending on the attainment of the specified goals. Consequently, they suffer a loss if they fail to achieve the performance.

Scientific Selection and Development. In order to earn the highest rate of pay, workers have to be scientifically selected to suit a certain job. The criteria include physical strength, intellectual capability, and work experience. Moreover, a systematic development of each individual ensures the overall efficiency of the production plan. Taylor (1911, p. 36) writes, “They [the managers] scientifically select and then train, teach, and develop the workman, whereas in the past he chose his own work and trained himself as best as he could.” Notice that the explicit division of labor is accompanied by a division of knowledge, as well. While a single worker is trained according to defined standards, it is assumed that the knowledge to identify these standards in the first place is held by a manager. This is further exemplified within the following citation.

> The work of every workman is fully planned out by the management at least a day in advance, and each man receives in most cases complete written instructions, describing in detail the task which he is to accomplish, as well as the means to be used in doing the work. (Taylor, 1911, p. 39)

The Science of Work and the Worker. Taylor maintains that managers inevitably resist the “mental revolution” (Pugh & Hickson, 1989, p. 92) caused by scientific management, while workers are willing to cooperate based on the opportunity to earn higher wages. Most managers oppose scientific management, indeed (Scott, 1998, p. 40). But it is not Taylor’s principles that they defy, it is the resulting implications that lead to disapproval. Moreover, workers are largely refusing to comply with the scientific standards, too. This is partly due to the experimental design which implicitly assumes that all men are lazy and therefore have to be (financially) motivated (Merkle, 1980, p. 291). Nonetheless, it is the division of knowledge that invokes most discontent, because scientific management shifts the power associated with knowledge to managers who now set production guidelines by scientific laws.

Cooperation of Manager and Worker. Under the management of “initiative and incentive” (Taylor, 1911, p. 35), there is hardly a single act on the part of the worker which is not supervised or controlled by management. The division of labor, however, does not only separate manual from administrative work, it furthermore sub-categorizes all kinds of tasks. Taylor (1911, p. 123, sic) calls this "functional management" where "the old-fashioned foreman is superseded by eight different men, each one of whom has his own special duties, and [. . .] each one chosen for his knowledge and personal skill in his speciality." Thus, the managerial tasks themselves are divided into different functions such as cost clerk, time clerk, inspector, repair boss, speed boss, and so on. This type of functional organization predominantly emphasizes a division of knowledge which is exactly why managers were reluctant to adopt scientific management principles. "After all, Taylor had questioned their good judgment and superior ability" (Bendix, 1956, p. 280).

Scientific Management is a "combination of elements which have not existed in the past, namely, old knowledge so collected, analyzed, grouped, and classified into laws and rules that it constitutes a science" (Taylor, 1911, p. 140). An individual is "quickly given the very best knowledge of his predecessors with standard implements and methods which present the best knowledge of the world up to date" (Taylor, 1911, p. 126). In other words, knowledge is found in standardized procedures and scientific laws, as well as in individual skills and experiences. Moreover, because "memory has frequently grown hazy with age" (Taylor, 1911, p. 22), individual knowledge is assumed to be job related only. Learning occurs on two levels, then. First, experimentation identifies best practices to be later rationalized, that is, every single step and motion in a task is analyzed in order to be optimized for superior performance. Second, individual learning is largely an instructive training by functional experts.

Taylor's work receives harsh critique over the past decades (e. g., Locke, 1982; Wrege & Hodgetts, 2000). His influence on management science and organization theory remains strong, however. Some of the most prominent management paradigms or, in provocative terms, management fads (Abrahamson, 1991; Abrahamson & Fairchild, 1999) are rooted in scientific management, for example, total quality management (Feigenbaum, 1991; Juran, 1999) and business process reeingineering (Davenport, 1993; Hammer & Champy, 1993).

2.1.3 Administration Theory

Unlike Weber or Taylor, the French engineer Henri Fayol (1841–1925) never lays claim to a coherent scientific theory (a report on classical management theory and in particular Fayol's contributions to the field of organization science can be found in Massie (1965)). His major work entitled *Administration Industrielle et Générale* appears only in 1916 when he retires as general manager in a mining company; the English translation appears in

1949 as *General and Industrial Management*. The work identifies groups of activities which are consecutively designated as technical, commercial, financial, security, accounting, or managerial activity. All of the activities are present in most jobs, but in varying measure. The managerial element, however, is greatest in senior jobs and least in production of lower clerical tasks (Pugh & Hickson, 1989, p. 86). Managing is also universal to all organizations, while at the same time it is the least understood activity. Hence, Fayol (1916, pp. 19–47) begins with an outline of fourteen management principles. These rules summarize his experience as a manager, and although he acknowledges that they are neither of universal application nor of great permanence, they are in fact but simple rules of thumb. The principles are implicitly or explicitly included in the definition of the five elements of management (Fayol, 1916, pp. 48–136), namely, (1) forecast, (2) organization, (3) command, (4) coordination, and (5) control. Later on, there are numerous other attempts to list the essential functions of management. Among the more prominent are the POSDCORB framework by Gulick (1937) and the five principles of organization by Mooney & Reiley (1939).

*Forecast (*Prévoyance*).* The process of forecasting draws up a plan of action to direct the future of the business. The plan itself has to suffice four conditions. First, the objectives of each part of the organization have to be unified. Second, the continuity of both short-term and long-term forecasting has to be maintained. Third, the plan as a whole has to be flexible enough to adapt to changing circumstances. Fourth and last, planning precision in detail is essential to accurately predict the course of action. Consequently, the essence of forecasting allows for the optimal use of resources.

Organization. An appropriate organizational structure is central to any business. In accordance with general rationalization arguments, administration theory favors specialization, as well. It is suggested that departmentalization based on similarity of purpose, processes, clientele, or place is most beneficial in developing individual expertise. Also proposed is the line-staff principle by which all activities concerned with the achievement of the organizational goal are designated as line functions, whereas all accompanying service activities are considered staff functions. Furthermore, all line and staff departments are separated in a scalar hierarchy of power (resembling a pyramid). In contrast to Taylor's functional authority (cf. Subsection 2.1.2), the hierarchical structure explicitly contains the unity of command and direction. Here, each worker has only one boss, and people engaged in the same kind of activities share the same objectives in a single plan. Fayol acknowledges the benefits of lateral communication, that is, as long as it is known by superiors. Nevertheless, there is a heavy emphasis on formalization. This is also pointed out by Scott (1998, p. 41) who remarks that "careful specification of work activities and concern for their grouping and coordination is the hallmark of the formalized structure."

Command. Command logically requires a plan and an organization. First, the organizational goals have to be defined. Second, the right structure to achieve these goals has to be implemented. "Third, the organization must be put in motion, which is command" (Pugh & Hickson, 1989, p. 87). Command refers to the relationship between managers and their subordinates concerning an immediate task. This is a two-sided phenomenon. On the one hand, there is the legal authority on part of the managers: the right to issue command along with the responsibility for its exercise; on the other hand, there is the discipline of employees: the obedience of orders in faith of good leadership. It is only when both sides come together that the hierarchy will yield productivity gains over any other organizational form. Similar to the division of labor, the command function of management clarifies the locus of knowledge in administration theory. Managers act on knowledge of business and knowledge of subordinates. Thus, they are assumed to know the best way to allocate resources, organize tasks, or distribute work—in short, they know the best way to manage. Technical knowledge is largely credited to the individual worker. Nevertheless, managerial activities receive the most attention, primarily because they are regarded as to induce superior organizational performance.

Coordination. Organizations have a variety of tasks to perform. The effective separation of similar functions into departments only highlights this fact. Coordination aims at aligning the various departmental activities, just like the unity of direction guarantees individual efforts to coincide with each other. Coordination is the managerial element by which the unity of direction is accomplished at the organizational level. Keeping all organizational goals in perspective requires "a constant circulation of information and regular meetings of management" (Pugh & Hickson, 1989, p. 87). Again, the knowledge most crucial to organizational efficiency is clearly attributed to managers only.

Control. Finally, there is control. It logically checks for proper performance of the four preceding activities. “To be effective, control must operate quickly and there must be a system of sanctions” (Pugh & Hickson, 1989, p. 87). Here the line-staff principle ensures the necessary decoupling of operational activities from inspectional task. General management establishes goals, organizes departments, issues commands, and coordinates activities, whereas independent and impartial staff departments take on the control function. Along with bureaucracy theory and scientific management, administration theory soon draws considerable criticism, particularly from within the rational systems perspective itself (Massie, 1965). Most of the criticism pronounces the so-called management principles as mere common sense that furthermore lack sophistication and even reveal ambiguities upon close inspection (Simon, 1976, pp. 21, 36). Nonetheless, Fayol paves the road to modern organization theory “in identifying the fundamental features of formal organizational structure, audaciously clinging to the view that all organizations contain certain common structural characteristics” (Scott, 1998, p. 42).

2.1.4 Administrative Behavior

The theory of administrative behavior is largely associated with the American Nobel laureate Herbert Simon (1916–2001), receiving the prize in 1978 for his pioneering research on the decision-making process within organizations. In his earlier work on administration (Simon, 1976, originally published in 1945) and in his later collaboration with James March (March & Simon, 1958), Simon questions the simplifying assumptions of classic organization theory and thereby removes himself from the impetus of the generalization approach to management studies, that is, the search for management principles. Nevertheless, administrative behavior above all contributes to the clarification of goal specificity and formalization and therefore clearly belongs to the rational systems perspective (Scott, 1998, p. 49 ff.). Chronologically, however, it marks the beginning of modern organization theory.

Administrative behavior establishes decision making as the basic organizational process. Management thus becomes a matter of executive choice. The actual process of making a decision consists of three stages (March & Simon, 1958, p. 191 ff.): First, identifying an occasion calling for a decision; second, developing a set of possible actions; and third, making a choice between available actions. In addition, carrying out the decision is regarded as a decision-making process in itself. Selecting a particular production plan, for example, leads to a new set of problems involving detailed decisions about the manufacturing procedure, the distribution of machine capacity, and the like. In this sense, organizations are nested hierarchies of decisions (Scott, 1998, p. 51). Each decided upon action is a goal affecting either future decisions of subordinate managerial ranks or choices within the same organizational level. Now, organizations frequently present profitability, growth, and, of course, survival as their ultimate goals. While these organizational purposes appear somewhat vague and imprecise, it is argued that they can serve as the starting point for the construction of means-ends chains (Simon, 1976, p. 62) with which cascading goal specificity is achieved.

Beside the simplification of managerial decisions by restricting ends toward which activity is directed, organizations also support individuals in their decsion-making process. A formalized structure provides necessary means to assist organizational participants in all of their actions. Among other things, this includes management information systems, standard operating procedures, and specialized expert roles. In contrast to the command and control structure in classic organization theory, administrative behavior relies on training and channeling of information to produce dependable organizational behavior (Perrow, 1986, p. 128). Yet another fundamental critique on the underlying assumptions of earlier theories aims at the concept of the economic man wherein all actors in organizations are presumed to maximize their utility on the basis of complete information and rational choice. Instead, Simon and March propose the concept of bounded rationality (or the administrative man) wherein information is always incomplete and rationality is only limited so. Simon (1976, p. 79) writes, "it is impossible for the behavior of a single, isolated individual to reach any high degree of rationality. The number of alternatives he must explore is so great, the information he would need to evaluate them so vast that even an approximation to objective rationality is hard to conceive." Because of these cognitive restrictions, individual decision makers then take only those factors into account that allow for satisfactory solutions.

Administrative behavior distinguishes between two different knowledge-based decision-making techniques in organizations: programmed and non-programmed decisions (Pugh & Hickson 1989, p. 120; Simon 1976, pp. 11, 242). First, decisions are programmed if they are repetitive in nature, and if organizational routines and procedures are established to deal with them. Individual knowledge, skills, and competences are thus incorporated in organizational routines, procedures, structure, and culture (Schein, 1988). Examples are decisions involved in processing a customer's order, restocking materials in a warehouse, or determining employee's Christmas gratifications. Second, non-programmed decisions are either new and unstructured, or they are particularly difficult to handle and important to organizational outcomes. In this case, it is the trained executive who by "the function of knowledge [...] determines which consequences follow upon which of the alternative strategies" (Simon, 1976, p. 68); that is to say, the manager decides to the best of his (limited) knowledge on a suitable course of action. For instance, decisions on new products, departmental reorganization, or whether to sell a major interest in a subsidiary are all considered such non-routine choices.

Addressing individual and organizational knowledge inevitably leads to the discussion of learning and memory. Considering the latter, Simon (1976, p. 87) remarks "that memory may be either natural or artificial—information may be stored in the mind, or it may be recorded on paper in such a way as to be accessible." Moreover, he adds,

> Since an organization is not an organism the only memory it possesses, in the proper sense of the term, is the collective memory of its participants. This is insufficient for organization purposes, first, because what is in one man's mind is not necessarily available to other members of the organization, and, second, because when an individual leaves an organization the organization loses that part of its "memory." Hence organizations, to a far greater extent than individuals, need artificial "memories." Practices which would become simply habitual in the case of the individual must be recorded in manuals for the instruction of new organization members. (Simon, 1976, p. 166)

Although narrow in its definition (and meager in its application), administrative behavior is the first organization theory to explicitly state a concept of organizational memory. A corresponding model of organizational learning is only introduced in later extensions to the rational systems perspective (Cohen, March, & Olsen, 1972; Cyert & March, 1963). At this, decision making is organizational action as well as learning process. First of all, decision makers do not start with comprehensive knowledge. Their job requires formal training, adjustment to permissible action within the organizational boundaries, and goal adaptation by trial-and-error procedures. Most of the time, learning occurs on the job. Subsequently, organizational learning takes place within individual action and learning processes, for instance, improvement of routines, editing of employee training documentation, or changes in the formal communication structure.

Administrative theory is primarily interested in the factors that determine with what skills, knowledge, and competence a member of an organization undertakes his work. Similar to the other rational systems approaches, administrative behavior stresses the gains from advantages of expertise in decision making, that is, "the responsibility for decision must be so allocated that all decisions requiring a particular skill can be made by persons possessing that skill" (Simon, 1976, p. 10). The shortcomings accompanying the division of labor (and decision making), however, are challenged by standard practices, formal training, and multi-lateral communication channels. Thus, administrative behavior truly embraces modernist thinking.

2.2 Organizations as Natural Systems

The natural systems perspective on organizations primarily develops a critical response to the rational systems approach. It furthermore provides a novel view on organizations and therefore deserves consideration and evaluation in its own right. The inadequacies of the rational systems perspective lead, first and foremost, to a focal shift from the individual in the organization to the organization as a collective of individuals. Rational systems theorists emphasize normative structures and place decisions and actions in the center of attention as if they were the principal outcomes of organizations, whereas natural systems theorists underline behavioral structures and concern themselves more with what is done rather than what is decided or planned (Scott, 1998, p. 58).

Although the natural systems approach acknowledges the existence of the two central characteristics of the rational systems perspective, goal specificity and formalization, its challenge extends to the notion of goal complexity and informal organizational structures (Scott, 1998, p. 57). Goal complexity addresses three general themes: First, the official organizational goals and the goals that are actually pursued by the organization are not necessarily congruent (March & Simon, 1958, p. 65); second, organizational goals are most ambiguous and frequently cause inadvertent individual behavior (March & Olsen, 1976, p. 12); and third, organizations are governed by the overriding goal of survival (Hannan & Freeman, 1989) which often leads to the neglect or distortion of other organizational goals. The concept of informal organizational structures attends to the norms and behavior patterns among organizational members that are guided by individual characteristics rather than formal authority (Roethlisberger & Dickson, 1939, pp. 525–548). Informal structures emerge within the formal organization and generate, for example, status and power systems, communication networks, sociometric structures, and working arrangements. At this, they are highly effective in applying “the organization’s most precious resource: the intelligence and initiative of its participants” (Scott, 1998, p. 60).

Of course, the natural systems perspective is merely an umbrella for a number of organizational theories. The remainder of this section discusses the most important schools with respect to their applications of knowledge, learning, and memory. This includes the beginning of the human relations movement which is inevitably linked to Elton Mayo and the Hawthorne experiments, Chester Barnard’s cooperative systems theory, Douglas McGregor’s proposal to distinguish organization studies in theory X and theory Y, William Ouchi’s respective theory Z, and organizational learning as suggested by Chris Argyris and Donald Schön.

2.2.1 Human Relations

During and after World War I, the shortcoming of scientific management (cf. Subsection 2.1.2) to address the need of the individual becomes all too apparent in augmenting industrial disputes, union strikes, individual absenteeism, and personnel turnover (Mayo, 1945, p. 10). In an effort to remedy these problems, Elton Mayo (1880–1949) conducts a research program with the Western Electric Company in Chicago, Illinois (an extensive overview of the studies is provided by Roethlisberger & Dickson (1939)). The aim of the now famous Hawthorne experiments (named after Western Electric’s Hawthorne plant), which run from 1927 until 1932, is to develop standardized working conditions and improved payment structures. The researchers study the effects of the intensity of illumination at work, rest pauses, length of working days and weeks, fatigue and monotony, wage incentives, individual differences in teams, and interpersonal relations on the production output of relay assembly, mica splitting, and bank wiring jobs. Their rather unexpected discovery is the importance of the social organization of employees. Roethlisberger and Dickson write,

> The study of the bank wiremen showed that their behavior at work could not be understood without considering the informal organization of the group and the relation of this informal organization to the total social organization of the company. The work activities of this group, together with their satisfactions and dissatisfactions, had to be viewed as manifestations of a complex pattern of interrelations. In short, the work situation of the bank wiring group had to be treated as a social system; moreover, the industrial organization of which this group was a

> part also had to be treated as a social system. (Roethlisberger & Dickson, 1939, p. 551)

The individual worker is granted considerable technical expertise, dexterity, and intelligence, all of which are measured in the experiments on individual differences (Roethlisberger & Dickson, 1939, pp. 135, 162–166). The overall production efficiency, however, is largely a consequence of formal process arrangements as well as cooperation and communication among fellow group members. In other words, single employees apply their personal skills in their daily work routines, whereas the informal group structure accounts for the output of the group as a whole. In group piecework, for example, workers manufacture items independently yet band together to protect mutual wage interests by restricting the group output to an average and informally set norm. Consequently, those workers who raise the bar are punished as rate busters. The implications from this research stand in contrast to the propositions of rational systems theorists who strive to reduce the likelihood and effect of the informal organization structures. Indeed, human relations theory enlarges the managerial skill repertoire by the ability to effectively utilize the social system of organizations (Mayo, 1945, p. 112). Beside formal authority, leadership qualities, and technical expertise, managers now (need to) have the knowledge about successful identification and manipulation of social norms and informal communication channels. The discovery of the importance of the informal organizational structure merely entails another domain upon which decisions need to be made, that is, how to control the behavior of the worker (Roethlisberger & Dickson, 1939, pp. 511–524). Of course, the power to do so remains within the scope of managers who exercise control through the formal hierarchy. Although management subordinates (e. g., supervisors, engineers, efficiency experts, or rate setters) receive specialized training according to rank and seniority, their abilities are primarily applied to the purpose of the managerial group which, in turn, affects the workers at the lower level. The most comprehensive knowledge is thus located at the top of the organization, and with each underlying level, knowledge not only becomes increasingly specialized but also sparse. In a similar line of reasoning, Roethlisberger & Dickson (1939, p. 534) conclude that "it is a fallacy that workers can effectively control the actions of management by acting in certain ways." Rather, managers are omniscient of all possible behavior of their subordinates and act accordingly.

The Hawthorne studies truly mark the beginning of the human relations movement. Although there is an ongoing dispute whether the research and the corresponding literature is trustworthy in the first place (e. g., Gale, 2004; Jones, 1992), the findings nonetheless acknowledge the importance of social structures and already hint, albeit in a subtle manner, that knowledge, learning, and memory are no longer attributable to just managers. Early on, the Hawthorne studies inspire several leading scholars in management science and organization theory (including McGregor, Likert, and Ouchi; cf. Subsection 2.2.3), despite the criticism they receive as of today and despite their eventual fallback on the notion of encompassing managerial discretion.

2.2.2 Cooperative Systems

At the same time that Mayo and his associates conduct the Hawthorne studies and begin to emphasize the importance of human relations, Chester Barnard (1886–1961) outlines his own theory of organizations. In 1938, he publishes *The Function of the Executive*, the first (American) attempt to present a coherent science of organizations. (Weber's extensive *Theory of Social and Economical Organization* is first published in 1924, but the English translation was not available until 1947.) Barnard's ideas contribute both to the human relations movement and Simon's theory of decision making (cf. Subsection 2.1.4). Although for some time his "insights remained undeveloped and, to many readers, seemed quaint and old-fashioned" (Scott, 1990, p. 43), contemporary scholars, including Deal & Kennedy (1982), Ouchi (1981), and Peters & Waterman (1982), re-discover him as "the father of the concept of corporate culture" (Scott, 1990, p. 43).

Barnard defines an organization "as a system of coöperative activities of two or more persons" (Barnard, 1972, p. 75, sic, emphasis in the original). Cooperative action, in turn, is based on the following six remarks (Barnard, 1972, p. 60 ff.): (1) Since individual choice is limited by situational factors, the strategic point of attack is to change the situation by operations on these factors. (2) Limiting factors are of biological, physical, or social nature. Cooperation is the most effective method of overcoming these restrictions; it requires the adoption of a social (i. e., group or at least non-personal) purpose. (3) Cooperation, however, also (a) gives rise to social limitations by means of physical operation, and (b) changes the motives and interest of those participating in the cooperation. (4) The persistence of cooperation depends upon its effectiveness as well as its efficiency. Effectiveness relates to the accomplishment of the social and non-personal purpose of the cooperation (goal achievement); efficiency relates to the satisfaction of personal motives of each individual (member participation). Therefore, (5) the survival of cooperation depends on (a) the cooperative process in relation to the environment, and (b) the creation or distribution of satisfaction among individuals. (6) Instability and failures in cooperative processes arise from either one of these two interdependent processes. The function of the executive is to secure the effective adaptation of these processes.

Hence, the initially necessary and sufficient conditions for an organization are its participating members, their interaction processes, and a common purpose. Similar to the rational systems perspective, cooperative activities are primarily functionalized, that is, departments are arranged in hierarchical manner so to benefit most from specialization (effort in series). Progressive cooperation is the interaction process between specialists where the output of one individual is the input of another. However, there is no simple top-down direction of goals and decisions anymore; cooperation—per definition—entails the necessity of approval by subordinates. Moreover, cooperative systems theory also stresses concurrent cooperation (simultaneity of effort). Organizational members engage in, for example, simultaneous communication to extend the range of perception of a single individual. Indeed, Barnard (1972, p. 46) stresses that communication is the most universal form of cooperation.

Cooperative activities, whether progressive or simultaneous in nature, rest on knowledge or, more precisely, scientific knowledge as "expressed in languages and symbolic systems [that] are socially developed with meanings that are socially determined; and all 'finally' accepted observations of phenomena are coöperatively arrived at" (Barnard, 1972, p. 287, sic). Therefore, scientific knowledge is either the very purpose or the basis of organizational cooperation. For example, engineers use a specific kind of (technical) language which they acquire in the process of formal training. The purpose of cooperation between engineers and their teacher(s) is to develop a collective acceptance of phenomena (shared beliefs). In comparison, cooperation between engineers in an organizational setting with the purpose to invent a new product or to optimize a manufacturing procedure is based on the accumulation of specialized knowledge held by each individual separately. Scientific knowledge is an agreed upon belief by members of an organization or any other social community (e. g., engineers, physicians, lawyers). In this sense, learning and memory are imputable to individuals, too. Learning, on the one hand, is mainly induced by communication, but an increase in scientific knowledge may always be traced back to an individual. Memory, on the other hand, is upheld as long as a particular language and symbols are used. It automatically changes with a shift in belief.

Organizational communication as the basic cooperative process is for the most part determined by formal structure. Specialists interact with their departmental peers, goals are imposed top-down but approved bottom-up the hierarchy, and in some cases decision-making processes span functional boundaries. Yet every organization has an informal structure, as well. Barnard (1972, p. 115) explains, "By informal organization I mean the aggregate of the personal contacts and interactions and the associated groupings of people." He (1972, p. 120) argues that "formal organizations arise out of and are necessary to informal organization; but when formal organizations come into operation, they create and require informal organization." By combining these two perspectives, it becomes obvious why organizations rely on the critical function of the executive to formulate and define a collective purpose that is morally binding on participants (Barnard, 1972, pp. 217–234). Cooperation is certainly the driving force of the business, but common goals provide the imperative direction to successful organization. An important part of management is thus to create and sustain a culture of beliefs and values that support cooperation (Levitt & March, 1990), to assign responsibilities to particular members of the organization, and to further specify objectives. The executive process is distinct from organizational cooperation in that it endows concrete ends with effective means. The task of leadership to integrate specialized thinking and produce beneficial situations is seen as more of an art than a science.

> In the common-sense, everyday, practical knowledge necessary to the practice of the arts, there is much that is not susceptible of verbal statement—it is a matter of know-how. It may be called behavioral knowledge. It is necessary to doing things in concrete situations. It is nowhere more indispensable than in the executive arts. It is acquired by persistent habitual experience and is often called intuitive. (Barnard, 1972, p. 291)

Moreover, behavioral knowledge is "local, individual, particular, ephemeral. It is the aspect of individual superiority" (Barnard, 1972, p. 260). With reference to the work of an entire organization, executives require a more general ability. Their efforts are directed towards all work essential to the vitality and endurance of the organization. Leaders possess (scientific) knowledge of the various organizational functions (e. g., manufacturing, accounting, sales), and by means of their actual executive know-how they coordinate the formal and informal cooperation between employees. In many respects, formal education is common to all organizational members, whether they work on the shop floor or make decisions in the executive office. Learning the art of leadership, however, is mostly experiential (Levitt & March, 1990) and thus falls into place with rank and seniority.

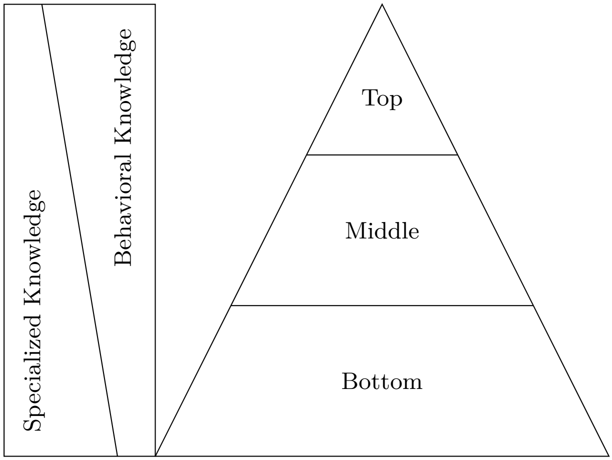

Figure 2.1: Specialized and Behavioral Knowledge in Cooperative Systems

In general, cooperative systems theory argues that the effectiveness of organizational operations ("are we doing the right things?") requires specialized knowledge, whereas the respective efficiency ("are we doing the things right?") is largely a matter of behavioral knowledge. Specialized knowledge prevails at the bottom of the organizational hierarchy, whereas behavioral knowledge is most common at the managerial level (Figure 2.1).

Still, all knowledge is individual knowledge, whether it is the shared belief among members of a group or the indispendable know-how of executive managers. Learning and memory are likewise individual achievements. However, with the unceasing emphasis on the importance of cooperation comes the insight that learning and memory nevertheless take place in communication (i. e., social interaction), at least concerning scientific knowledge. As for behavioral knowledge, learning and memory is only part of the individual art and practice of management. Despite the persistent praise for his contributions to management and organization science (cf. Williamson, 1995), Barnard stops short at the continuous application of his own inspiring ideas. For example, he frequently refers to an organization as a cooperative system of communication (i. e., a social entity in its own right) but inadvertently reverts to the statement that "such a system of communication implies centers or points of interconnection and can only operate as these centers are occupied by persons who are called executives" (Barnard, 1972, p. 215). Once again, the focus is on individuals in general and leaders in particular.

2.2.3 Theories X, Y, and Z

Beginning in the late 1950s, an increasing number of scholars with strong ties to neighboring disciplines such as psychology and sociology enter American business schools. Among them are Douglas McGregor (1906–1964) and Rensis Likert (1903–1981). McGregor quickly establishes himself as leading scholar in the scientific community by labeling the rational systems perspective *Theory X: The Traditional View of Direction and Control* (McGregor, 1960, pp. 33–44) and, in contrast, calling the natural systems approach to management *Theory Y: The Integration of Individual and Organizational Goals* (McGregor, 1960, pp. 45–58). As of today, Likert is most famous for the psychometric scale that he invents in 1932, but his work on *The Human Organization* (1967) equally shapes management science and organization theory of the times.

In particular, theory X recalls the textbook principles of organizations, that is to say, the hierarchical structure, authority, unity of command, task specialization, division of staff and line, span of control, equality of responsibility and authority, and so on, only to mock this "logically persuasive set of assumptions which have had a profound influence upon managerial behavior over several generations" (McGregor, 1960, p. 15). McGregor (1960, pp. 16–18) rests his critique on three main reasons: The classical principles of organizations (1) derive from inappropriate models (e. g., the military and the Catholic Church), (2) suffer from ethnocentrism (i. e., they are unrelated to the political, social, economic, and technological milieu), and (3) rely on erroneous assumptions about human behavior.

Theory Y replaces the assumption that all employees are essentially lazy with an image of an ambitious workforce thriving for responsibility and self-control. Consequently, authority and supervision give way to participation in perspective (McGregor, 1960, pp. 124–131) and self-control (McGregor, 1960, pp. 160–163). Managers depend on the specialized knowledge of subordinates, and they recognize the inadequacy of authorative methods to earn the confidence of their subordinates. Instead of exercising command and control, they delegate some of their authority and responsibility to their subordinates, effectively involving them in decision making (hence, participation in perspective). The delegation of authority and responsibility requires that managers control their own, not their subordinates' jobs (hence, self-control).

At the backwash of participative leadership, research on group patterns gradually emerges in management science and organization theory. For instance, Likert (1967, pp. 47–77) devotes a significant amount of attention to the interdependent, interacting character of effective organizations, wherein he emphasizes that "interaction and decision making relies heavily on group processes" (Likert, 1967, p. 50, sic). Still, the major concern among scholars is with leadership style in groups, not the groups themselves. The mere definition of a group as "a superior and all subordinates who report to him" (Likert, 1967, p. 50) exemplifies this matter.

Theory Y presents commonplace concepts of knowledge and learning but misses out on an elaboration of memory. McGregor (1960, p. 3) opens, "Every professional is concerned with the use of knowledge in the achievement of objectives," whereby he "draws upon the knowledge of science and of his colleagues, and upon knowledge gained through personal experience." Theory Y attributes knowledge to each and every individual separately, notwithstanding the importance of shared languages and symbolic systems (i. e., scientific knowledge; cf. Subsection 2.2.2) and the interdependencies among individuals. In like manner, learning is an individual achievement, too. "Above all, it is necessary to recognize that knowledge cannot be pumped into human beings the way grease is forced into a fitting on a machine. The individual may learn; he is not taught" (McGregor, 1960, p. 211).

In terms of knowledge and learning, the main concern is with the development of managerial talent (McGregor, 1960, pp. 177–243). However, the conclusions of theory Y are certainly valid for the development of all kinds of professional talent: Learning is (1) an active process of (2) practice and effective feedback. It largely depends on (3) individual motivation (i. e., a felt need for new knowledge or increased skill). Learning is (4) effective only within an organizational climate conducive to growth. (5) The skills of social interaction are among the most essential and most difficult to improve. In view of the complexities and difficulties involved in improving professional competence, (6) the expectations of formal training (e. g., classroom education) are modest, at best.

The scientific literature of the late 1970s introduces yet another theory bearing a single capital letter: theory Z (Ouchi & Jaeger, 1978; Ouchi & Price, 1978). The 1981 book *Theory Z: How American Business Can Meet the Japanese Challenge* by William Ouchi is the first business press bestseller, quickly selling over 100,000 copies (Daft, 2004). For the most part, it is a sociological follow-up to the works of McGregor and Likert. While the latter "observed that humanistically successful organizations tend to have many cohesive working groups in them, they were cautious about concluding that organizational success can be achieved through group development" (Ouchi & Price, 1978, p. 27). They concentrate on how to migitate the negative effects of hierarchy and lay claim to the effectiveness of participative leadership. Contrastingly, theory Z suggests that organized effort can be managed through one of three basic social mechanisms, namely, markets, hierarchies (i. e., bureaucracies), and clans. Clans, in particular, prove superior for a number of reasons.

"A clan is a culturally homogeneous organization, one in which most members share a common set of values or objectives plus beliefs about how to coordinate effort in order to reach common objectives" (Ouchi & Price, 1978, p. 36). The prime example of a clan is always the ideal-type Japanese cooperation. Unlike the American bureaucracy, it features low levels of turnover, slow evaluation and promotion, generalized knowledge and skills, implicit control mechanisms, consensual decision making, collective responsibility, and a holistic concern for people (Ouchi, 1981, p. 57 ff.). Accordingly, these seven characteristics are the solid foundation of the Japanese success throughout the 1980s.

Along the lines of theory Z, the focus of management science and organization theory shifts from leaders and other members of organizations to organizations and their leaders and other members. Unfortunately, theory Z offers no alternative descriptions of knowledge, learning, and memory, a fact which is partly due to its prescriptive nature (Keys & Miller, 1984; Sullivan, 1983).

2.2.4 Organizational Learning

Management science and organization theory address the issue of learning since Weber, and as the ever-growing body of literature shows, it remains a strong concern. The rational systems perspective, however, tends to examine the outcomes of learning, rather than to inquire into the processes of learning: Workers are more productive if they act in accordance with rationalized best practices (cf. Subsection 2.1.2), managers adapt to goals by trial and error (cf. Subsection 2.1.4), et cetera. Already Cyert & March (1963) take cautious first steps to delve into the (behavioral) processes of learning. But it is not until Argyris & Schön (1978) introduce their concept of organizational learning that this gap is finally bridged. At first simple *Single-Loop and Double-Loop Models in Research on Decision Making* (Argyris, 1976), organizational learning quickly becomes a full-fledged theory with paradigmatic ambitions for all of management science and organization theory. Further debates foster dialogue and largely develop what is now simply the taken-for-granted background in scientific research. This includes levels of learning, whether learning necessarily implies cognitive or behavioral change, the relationship between learning and unlearning, the distinction between organizational learning and the learning organization, and the measurement of organizational learning (Easterby-Smith, Crossan, & Nicolini, 2000). Reviews of the vast body of existing literature on organizational learning are provided by Hedberg (1981), Shrivastava (1983), Fiol & Lyles (1985), Huber (1991), Levitt & March (1988), Dodgson (1993), Miller (1996), Miner & Mezias (1996), and Easterby-Smith, Crossan, & Nicolini (2000). In part, organizational learning develops and branches off into adjacent lines of research, for example, communities of practice (cf. Subsection 2.3.4).

There is no general agreement as to what learning is, and how it occurs, not in management science, not in organization theory, not in economics, let alone among disciplines (Fiol & Lyles, 1985). As for single-loop and double-loop models, Argyris (1976, p. 365) defines learning as "the detection and correction of errors, and error as any feature of knowledge or of knowing that makes action ineffective." In fact, learning meets two conditions: Besides the detection and correction of an obvious mismatch between intentions and outcomes, learning also occurs "when an organization achieves what it intended; that is, there is a match between its design for action and the actuality or outcome" (Argyris, 1992, p. 8). Learning thus accompanies all action, though the more precarious case is apparently turning a mismatch into a match, that is, the case of changing knowledge or knowing so to make action more effective. Single-loop learning, in this sense, is the detection and correction of errors without questioning the governing variables of organizational actions; whether organizational goals, programs, routines, or structures, everything remains unquestioned. On the contrary, double-loop learning is the detection and correction of errors where the correction requires changing organizational actions and the variables that govern these actions; changing organizational goals, for instance, commonly allows for organizational actions which are not feasible beforehand, that is to say, not readily available alternatives in the single-loop model. To give another example, a thermostat programmed to increase or decrease the heat in order to keep the temperature constant is in single-loop learning mode. For double-loop learning to occur, the thermostat needs to inquire into why it should measure heat and why it is set so that the temperature is constant (Morgan, 1986, p. 86).

Figure 2.2 indicates that the detection of errors is a necessary, but not sufficient condition, for learning; a match or mismatch is always required. "Learning may not be said to occur if someone (acting for the organization) discovers a new problem or invents a new solution to a problem. Learning occurs when the invented solution is actually produced" (Argyris, 1992,

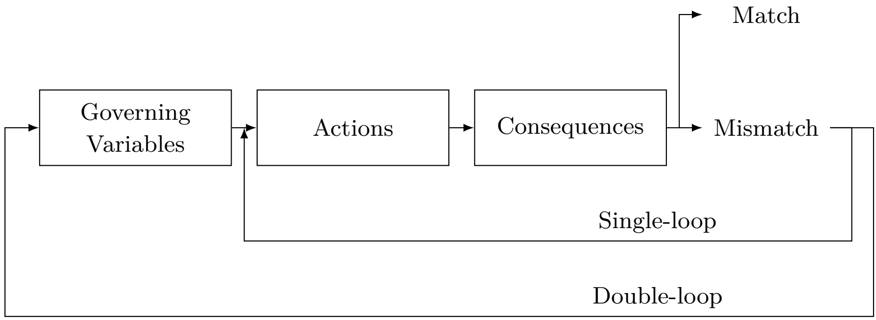

Figure 2.2: Single-loop and Double-loop Learning (Argyris, 1992, p. 5)

p. 9). Single-loop learning increases organizational efficiency within the range of (existing) organizational behavior. Double-loop learning expands the range of (potential) organizational behavior; it increases organizational effectiveness. In any case, learning requires information of a match or mismatch (i. e., the detection of errors), rendering the consequences of organizational actions observable in retrospect. Much like the dilemma between the exploration of new possibilities and the exploitation of old certainties (March, 1991), both single-loop learning and double-loop learning are essential for organizations; therefore, they are intertwined phenomena. On the one hand, an organization must innovate in order to stay competitive (exploration), on the other hand, it must reap the benefits from its innovations in order to invest in yet further innovations (exploitation), and so on. Similarly, single-loop learning exploits old certainties (i. e., it improves decision making within current strategies), whereas double-loop learning explores new possibilities, for example, by venturing into new strategies.

Organizations decide whether to pursue single-loop learning or double-loop learning on a level beyond the simple detection and correction of errors, just as they ameliorate performance by strategically deciding on exploration versus exploitation. In extension to the twofold model, Argyris and Schön call this deutero-learning or, in simpler words, learning how to learn.

> When an organization engages in deutero-learning its members learn about previous contexts for learning. They reflect on and inquire into previous episodes of organizational learning, or failure to learn. They discover what they did that facilitated or inhibited learning, they invent new strategies for learning, they

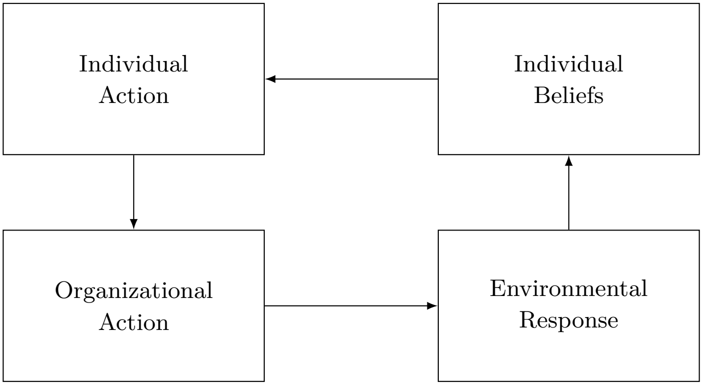

Figure 2.3: The Cycle of Organizational Learning (Hedberg, 1981, p. 3)

> produce these strategies, and they evaluate and generalize what they have produced. (Argyris & Schön, 1978, p. 4)

As the natural systems perspective primarily concerns itself with the description of social processes and the consecutive prescription of how to improve them, this basic introduction to the concept of organizational learning offers valuable insights into the very processes of learning and how to facilitate them. But it leaves open the question whether organizations are entities in their own right and thus are equipped with knowledge, learning, and memory of their own, or whether they are merely collectives of individuals who know, learn, and remember only through their current members. The corresponding literature provides a number of almost homonymous answers to this question; among the most prominent concepts is the cycle of organizational learning (Hedberg, 1981) (for a similar cyclic model of organizational choice, cf. March & Olsen, 1976).

The cycle of organizational learning (Figure 2.3) clearly states that "it is individuals who act and who learn from acting; organizations are the stages where acting takes place. Experiences from acting are stored in individuals' minds, and these experiences modify organizations' future behaviors" (Hedberg, 1981, p. 3). In other words, individuals' actions lead to organizational actions which evoke environmental responses; these responses are fed back into organizations, affect individuals' cognitions and preferences, and in that influence future actions (March & Olsen, 1976). Knowledge grows with changes in individuals' understanding of the environment (i. e., changes in beliefs, expectations, viewpoints, etc.) and subsequent actions thereon. This involves both learning new knowledge and discarding obsolete and misleading knowledge. Discarding knowledge or, to use the appropriate terminology, unlearning is as important as adding new knowledge (Hedberg, 1981).

The cycle of organizational learning implies that organizations are made by, and comprise of, individuals; thus, they cannot act on their own terms but only through their members. Exemplary citations in correspondence with this line of argument are easy to come by. In straightforward manner, Carley & Behrens (1999, p. 659) state, "Organizations do not make decisions, people do." March & Olsen (1976, p. 15) view organizational choices "as derivative of individual actions." Argyris, once more, clarifies that

> Organizations do not perform the actions that produce the learning. It is individuals acting as agents of organizations who produce the behavior that leads to learning. Organizations can create conditions that may significantly influence what individuals frame as the problem, design as a solution, and produce as action to solve the problem. (Argyris, 1992)

Likewise, Simon (1991, p. 125) points to conditions which facilitate individual learning in organizations when he says, "What an individual learns in an organization is very much dependent on what is already known to (or believed by) other members of the organization and what kinds of information are present in the organizational environment."

The assumption that organizations cannot act on their own terms proves tricky with respect to an ample description of how exactly organizations influence individual problem definition, solution planing, and decision making. Taking a slightly relaxed stance towards this assumption, some scholars then admit that organizational learning is not just the sum of each member's learning (e. g., Dodgson, 1993; Fiol & Lyles, 1985). "Organizations do not have brains, but they have cognitive systems and memories," Hedberg (1981, p. 6) reminds his readers. They develop and maintain learning capabilities with which they influence not only immediate members but also others by way of preserving and transmitting programs, procedures, routines, norms, values, et cetera. In other words, individual behavior is to some extent governed by organizational "strategies and structures purposefully being developed to facilitate and coordinate learning in rapidly changing and conflictual circumstances" (Dodgson, 1993, p. 380). For better or worse, this is just the cycle of organizational learning.

Consequently, the answer to the above question remains ambiguous. So far, the literature provides no clear-cut theoretical distinction between organizations as entities in their own right and organizations as collectives of individuals. Indeed, at the crossroads of old and new paths in organizational learning research, the concerns are somewhat more subtle. Table 2.1 (in part adapted from Easterby-Smith, Crossan, & Nicolini, 2000; Miner & Mezias, 1996; Shrivastava, 1983) summarizes the key issues contemporary scholars deal with.

At this point, it is noteworthy that management science and organization theory are among the first disciplines in social science to employ simulation tools and techniques. Besides qualitative and quantitative empirical studies, there are several simulation models revolving around knowledge, learning, memory, and, last but not least, decision making. Cohen, March, and Olsen's *Garbage Can Model of Organizational Choice* (1972), March's *Model of Mutual Learning* (1991), and Carley's *Model of Organizational Learning* (1992) are but a few examples from prestigious scholary journals. The below simulation model (cf. Chapter 5) heavily relies on this line of research.

With an interest in individual and organizational knowledge, learning, and memory, organizational learning is certainly among the most prolific theories to turn to. Unfortunately, the ever-increasing popularity of these topics in scientific research, university curricula, and business press publications waters down the value of (once) rigorous theories, among them organizational learning. Instead of fruitful advancements to theory, more and more papers, books, and reports appear without making any serious contributions to the field of interest. In many cases, new research simply puts alternative labels on known issues (cf. Subsection 2.3.4 on knowledge management).

Table 2.1: Key Issues in Organizational Learning

Levels of Learning	Learning Processes	Detriments to Learning
Individuals Acquisition of new skills, norms, and values; effects of experience and ambiguity; individuals interpretation	*Trial-and-Error-Learning* Repetition of successful routines, behavior, and competencies; standard operating procedures; learning curve effects (Abernathy & Wayne, 1974; Argote, 1999; Cohen & Levinthal, 1990; Duncan & Weiss, 1979; Yelle, 1979)	*Superstitious Learning* Subjective experience of learning is compelling, but the connections between actions and outcomes are misspecified (Argyris & Schön, 1978; Levitt & March, 1988)
Groups and Communities Performance feedback; shared understanding; coordinated behavior	*Inferential Learning* Informed observation; active experimentation; interpretation and information acquisition (Argyris & Schön, 1978; Daft & Weick, 1984; Weick, 1991; Weick & Roberts, 1993)	*Myopic Organization* Overvalueing information from current period, local situation, or past success (Levinthal & March, 1993)
Organizations Aspiration level; intraplant and interplant learning; organizational information processing	*Adaptive Learning* Adjusting to environmental change; adopting competitors' strategies; copying of successful routines (Cyert & March, 1963; Levitt & March, 1988; March, 1991; March & Olsen, 1976)	*Level of Noise* Rapid learning can be dangerous in the presence of substantial noise in the feedback process (Lounamaa & March, 1987; March, 1991)

Table 2.1: (continued)

Levels of Learning	Learning Processes	Detriments to Learning
Populations of Organizations Shared experience; timing; technological standards; effects of varied copying rules	*Generative Learning* Active and creative discovery processes (Nonaka, 1994; Senge, 1993)	*Number of Independent Subunits* Many learning frontiers can reduce usefulness of learning (Lounamaa & March, 1987) *Timing* Learning too early or too late (March, 1991) *Interaction Between Levels of Learning* Same event may facilitate learning at one level but inhibit it at another (Levinthal, 1991)

2.3 Organizations as Open Systems

Moving from the rational to the natural systems perspective, the discussion continues with selected schools from the open systems perspective and their respective understanding of knowledge, learning, and memory in and of organizations. About the time of the human relations movement, systems thinking gains significant attention in management science and organization theory, though its roots are much older (e. g., Galileo Galilei's *Dialogo Sopra I due Massimi Sistemi del Mondo*, his dialogue on the two main world systems, is an epitome of systems thinking; published in 1632, the book is banned a year later due to accusations of heresy from the Catholic Church). The open systems perspective is in fact the first scientific school of thought to explicitly call attention to systems.

In the late 1940s and early 1950s, Ludwig von Bertalanffy (1901–1972) promotes the idea that the most important entities studied in scientific disciplines, whether they are atoms, molecules, cells, organisms, individuals, organizations, societies, or even the solar system, are all subsumable under a *General System Theory* (his collected works are published under the same name in 1968). By definition, systems are combinations of parts whose relations make them interdependent. Inspired by von Bertalanffy, Boulding (1956) identifies nine types of systems that vary both in the complexity of their parts and in the nature of the relations among their parts (Table 2.2).

2.3.1 Cybernetics

Cybernetics is the science of communication, control, and feedback in machines, individuals, organizations, societies, and any combination thereof (Ashby, 1956; Wiener, 1965). Today, many subject matters run under its heading (e. g., adaptive systems, artificial intelligence, complex systems, learning classifiers, operations research, systems engineering). Cybernetics associates with the names of Norbert Wiener (1894–1964) and William Ross Ashby (1903–1972), though it receives considerable extensions from Heinz von Foerster (1911–2002). It puts the emphasis on the functional relations between the parts of a system, rather than the parts themselves. These relations include information processing, communication channels, environmental feedback, and the like. The later works of von Foerster on the *Cybernetics of Cybernetics* (1979) and *Observing Systems* (1981b) point out that the study of any system is indeed an observation of second order, thus including the observer in the system. In effect, observation constitutes another important functional relation between the parts of a system.

Table 2.2: Boulding's (1956) Hierarchy of Systems

Level	Description and Examples
1. Frameworks	Systems comprising static structures, such as the arrangement of atoms in a crystal, the anatomy of an animal, or the mapping of the earth
2. Clockworks	Simple dynamic systems with predetermined, necessary motions, such as pulleys, steam engines, and the solar system
3. Control Mechanisms	Systems capable of self-regulation in terms of some externally prescribed target or criterion; for example, thermostats
4. Open Systems	Systems exhibiting a self-maintaining structure, based on a throughput of resources from their environment. Examples include cells, flames, and rivers
5. Genetic-Societal Systems	Plant-like systems with increasing differentiation of mutually dependent parts (roots, leaves, seeds, etc.) and the ability of blue-printed reproduction
6. Image-Processing Systems	Self-aware systems with an image or knowledge structure of their environment, typified by increased mobility and teleological behavior of animals
7. Symbol-Processing Systems	Self-conscious and self-reflexive systems bound with the phenomenon of language and symbolism, such as human beings
8. Social Systems	Systems of role-person interrelations tied together with channels of communication; for example, symbol-determined communities (cultures)
9. Transcendental Systems	Systems composed of "the ultimates and absolutes and the inescapable unknowables" (Boulding, 1956, p. 205)

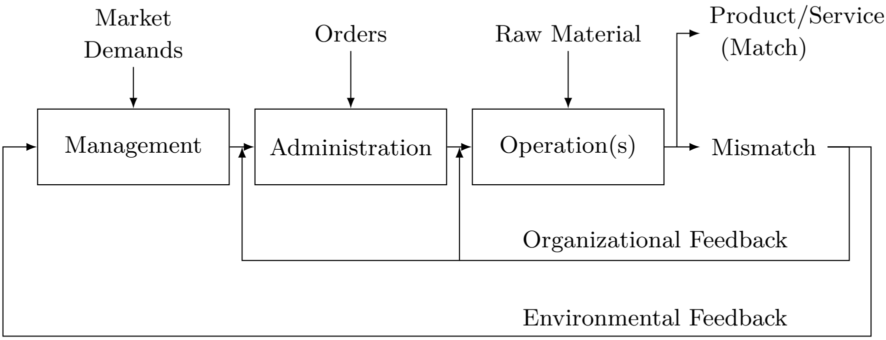

Figure 2.4: Communication, Control, and Feedback in Cybernetic Organizations

To view organizations as cybernetic systems is to recognize the parts of management, administration, operation(s), and the flows among them (cf. Scott, 1998, p. 86). Management anticipates, faces, or responds to demands of the market and sets the goals, plans, and programs for the entire organization accordingly. Bound by these goals, plans, and programs, administration receives orders from, for example, customers or higher-level organizations and applies norms, procedures, routines, rules, and standards to operations where raw materials are transformed into services or products. Much like in single-loop and double-loop learning (cf. Subsection 2.2.4), discrepancies between the outputs of an organization and its goals, plans, programs, norms, and so on (organizational feedback) call for managerial or administrative revision thereof. Mismatches between the quality or quantity of services or products and the corresponding market demands (environmental feedback) are occasions for corrective actions by management only (Figure 2.4).

This analytic framework may be applied to organizations as a whole or to any of their subsystems. Consider, for example, a department of human resources which must meet the demands of other departments for trained employees. Hiring is restricted by the maximum number of employees management allows, operational training faces budget limitations, and personnel turnover requires close monitoring.

The dangers of cybernetics, alas, are obvious. Its analytic rigor abstracts individuals from the organization they are members of, at least in theory. Indeed, cybernetics does not conceal its lack of empiricism. “In somewhat harsher terms, man in the Big System is to be—and to a large extent has become—a moron, button-pusher or learned idiot, that is, highly trained in some narrow specialization but otherwise a mere part of the machine" (von Bertalanffy, 1968, p. 10, sic).

On the upside of this rather anti-humanistic stance, cybernetics presents elaborated concepts of knowledge, learning, and memory which lay the foundations of theories to come. In reference to Boulding's hierarchy of systems (Table 2.2), knowledge requires at least image-processing systems at level six. Hence, knowledge is information destilled into an image, view, or representation of the environment as a whole. At this point, note that "the environment contains no information; the environment is as it is" (von Foerster, 2003b, p. 252, emphasis in the original). Information, in this sense, is always a selective observation of, say, an external reality. In the words of Boulding,

> Knowledge is not something which exists and grows in the abstract. It is a function of human organism and of social organization. Knowledge, that is to say, is always what somebody knows: the most perfect transcript for knowledge in writing is not knowledge if nobody knows it. Knowledge however grows by the receipt of meaningful information—that is, by the the intake of messages by a knower which are capable of reorganizing his knowledge. (Boulding, 1956, p. 198)

The relationship between the receipt of meaningful information at the system boundary to the environment and the knowledge at hand is exceedingly complex. Undeniably, however, learning brings about the growth of knowledge. "It is not a simple piling up or accumulation of information received, although this frequently happens, but a structuring of information into something essentially different from the information itself" (Boulding, 1956, p. 204). If learning is structuring and restructuring of information into an image, view, or representation, then this knowledge accounts for the information received next, thence further learning, and so on. Neither does learning pile up or accumulate knowledge, nor does it simply respond to any feedback there is. Rather, learning is recursive, it evolves systems over time. Truth be told, recursiveness is the hallmark of second-order cybernetics.

Two pairs of terms frequently occur and re-occur in discussions of memory. They are (1) storage and retrieval (e. g., Levitt & March, 1988; Olivera, 2000; Simon, 1976; Walsh & Ungson, 1991) and (2) recognition and recall (e. g., Haist, Shimamura, & Squire, 1992; Weick & Roberts, 1993; von Foerster, 2003d). Inherent to storage and retrieval is "a certain invariance of quality of that which is stored at one time and then retrieved at a later time" (von Foerster, 2003d, p. 102). A family who stores their expensive jewelry in a lock box at a bank counts on getting precisely this jewelry back, not any other jewelry, imitation, or else. Libraries store books, journals, and micro-fiches and, upon request, retrieve just those books, journals, and micro-fiches from their archives, nothing else. On the contrary, recognition and recall reflect "the overt manifestations of results of certain operations," and they are not to be confused "with either the operations themselves or the mechanisms that implement these operations" (von Foerster, 2003d, p. 103). Once more, von Foerster provides his readers with the most vivid illustration, and there is no better way than to cite him in full.

> After arrival from a flight I am asked about the food served by this airline. My answer:
>
> "FILET MIGNON WITH FRENCH FRIES AND SOME SALAD, AND AN UNDEFINABLE DESSERT."
>
> My behavior in response to this question—I believe—appears reasonable and proper. Please note that nobody expects me to produce in response to this question a real
>
> filet mignon with French fries and some salad, and an undefinable dessert. (von Foerster, 2003d, p. 104, sic)

Clearly, von Foerster's verbal response cannot be accounted for by any system of storage and retrieval. Recognition is the faculty to identify experiences and to classify these with other earlier experiences, and recall is the faculty to make symbolic representations of these experiences. Therefore, the memory of any system at or beyond level six on the above hierarchy of systems (e. g., individuals, organizations, and societies) is characterized by recognition and recall rather than storage and retrieval.

This short literature review of the most concise cybernetic concepts of knowledge, learning, and memory neglects several other key works. Among them are *The Computer and the Brain* (von Neumann, 2000, first published in 1958), *Embodiments of Mind* (McCulloch, 1965), and *Steps to an Ecology of Mind* (Bateson, 1987, first published in 1972). The authors of these works address issues such as what constitutes knowledge, where and in which form does knowledge exist, and whether or not knowledge must represent itself. Other contributions seek to explain matters of organized complexity, for example, *The Sciences of the Artificial* (Simon, 1996, first published in 1969), wherein memory builds somewhat of a second environment. These and other ideas are elaborated on below (cf. Chapter 3). For in-depth reviews and discussions of key works in systems thinking, turn to Baecker (2005).

2.3.2 Contingency Theory

First and foremost, contingency theory responds to the works of Likert (1967), March & Simon (1958), and McGregor (1960). Lawrence & Lorsch (1967a, p. 3), the founding fathers of contingency theory, state, "All of these writers tend to start with the individual as the basic unit of analysis and build toward the large organization, while we are proposing to start with larger, sociological entities—the entire organization and its larger subsystems." Following this proposal, many scholars embark upon the premises of contingency theory which succinctly summarize: (1) there is no one best way to organize, (2) any way of organizing is not equally effective (Galbraith, 1973, p. 2), and (3) the best way to organize depends on conditions of complexity and change in the environment organizations relate to (Hatch 1997, p. 77; Scott 1998, p. 94).

The relationship between organizations and their environment(s) is the common denominator of early research on innovation (e. g., Burns & Stalker, 1961), resource dependence theory (Pfeffer & Salancik, 1978), institutional theory (DiMaggio & Powell, 1983; Meyer & Rowan, 1977), and population ecology (Carroll & Hannan, 2000b; Hannan & Freeman, 1977, 1989). The working hypothesis of these elaborations on contingency theory reads that organizations whose internal features best match external (i. e., environmental) opportunities and constraints (i. e., contingencies) entail superior performance. More specifically, to cope with environmental uncertainty (defined by the amount of complexity and the rate of change in the environment; cf. Duncan, 1972), organizations create specialized subunits (e. g., research and development, production and manufacturing, marketing and sales) which, in turn, consist of "the patterned activities of a number of individuals" (Katz & Kahn, 1966, p. 28). According to the more general idea of open systems, these subunits exhibit different levels of formalization, depending on their transformation of inputs (information, human resources, raw materials, etc.) into outputs (e. g., production and cost effectiveness, employee and customer satisfaction, quality processes and products).

Contingency theory and its follow-ups have little specific to say about knowledge, learning, and memory. Neither do these key words appear in the subject index of any of the above cited books, nor do the relevant articles present concepts of knowledge, learning, or memory. In general, knowledge is treated as a matter of individual possession. Pfeffer & Salancik (1978, p. 48) write, "An individual possesses his knowledge in a direct and absolute manner. He is the sole arbiter of its use by others. The basis for the power of such professionals as doctors, lawyers, and engineers, with respect to their clients, lies in the access to knowledge." Morgan (1986, p. 78) concludes, "Contingency theorists suggest that we can best proceed by appointing 'the right people' to the job we have in mind, and by creating flexible authority, communications, and reward structures that will motivate them to satisfy their own needs through the achievement of organizational goals." In other words, organizations obtain, use, and discard knowledge in that they hire, employ, and dismiss employees. Knowledge, to them, is simply another resource. Unfortunately, this is a common belief in the popular business press, too (e. g., Allee 2003, p. 93 ff.; McElroy 2003, p. 72 ff.).

Similar to resource dependence theory, population ecology assumes that organizations heavily depend on their environments for the resources they need to operate on. However, whereas resource dependence theory clearly adopts the perspective of the organization, population ecology looks at organizations from the perspective of the environment. The research interest consequently shifts from micro-level issues of resource scarcity to macro-level patterns of success and failure among competing organizations in a population. A lack of skilled personnel (i. e., knowledge scarcity), for example, gives rise to organizational change (i. e., organizational learning). Following the three stages of variation, selection, and retention, organizational change is synonymous to the creation, survival or failure, and diffusion of organizational forms (Hannan & Freeman, 1977). Aldrich (1979, p. 28) explains, "Organizational forms—-specific configurations of goals, boundaries, and activities—-are the elements selected by environmental criteria, and change may occur either through new forms eliminating old ones or through the modification of existing forms." Skilled personnel constitutes a variation within or among organizations, obviously. The lack of skilled personnel forces some organizations to develop their members' skills themselves, while others try to hire new personnel all along. Over time, some organizations are positively selected and survive, while others fail to meet environmental demands and vanish. The continuous selection eventually leads to the retention of isomorphic organizational forms (DiMaggio & Powell, 1983; Meyer & Rowan, 1977). Successful organizations institutionalize "an increasingly elaborate base of beliefs and rules that furnish the foundation for [other] organizations: forms that embrace these models" (Scott, 1998, p. 117). In this sense, institutionalized organizational goals, boundaries, and activities are the very memory of organizational populations.

Contingency theory is criticized for its "attempts to build a theoretical edifice from bricks of non-universality" (Longenecker & Pringle, 1978, p. 680). More specifically, Schoonhoven identifies several grave inconsistencies hidden within the language of contingency theory; she writes,

> contingency theory is not a theory at all, in the conventional sense of theory as a well-developed set of interrelated propositions. It is more an orienting strategy or metatheory, suggesting ways in which a phenomenon ought to be conceptualized or an approach to the phenomenon ought to be explained. Drawn primarily from large-scale empirical studies, contingency theory relies on a few assumptions that have been explicitly stated, and these guide contingency research. (Schoonhoven, 1981, p. 350)

In addition to misguided theory building, empirical studies in this tradition lack an appropriate scheme for delineating the domain of the research as well as a systematic development of analytical dimensions (Ginsberg & Venkatraman, 1985). Lest not forget, knowledge, learning, and memory are largely excluded from any innovative conceptions.

2.3.3 Loose Coupling, Interpretation, Sensemaking

Throughout the 1960s, management science and organization theory centers on how organizations can achieve the functional alignment of goals, structure, technology, and environment in the presence of uncertainty (e. g., Burns & Stalker, 1961; Cyert & March, 1963; Lawrence & Lorsch, 1967b). With reference to Boulding's hierarchy of systems (cf. the introductory part of Section 2.3), Pondy & Mitroff (1979, p. 9, sic) remind their readers that "organizations are level 8 phenomena, but our conceptual models of them (with minor exceptions) are fixated at level 4, and our formal models and data collection efforts are rooted at levels 1 and 2" (moreover, cf. Table 2.2). Hence, they call for research on phenomena of organizational birth, death, and reproduction, the creation of meaning, the development of organizational cultures, and other subjects of interest. First published in the late 1970s, early 1980s, the interrelated theoretical ideas of loose coupling (Orton & Weick, 1990; Weick, 1976), interpretation (Daft & Weick, 1984; Weick & Daft, 1983), and sensemaking (Weick, 1969, 1995; Weick, Sutcliffe, & Obstfeld, 2005) are indeed conceptualizations of organizations at a higher level of system complexity, incorporating organizational activities and variables that have not been captured in other approaches.

Loose coupling intends "to convey the image that coupled events are responsive, but that each event also preserves its own identity and some evidence of its physical or logical seperateness" (Weick, 1976, p. 3). More specifically, Orton & Weick explain,

> Loose coupling suggests that any location in an organization (top, middle, or bottom) contains independent elements that vary in the number and strength of their interdependencies. The fact that these elements are linked and preserve some degree of determinancy is captured by the word coupled in the phrase loosely coupled. The fact that these elements are also subject to spontaneous changes and preserve some degree of independence and indeterminancy is captured by the modifying word loosely. The resulting image is a system that is simultaneously open and closed, indeterminate and rational, spontaneous and deliberate. (Orton & Weick, 1990, p. 204 f.)

Thus, in the case of a manufacturing company, it may be that the production line is loosely coupled to the sales department. The chief engineer and the head of sales are somewhat attached, but each one of them retains some identity and separateness. Their attachment may be infrequent, weak in its mutual affects, slow to respond, and so on, and so forth.

In an attempt to reconceptualize earlier theories of loose coupling, Orton & Weick (1990) review the relevant literature and distill five voices thereof. (1) The voice of causation seeks to explain why some systems are loosely coupled and others are not. Similar to the causes of loose coupling, (2) the voice of typology is not directly concerned with the value of loose coupling as a management tool but emphasizes descriptive clarity as a precursor to causal clarity. Research which uses (3) the voice of direct effects strongly advocates loose coupling; its theme is, "loose coupling has specific effects and the effects are desirable" (Orton & Weick, 1990, p. 210). Contrastingly, (4) the voice of compensations presents loose coupling as an unsatisfactory condition that should be reversed. Lastly, (5) the voice of organizational outcomes predicts and measures the effects that loose coupling has on the performance of organizations. Orton and Weick combine the five voices distilled from the literature in a simple, sequential model (Figure 2.5).

It is not necessary to introduce the causes, types, effects, compensations, and outcomes of loose coupling in detail. More importantly, note that loose coupling incorporates the structural aspects of contingency theory (e. g., flexible authority, communications, and reward structures at the face of environmental uncertainty; cf. Subsection 2.3.2) into a more procedural model of organizing, rather than organizations. Therefore, organizational interpretation and sensemaking are at close hand.

> Organizations must make interpretations. Managers literally must wade into the swarm of events that constitute and sur-

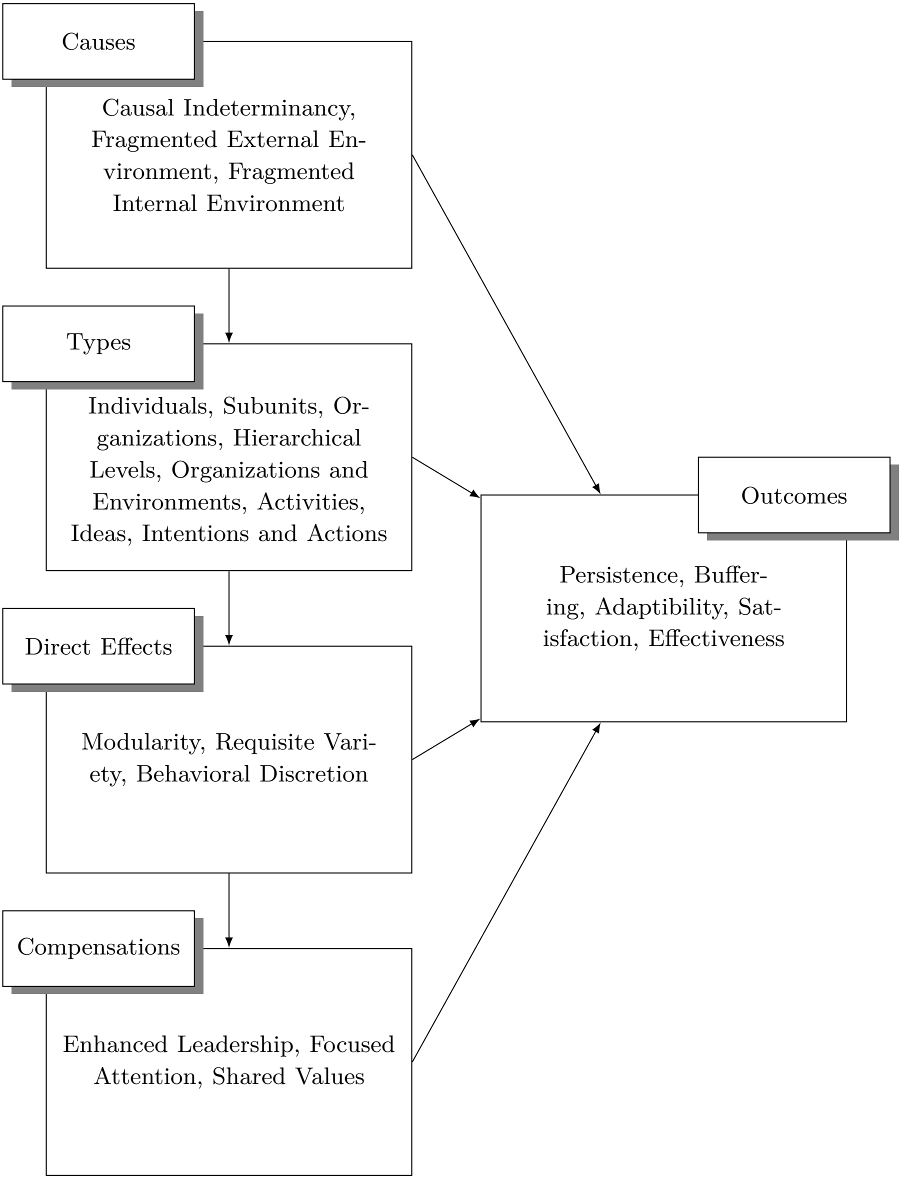

Figure 2.5: Loose Coupling Theory (adapted from Orton & Weick, 1990)

> round the organization and actively try to impose some order on them. Organization participants physically act on the environment, attending to some of it, ignoring most of it, and talking to other people to see what they are doing. Structure must be imposed on the apparent randomness in order for interpretation to occur. Interpretation is the process of translating these events, of developing models for understanding, of bringing out meaning, and of assembling conceptual schemes. (Weick & Daft, 1983, p. 74)

Interpretations inform and modify that which they are intended to explain; they interpret interpretations. Interpretations are made a posteriori; they focus on past action. Interpretations construct environments; they write cause-effect maps of some environment that could have produced a particular outcome. Interpretations are arbitrary, reasonable rather than right, et cetera (Weick & Daft, 1983, pp. 74–76). All of these statements reify that an interpretation is as much a process as it is a product.

Sensemaking, in turn, is clearly about a process. While it is common to say that someone made an interpretation, it is unlikely to hear that someone made a sensemaking. Weick (1995, pp. 17–62) distinguishes at least seven characteristics that set sensemaking apart from other explanatory processes such as understanding, interpretation, and attribution. Sensemaking is (1) grounded in identity theory (i. e., the identity of a single sensemaker constitutes in the process of interaction), (2) retrospective, (3) enactive of sensible environments (the term enactment preserves the fact that part of someone's environment is self-constructed), (4) social, (5) ongoing, (6) focused on and by extracted cues (familiar structures, points of reference, etc.), and (7) driven by plausibility rather than accuracy.

As of late, sensemaking replaces interpretation as the leading cognitive concept in management science and organization theory, at least with respect to the number of relevant publications. Weick, too, favors the somewhat more comprehensive concept of sensemaking, although there is no denying that sensemaking closely resembles interpretation. After all, the inherent goal of both theories is to enable organizations "to create and identify events that recur to stabilize their environments and make them more predictable" (Weick, 1995, p. 170). Figure 2.6 contrasts interpretation (adapted from Daft & Weick, 1984, p. 286) and sensemaking in organizations (adapted from Weick, Sutcliffe, & Obstfeld, 2005, p. 414).

By now it is obvious that interpretation (scanning, interpretation, learning) and sensemaking (enactment, selection, retention) inextricably link

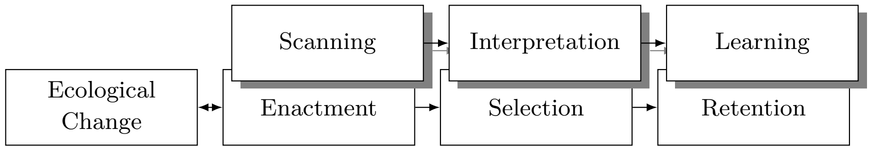

Figure 2.6: Organizational Interpretation Versus Sensemaking

back to loose coupling. For example, due to their bounded rationality (i. e., their limited information-processing capabilities; cf. Simon, 1955, 1991), individuals perceive different parts of their environment (scanning, enactment), tune them out at different times (interpretation, selection), and process them at different speeds (learning, retention). "As a result of the idiosyncratic worlds formed under these conditions, people will find it difficult to coordinate their actions and will share few variables or weak variables, all of which leads to loose coupling" (Orton & Weick, 1990, p. 206). Figure 2.5 refers to this cause of loose coupling as causal indeterminancy.

Already this brief introduction hints the importance of knowledge, learning, and memory in the interpretation and sensemaking activities of loosely coupled systems. Indeed, Daft & Weick build their approach to organizations on the assumption

> that the organizational interpretation process is something more than what occurs by individuals. Organizations have cognitive systems and memories (Hedberg, 1981). Individuals come and go, but organizations preserve knowledge, behaviors, mental maps, norms, and values over time. The distinctive feature of organizational level information activity is sharing. A piece of data, a perception, a cognitive map is shared among managers who constitute the interpretation system. (Daft & Weick, 1984, p. 285)

Similar statements about knowledge, learning, and memory are found in Weick, Sutcliffe, & Obstfeld's account of nurses in high pressure situations; the authors conclude,

> Medical sensemaking is as much a matter of thinking that is acted out conversationally in the world as it is a matter of knowledge and technique applied to the world. Nurses (and physicians), like everyone else, make sense by acting thinkingly, which means that they simultaneously interpret their knowledge

> with trusted frameworks, yet mistrust those very frameworks by testing new frameworks and new interpretations. The underlying assumption in each case is that ignorance and knowledge coexist, which means that adaptive sensemaking both honors and rejects the past. (Weick, Sutcliffe, & Obstfeld, 2005, p. 412)

Other publications by Weick and colleagues refer to knowledge, learning, and memory in terms of cognitive maps (Weick & Bougon, 1986), collective minds (Weick & Roberts, 1993), or schemes of interpretation (Weick & Quinn, 1999). Along with research in organizational learning (cf. Subsection 2.2.4), these publications are among the first to distinguish between individuals and the organization(s) these individuals are members of. "Our focus is at once on individuals and the collective, since only individuals can contribute to a collective mind, but collective mind is distinct from an individual mind because it inheres in the pattern of interrelated activities among many people," Weick & Roberts (1993, p. 360). Clearly, interpretation and sensemaking are as much individual processes as they are organizational processes.

As elaborate as the concepts of interpretation and sensemaking in loosely coupled systems are, they lack a comprehensive and consistent terminology. Construction, enactment, perception, representation, and the like terms mix with attribution, improvisation, interpretation, sensemaking, et cetera. Cognitive maps, collective minds, and schemes of interpretation are as much instances of knowledge as they are historical accounts of memory developed in learning. Nevertheless, the theoretical ideas of loose coupling, interpretation, and sensemaking provide an inspiring foundation for further research (cf. Chapter 3).

2.3.4 Knowledge Management

Throughout the 1990s, several scholars attempt to remedy the fact that knowledge, despite its undeniable importance, is but a commonplace in all of management science and organization theory. Bestsellers such as *Post-Capitalist Society* (wherein knowledge is the basic resource; Drucker, 1993), *The Knowledge-Creating Company* (Nonaka & Takeuchi, 1995), and *Working Knowledge* (Davenport & Prusak, 1998) quickly establish knowledge as the new dimension of managerial practice, consequently calling it knowledge management.

However, this kind of practitioner-oriented literature all too often presents knowledge as an all-encompassing and therefore little-revealing concept. Just consider Davenport & Prusak's definition of knowledge where

> Knowledge is a fluid mix of framed experience, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information. It originates and is applied in the minds of knowers. In organizations, it often becomes embedded not only in documents or repositories but also in organizational routines, processes, practices, and norms. (Davenport & Prusak, 1998, p. 5)

Now, if individual knowledge is indeed a fluid mix of framed experience, values, contextual information, and expert insight, what is not knowledge? If it originates and is applied in the minds of knowers, how can it possibly exist independent of these individual minds? And if organizational knowledge is often embedded in documents, repositories, routines, processes, practices, and norms, where does it come from in the first place?

Admittedly, these questions deride Davenport and Prusak's definition. Nonetheless, they call attention to the fact that knowledge remains an ill-defined concept, even in bestselling publications. Knowledge may well be the basis of effective task performance (Carley, 1992; Fayol, 1969), the source of competitive advantage (Grant, 1996; Kogut & Zander, 1992; Nahapiet & Ghoshal, 1998; Nonaka, 1991, 1994; Prahalad & Hamel, 1990), and the underlying structure of decision making (Cyert & March, 1963; March, 1991; March & Simon, 1958), but there is certainly no agreed upon terminology to address knowledge (and, as a matter of fact, learning as well as memory) in the literature.

The disparate use of the term knowledge is a frequent critique in scientific research, indeed. For example, in his review of the managerial and organizational cognition literature, Walsh (1995, p. 284) identifies no less than 77 "idiosyncratic references to [knowledge as] a top-down information-processing construct," otherwise referred to as the cognitivist perspective on knowledge (Varela, Thompson, & Rosch, 1991; von Krogh, Roos, & Slocum, 1996). Among these references are labels such as frame of reference (March & Simon, 1958), world view (Starbuck & Hedberg, 1977), theory of action (Argyris & Schön, 1978), interpretation system (Daft & Weick, 1984), cognitive map (Weick & Bougon, 1986), and knowledge structure (Galambos, Abelson, & Black, 1986; Nisbett & Ross, 1980). More recent references include terms such as informed experience (McDermott, 1999), cognitive structure (Baecker, 1999), and distinction capability (Tsoukas & Vladimirou, 2001).

In hope of a more precise theory, scholars often distinguish knowledge from information and data by arranging the three concepts along a single continuum (e. g., Boisot, 1995; Choo, 1998; Davenport & Prusak, 1998; Nonaka, 1994). Accordingly, (1) data is an ordered sequence of symbols (e. g., stock quotes in alphabetic order), a raw fact used as a basis for reasoning, discussion, calculation, and the like; (2) information is a context-based arrangement of data (e. g., annually top performing stocks), that is to say, a meaningful interpretation of raw facts; and (3) knowledge is the understanding of information in a particular context (e. g., the construction of a stock portfolio by a fond manager). In this sense, Nonaka & Takeuchi (1995, p. 58) argue that "information is a flow of messages, while knowledge is created and organized by that very flow of information, anchored in the beliefs and commitment of its holder" (moreover, cf. Machlup, 1983, who sees information as a flow of messages or meanings which adds, restructures, or changes knowledge). Kogut & Zander (1992, p. 386) further state that "knowledge as information implies knowing what something means. Know-how is, as the compound words state, a description of knowing how to do something." As a final example, consider once more Davenport & Prusak‘s (1998) working knowledge where the fluid mix of knowledge includes contextual information that is often embedded in documents and repositories (which, in turn, are merely vehicles for data).

Despite the convenient distinction between data, information, and knowledge, these exemplifying citations are ambiguous in their definition of knowledge, too. Nevertheless, they indicate another distinction made in the literature, the distinction between the structure of knowledge and the content of knowledge. On the one hand, scholars such as Weick & Bougon (1986) defend their interest in studying the structure of knowledge (in terms of cognitive maps) with the argument that it is difficult to fully comprehend what the content of knowledge truly means to an individual. On the other hand, Walsh (1995, p. 285) asserts that "the study of knowledge structure content is important for applied research because the identification of content is typically the first step in the study of managerial cognition. After all, one cannot investigate a knowledge structure without identifying it by the information environment it represents." In like matter, Nonaka (1994, p. 16) writes, "in terms of creating knowledge, the semantic aspect of information is more relevant as it focuses on conveyed meaning. The syntactic aspect does not capture the importance of information in the knowledge creation process."

Knowledge may thus be a top-down information-processing construct as well as a construct of information processing. The latter view, however, is particularly prone to the promises of information technology. Today's rapid and almost universal access to data (e. g., reports, guidelines, and hand-

Table 2.3: Modes of Knowledge Creation (Nonaka, 1994, p. 19)

	Tacit Knowledge	Explicit Knowledge
Tacit Knowledge	(1) Socialization	(2) Externalization
Explicit Knowledge	(4) Internalization	(3) Combination

books on corporate servers, public databases, or the Internet) is of course an invaluable source to information and, consequently, to the construction of knowledge. At the same time, McDermott (1999, p. 103) states several reasons "why information technology inspired but cannot deliver knowledge management." He argues that knowledge is an "experience that is informed by theory, facts, and understanding" (McDermott, 1999, p. 106), not constructed by information processing. In this sense, (access to) data is still an invaluable source to information, but information no longer adds to, restructures, or changes knowledge; rather, it is the process by which knowledge is acquired (von Foerster, 2003d).

Neither the distinction between data, information, and knowledge nor the distinction between knowledge as a top-down information-processing construct (knowledge structure) and knowledge as a construct of information processing (knowledge content) yields a sufficient enough definition of knowledge by itself. A combinational approach in every aspect seems indespensible, as the widely cited spiral of knowledge (a.k.a. the four modes of knowledge creation or the SECI model; Nonaka, 1991, 1994) shows. The model distinguishes between data, information, and knowledge and furthermore combines the structure of knowledge with the content of knowledge. It builds on the complementary duality of tacit (or implicit) and explicit knowledge (Polanyi, 1958, p. 49 ff.), that is to say, on personal, embodied knowledge which is hard to formalize and communicate, and on impersonal, codified knowledge which is transmittable in formal, systematic language. On the assumption that knowledge is created through conversion between tacit and explicit knowledge, Nonaka (1994) postulates four modes of knowledge creation: (1) from tacit knowledge to tacit knowledge, (2) from tacit knowledge to explicit knowledge, (3) from explicit knowledge to explicit knowledge, and (4) from explicit knowledge to tacit knowledge (Table 2.3).

Socialization denotes the creation of knowledge through shared experiences between individuals, mainly by observation, imitation, and practice. This corresponds to training on the job advocated by rational systems thinkers (e. g., Weber; cf. Subsection 2.1.1). Combination is the social process that combines different bodies of explicit knowledge held by individuals. Most commonly, information and communication technologies such as management information systems facilitate this process by reconfiguring (sorting, adding, recategorizing, recontextualizing) existing knowledge so that it leads to new knowledge. The externalization of tacit knowledge and the internalization of explicit knowledge capture the idea that knowledge is always part tacit and part explicit (Polanyi, 1958, p. 49 ff.). Externalization is best described by the practice of documentation, whereas internalization bears resemblance to earlier notions of learning (cf. Subsection 2.2.4).

The model is part of *A Dynamic Theory of Organizational Knowledge Creation* (Nonaka, 1994). Therefore, it is only reasonable to ask how organizations may go about creating knowledge, particularly since "knowledge always begins with the individual" (Nonaka, 1991, p. 97). The answer is that knowledge creation is organizational as far as individuals create knowledge in an organization they are members of. Consequently, the main purpose of knowledge management is to complement the aspects of individual commitment to knowledge creation with organization-wide conditions that promote a more favorable climate for effective knowledge creation per se, ultimately leading to "specific proposals for two management models: 'middle-up-down management' and a 'hypertext' organization" (Nonaka, 1994, p. 27).

> In the middle-up-down model, top management provides "visions for direction" and also the deadline by which the visions should be realized. Middle management translates these visions into middle-range visions, which are to be realized in the fields—the groups. Middle managers create their visions out of those from top and lower managers and materialize then vis-a-vis the two levels. In other words, while top management articulates the dreams of the firm, lower managers look at the reality. The gap between these two forms of perspectives is narrowed down by and through middle management. (Nonaka, 1994, p. 30, sic)

The image of a hypertext organization provides the structural basis for organizational knowledge creation. It "combines the efficiency and stability of a hierarchical bureaucratic organization with the dynamism of the flat, cross-functional task-force organization" (Nonaka, 1994, p. 33). The core feature of hypertext organizations is a network of loosely-coupled individuals and self-organizing teams, all of which collaborate to promote knowledge creation. Some individuals occupy central positions in the organizational hierarchy, thus providing visions at different scale; others form communities of practice (Brown & Duguid, 1991; Lave & Wenger, 1991; Wenger, 1999) in which they continuously create, exploit, and accumulate knowledge in their daily business of bringing these visions to life.

While "the knowledge management umbrella can be a convenient rubric for integrating important work in accounting, economics, entrepreneurship, organizational behavior, marketing, sociology, and strategy" (Teece, 1998, p. 289), its critics call it a mere consultancy practice (Wilson, 2002), a management fad (Ponzi & Koenig 2002, although these authors later revoke their critique; Scarborough & Swan 2001), and an erroneous economic theory of the firm to begin with (Foss, 1996a,b). Moreover, knowledge management is said to be technology-determined (Currie & Kerrin, 2004; Hildreth & Kimble, 2002; McDermott, 1999), careless in its application (von Krogh, 1998), and imprecise in its definitions (as just argued). In the end, it is more of a managerial practice than a scientific theory, a resource-based approach to knowledge rather than a comprehensive treatise of knowledge, learning, and memory.

2.4 Summary and Development Potential

Management science and organization theory blend together when it comes to describing knowledge, learning, and memory in and of organizations. Within the rational systems perspective, bureaucracy theory, scientific management, and administration theory combine a pragmatic attitude with normative ambitions. Above all, they offer principles of management that promise maximum organizational performance. Administrative behavior, a rational systems approach to organizations itself, presents a more reserved description of the decision-making process. Common to all of these theories is their concern with individuals in general and managers in particular.

The natural systems perspective shifts the focus from individuals in organizations to organizations of individuals. Human relations, cooperatives systems, and theories X, Y, and Z acknowledge the importance of social interaction for organizational performance but adhere to managerial competence, experience, and skill as last means to achieve this end. Also under the heading of natural systems, organizational learning distinguishes between individual and collective action at first, and then bridges these two levels by means of conceptual metaphors such as thinking, learning, unlearning, and forgetting. While it is an insightful and inspiring theory, a closer look reveals that individuals are the prime movers in organizational learning. Calling attention to organizational knowledge, learning, and memory as it relates to programs, procedures, routines, norms, values, et cetera is a step in the right direction, however. The lack of commitment to a more rigorous definition of organizations is an opening for further research.

Cybernetics and the interrelated theoretical ideas of loose coupling, interpretation, and sensemaking take an open systems approach to organizations. Their descriptions of knowledge, learning, and memory fit individuals as well as organizations, thus emphasizing system dynamics at large. Similar to organizational learning, these theories provide inspiring insights and are particularly suited for further research. Contingency theory and its follow-up theories concern themselves with organizational dynamics, too. However, their population-level view permits but a resource-based approach to knowledge, learning, and memory, if indeed these concepts are elaborated on at all. The last theory within the open systems perspective is knowledge management. In normative, practitioner-oriented manner, knowledge management brings together insights from organizational learning, cybernetics, and many other theories. Unfortunately, its best-selling publications hardly reveal anything new about knowledge, learning, and memory. Theoretical models such as the spiral of knowledge, in turn, deserve consideration in their own right. The following table summarizes these theories from the rational, natural, and open systems perspective with respect to their understanding of knowledge, learning, and memory in and of organizations.

First and foremost, the literature review is a selection of theories which provide conceptualizations of knowledge, learning, and memory. All of these theories are furthermore prominently featured in textbooks on organization theory (Hatch, 1997; Scott, 1998; Shafritz & Ott, 2001, e. g.,). In terms of a tentative conclusion, reading and reviewing set the stage for critical writing. Much of the above critique concerns the insufficient distinction between individuals and organizations, the lack of rigorous definitions of knowledge, learning, and memory, and the disparate terminology in use thereof. If there is one question left to ask, it is whether or not there are other theories which offer more compelling definitions of organizations to begin with, and of organizational knowledge, organizational learning, and organizational memory in the end.

Table 2.4: Rational, Natural, and Open Systems Perspectives on Knowledge, Learning, and Memory

	Knowledge	Learning	Memory
Bureaucracy Theory	General, technical experiences held by managers	On-the-job learning as managers climb the hierarchy	Personal, documentary facts
Scientific Management	Specialized, technical skills held by managers	Scientific experimentation upon which managers select and train workers	
Administration Theory	General know-how and know-who held by managers; specialized, technical skills held by workers		
Administrative Behavior	Information chunks held by decision makers; organizational routines and procedures	Decision makers receive formal training, adjust to organizational boundaries, and adapt goals by trial and error; decisions improve organizational routines and procedures	Individual (natural) memory as information storage in the human mind; organizational (natural) memory as information as collective of individual minds, organizational (artificial) memory as information storage in repositories

Table 2.4: (continued)

	Knowledge	Learning	Memory
Human Relations	General know-how and know-who held by managers; specialized, sparse skills held by workers	Specialized training according to rank and seniority	
Cooperative Systems	Scientific (organizational) knowledge as languages and symbolic systems that are socially determined (shared beliefs); behavioral knowledge as habitual experience of managers	Formal training for all organizational members; experiential, on-the-job learning by mangers	Memory as continuous practice of particular languages and symbols
Theories X, Y, and Z	Scientific knowledge (shared languages and symbol systems), personal experience; skills in social interaction	Learning at free will, not formal education; active process of practice and feedback	
Organizational Learning	Individual beliefs, expectations, view-points, etc.; organizational routines, procedures, norms, structures, etc.	Single-loop, double-loop, and deutero learning; unlearning (discarting) knowledge	

Table 2.4: (continued)

	Knowledge	Learning	Memory
Cybernetics	Individual or organizational image, view, or representation of the environment	Learning recursively structures and restructures knowledge; requires effective feedback	Recognition and recall rather than storage and retrieval
Contingency Theory	Sole resource of individual possession	Adaptation to environmental pressures; imitation leads to isomorphism	
Loose Coupling, Interpretation, Sensemaking	Cognitive maps, collective minds, schemes of interpretation		Cognitive maps, collective minds, schemes of interpretation
Knowledge Management	Beliefs, experiences, values, contextual information, expert insight; documents, repositories, routines, processes, practices, norms; structure versus content; tacit and explicit	Development of knowledge; tacit/explicit knowledge conversion	

3 Organizations as Social Systems

Rational, natural, and open systems approaches to organizations serve the classification of organization theories well. They summarize the concepts, highlight the strengths, and value the contributions of each one of their individual theories. At the same time, they reveal the deficiencies, the shortcomings, and the weaknesses. The previous chapter therefore suggests considering alternative approaches to organizational knowledge, learning, and memory.

Social systems theory (Luhmann, 1984, 1995) is such an alternative. As a whole, it is a theory of society. It nevertheless develops a comprehensive terminology for individuals and organizations, consciousness and communication, operations and observations, and so on, and so forth. In contrast to normative scientific frameworks such as Habermas' (1984) *Theory of Communicative Action*, social systems theory is descriptive in nature. Notwithstanding or just therefore, it finds reference in administrative behavior (Subsection 2.1.4), cybernetics (Subsection 2.3.1), as well as sensemaking (Subsection 2.3.3).

The chapter first introduces fundamental concepts of social systems theory such as communication whereby organizations are distinguished from the consciousness of individuals. Social systems theory shares this distinction with other communication-centric organization theories (e.g. Putnam & Pacanowsky, 1983; Taylor & Van Every, 2000; Weick, 1995; Yates & Orlikowski, 1992), although few of them are as rigorous in their application as social systems. Then, the chapter develops its own definitions of organizational knowledge, learning, and memory. This theoretical advancement complements autopoietic organization theory (Bakken & Hernes, 2003; Seidl & Becker, 2006) which itself is a derivative of social systems theory.

3.1 Fundamental Concepts of Social Systems Theory

Social systems theory is inextricably linked to Niklas Luhmann (1927–1998) who is without a doubt one of the most influential social theorists of the last century. Over the years, Luhmann publishes on a variety of societal topics such as art, ecology, economy, education, law, love, mass media,

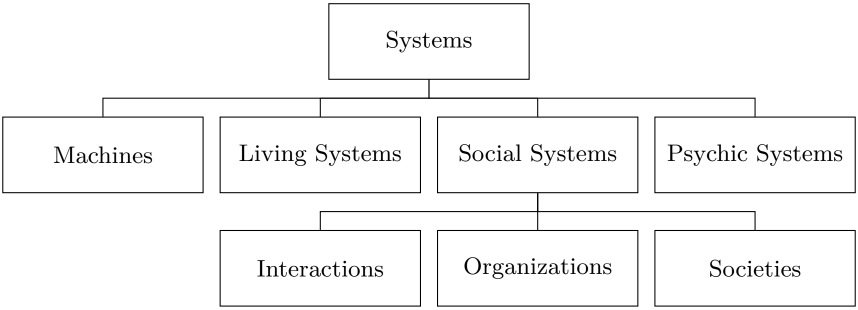

Figure 3.1: Levels of System Analysis (adapted from Luhmann, 1984, p. 16; Luhmann, 1986, p. 173)

politics, religion, and science. As diverse as these topics seem, all of his contemplations rest on a systems theoretical framework he develops and finally publishes in the 1984 volume entitled *Soziale Systeme* (the English translation, *Social Systems*, only appears in 1995).

Social systems theory does not attain the level of general systems theory (cf. Section 2.3). It rather follows a multi-level approach by distinguishing machines, living (organic) systems, social systems, and psychic systems. Examples of living systems are cells, brains, and organisms; social systems comprise of short-term interactions, organizations, and societies; and psychic systems refer to the consciousness of individuals (Figure 3.1).

With a particular interest in organizations, the following subsections introduce the respective concepts of social systems theory. On the one hand, these are the distinction between system and environment, and between operation and observation; on the other hand, these are the complementing concepts of communication and expectation, and of organization and decision.

3.1.1 System and Environment

The central paradigm in newer (sociological) systems theory is called system and environment (Luhmann, 1984, p. 242). Correspondingly, it is not the function of the system or the contingency of the environment but the relation between system and environment that is of particular interest in the following contemplations (cf. Baraldi, Corsi, & Esposito, 1997, pp. 195–199; Luhmann, 1984, pp. 242–285).

Every scientific inquiry begins with a distinction. The particular objects of interest are designated with respect to their internal operations, relations to other objects, et cetera. Hence, they are distinguished from objects of no or lesser interest which are necessarily left unspecified in their respective operations, relations, et cetera (Spencer-Brown, 1979, p. 3 ff.). The point of departure in social systems theory is the distinction between system and environment. A system emerges from boundary-producing operations which constitute an environment as everything the system is not (Luhmann, 1984, p. 35). The environment is thus the negative correlate to the system: It is not life to living systems, it is not consciousness to consciousness systems, and it is not communication to communication systems.

The system and the environment are antidotes. The distinction between them is essential to both sides. There is no system without a corresponding environment and no environment without a boundary-producing system; both emerge simultaneously from system operations. The environment is not environment per se, just as there is not one objective reality. Each system constructs its own unique environment (Luhmann, 1984, p. 249 ff.; Weick, 1969, p. 63 ff.), its own unique reality (Berger & Luckmann, 1966; von Foerster, 2003b). The system is autonomous at this. Its operations produce a boundary to the per definition non-operational environment. Boundary maintenance, in this sense, is system maintenance.

System operations are always system internal operations. No system can operate outside its boundary. This is not to say that a system is an isolated entity. Operational limitations are overcome on the level of observation (Luhmann, 1986). Indeed, all interdependencies between a system and its environment take form in observations. On the one hand, the environment is source of irritations (Luhmann, 1984, p. 252; Maturana & Varela, 1980, p. xxi); the observed distinction between system and environment is incorporated into system operations whereby it facilitates information processing (Luhmann, 1984, p. 68 ff.). On the other hand, the environment enables externalization, that is, the attribution of causes which lie outside the system reach (Luhmann, 1984, p. 123 ff.).

The distinction between system and environment neither implies a superior nor a subordinate role of either side. The capacity to operate on distinctions, however, is system inherent. Only systems are able to internalize irritations or attribute causes. The asymmetry in the system/environment relation concurrently reveals the environment as more complex than the system. Here, complexity denotes the impossibility of simultaneously connecting all elements in a system (Luhmann, 1984, p. 45); it emphasizes the temporal selection of a particular set of system relations. More specifically, complexity indicates that (1) the possible transitions from one selective system state to another and the probability of these transitions are unknown, and that (2) the states themselves, the transitions between them, and the probabilities of states and transitions change over time (Baecker, 1999, pp. 16, 28 f.). The environment is necessarily the more complex side of the distinction; it always comprises more possibilities than the system is selectively able to constitute as its environment (Baecker, 1999, p. 28 f.; Luhmann, 1984, p. 249).

The complexity asymmetry between system and environment results from the contingency of system operations. Particular system states are actualized in one way and not another. Simultaneously, respective environments emerge from boundary-producing operations. Although the environment disposes of no capacity to operate on its own, it is by no means passive and unresistingly suspend to system operations (Luhmann, 1984, p. 265 ff.). The further pursuance of environmental dynamics requires distinguishing the environment of a system from systems in the environment of that system (Luhmann, 1984, pp. 36 ff., 258 ff.). Within this new distinction, systems are mutually environment to each other. Living systems are environment to consciousness and communication systems, psychic systems are environment to living and communication systems, and communication systems are environment to living and psychic systems. This circular exclusion deprives systems of any immediate influence because no system can determine system/environment relations apart from its own. However, systems distinguish the necessarily more complex environment (i. e., system/environment distinctions) from intersystem relations (i. e., system/system distinctions) (Luhmann, 1984, p. 249) whereby they perceive their environment at large as dynamic, turbulent, or even chaotic.

3.1.2 Operation and Observation

The relation between system and environment is based on both operations and observations. On the one hand, operations separate the system from its environment, while observations consecutively overcome the endogenous system boundary, on the other hand. Social systems theory conceptualizes the operation/observation distinction as a sociological extension to the autopoiesis of living systems (cf. Baraldi, Corsi, & Esposito, 1997, pp. 123–128; Luhmann, 1986; Mingers, 2002).

The term autopoiesis (self-production; from the Greek auto for self- and poiesis for creation or production) describes a general form of system building using self-referential closure. It originates as a definition of life in the works of Chilean biologists Humberto Maturana and Francisco Varela (1980). Autopoietic systems (1) recursively generate their networks of production through the interactions of previously produced components and (2) realize these networks as composite unities in space and time by constituting their boundaries to an external environment (Maturana & Varela, 1980, pp. 26–29). At this, they are self-organizing and autonomous; their organization, constraints, or redundancies spontaneously in- or decrease without external interferences (Kauffman, 1993, pp. 71, 99). But "autopoietic systems, then, are not only self-organizing systems. Not only do they produce and eventually change their own structures but their self-reference applies to the production of other components as well" (Luhmann, 1986, p. 174). The autonomy of system operations therefore refers to the production of elements (i. e., for the system indecomposable last components), processes, boundaries, and, last but not least, the unity of the system itself.

The autopoiesis of living systems (e. g., cells, brains, or organisms) delineates (biological) life as the mode of self-production.

> Living systems are dynamic molecular structure determined systems, organized as closed networks of molecular interactions that produce the same kinds of molecules that produced them, and specify dynamically at every instant the extension and boundaries of the network. Such a network is closed in terms of its dynamics of states of molecular productions, but is open to the flow of matter and energy through it. (Mpodozis, Letelier, & Maturana, 1995, p. 131)

However, autopoiesis as a truly general theory of self-referential systems extends beyond its definition of life only under the anti-Aristotelian premise that social and even psychic systems are not living systems (Luhmann, 1986, p. 173). In accepting this theoretical decision, a precise definition is required of what the components of social and psychic systems are that are produced by and reproduce the same components of the same system.

> Social systems use communication as their particular mode of autopoietic reproduction. Their elements are communications which are recursively produced and reproduced by a network of communications and which cannot exist outside such a network. Communications are not "living" units, they are not "conscious" units, they are not "actions." (Luhmann, 1986, p. 174)

The basic unit of all social systems is a single communication event. Social systems operate in self-referential closure whether they are designated as interactions, organizations, or societies (see Figure 3.1). Their (re)production of communication in networks of communication is structurally determined only by the systems themselves. Communication produces communication from communication. Or, as Luhmann (1992, p. 251) maintains, “only communication can communicate.”

Similarly, psychic systems use consciousness as their particular mode of autopoietic reproduction. Their basic operational unit is a single conscious thought. Psychic systems recursively produce and reproduce consciousness in networks of thoughts, their minds. In social systems theory, mind refers to an individual, a person, a personality. The (biological) body of an individual is contrastingly designated as a living system. Of course, neither one is possible without the other. Because of their autopoietic closure, thoughts cannot exist outside a particular psychic system. After all, there is no conscious link between one mind and another (Luhmann, 2002).

On the level of autopoiesis, systems are required to connect each operation to a new operation of the same system. This plain reproduction of communication from communication or consciousness from consciousness is independent of any teleological function or need of adaptation. All systems are closed with respect to their operations. Social system theory further assumes that all systems are self-referential (Luhmann, 1984, p. 31 ff.). Self-reference implies the capability of systems to observe their own operations, and to consecutively include these observations in the operations of the same system. In fact, an observation is a specific type of operation which uses a distinction to indicate one or the other side of the distinction. This definition of observations is based on the *Laws of Form* put forth by George Spencer-Brown (1979). His calculus begins with a first injunction, “draw a distinction” (Spencer-Brown, 1979, p. 3), which differentiates a marked space from an unmarked space. From this first distinction, it is possible to reproduce an indication of either the marked or the unmarked space in a new distinction. The sequence of operations therefore allows for the development of complex systems from a single mode of operation (i. e., communication, consciousness, life). In yet other words, (self-)observation is the re-entry of the system/environment distinctions into systems (Luhmann, 1984, p. 63; Spencer-Brown, 1979, p. 49). In case of social systems, communication creates a memory that further communication can call upon in quite different ways. Systems pulsate in self-production and self-observation as if they were a constant creation of overflow and selection (Luhmann, 1992, p. 254). Their self-reference is based on communication which refers to itself as processing the distinction between itself and its topics (Luhmann, 1986, p. 175).

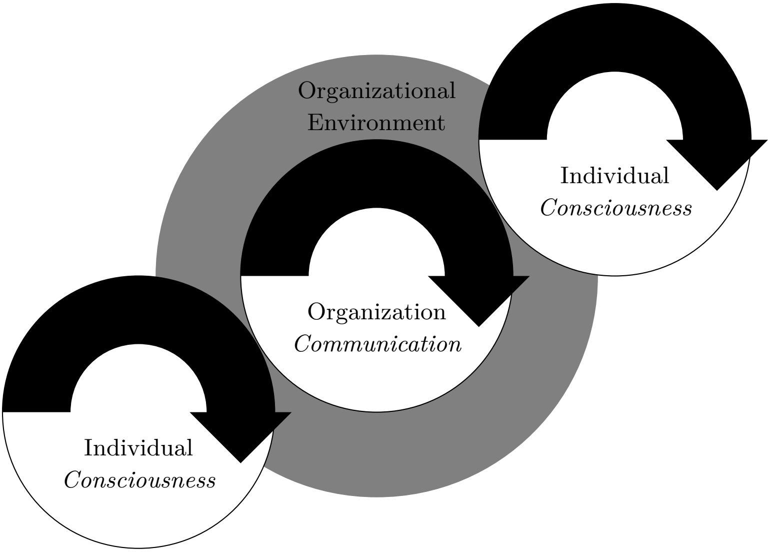

Figure 3.2: The Autopoiesis of Organizations and Individuals

Observations are directed either towards system internal operations or operations of other systems in the environment of the observing system. In addition to the information generated by self-observation, systems are capable to incorporate information about their environment in their own operations. On the level of observations, systems overcome their operational boundaries. Because of the reciprocity of observations between systems, environmental irritations (disturbances, perturbations, stimulations, etc.) evoke structural drifts in the autopoiesis of systems. This is not to say that systems are capable of exercising direct influence on other systems. Still, no system can operate outside its boundary. But observations structurally couple systems to one another (cf. Maturana & Varela, 1980, p. 8; Orton & Weick, 1990; Weick, 1976) in that information about the environment produces particular system/environment distinctions which, in turn, affect the possibilities of further system operations. Organizations, for example, are social systems in the environment of individuals (psychic systems), just as individuals are in the environment of organizations (see Figure 3.2). The notion that organizations and individuals are mutually environment to each other is not nearly new. Almost half a century ago March & Simon (1958, p. 2) write, "for most people formal organizations represent a major part of the environment." Nonetheless, the authors do not pursue this approach as stringently as social systems theory.

With respect to the autopoiesis of organizations and individuals, communication and consciousness are completely independent of each other. Communication cannot think, and the mind cannot consciously communicate. However, communication hardly comes into being without the mind, and even though a system of consciousness can be active without communication, its initial existence largely depends on communication (Luhmann, 2002). While there is no interaction between organizations and individuals in the true sense of the word, communication observing individuals and consciousness observing organizations account for concertedly structural drifts. Social and psychic systems use each other for reciprocal initiation of structural changes in their autopoiesis. "Systems of communication can be stimulated only by systems of the mind, and these in turn are extremely attracted to what is conspicuously communicated by language" (Luhmann, 2002, p. 177).

3.1.3 Communication and Expectation

Social systems proceed blindly in the autopoietic reproduction of communication, for they cannot reproduce and simultaneously observe themselves. Observations of communication are of second order (von Foerster, 2003b); they are either further communications of the same system or autopoietic operations of other systems altogether (e. g., communications of a second organization or thoughts of an individual consciousness). Social systems thus oscillate between reproductive communication and retrospective observation. The unique sequence of operations maintains the evolution of systems at large. Communication as the basic element of the evolution of social systems is either reproduced in the autopoietic networks of communication or not. And although communication is indecomposable for social systems, it comes about a precisely defined process (cf. Baraldi, Corsi, & Esposito, 1997, pp. 89–93; Luhmann, 1984, pp. 191–241; Luhmann, 1992).

> Just like life and consciousness, communication is an emergent reality, a state of affairs *sui generis*. It arises through a synthesis of three different selections, namely, selection of *information*, selection of *utterance* of this information, and a selective *understanding or misunderstanding* of this utterance and its information.

> None of these components can be present by itself. Only together can they create communication. Only together—and that means only when their selectivity can be made congruent. Therefore communication occurs only when a difference of utterance and information is understood. That distinguishes it from mere perception of the behavior of others. In understanding, communication grasps a distinction between the information value of its content and the reasons for which the content was uttered. It can thereby emphasize one or the other side. It can concern itself more with the information itself or with the expressive behavior. But it always depends on the fact that both are experienced as selection and thereby distinguished. (Luhmann, 1992, p. 252, sic)

Due to the operational closure of communication, information, utterance, and (mis)understanding are necessarily selections of, and therefore within, a system. Information conveyed in the communication of social systems, for example, is different from information conceived by psychic systems from the participation in that same communication. In the first instance, communication marks a particular system/environment distinction whereupon consciousness evokes a system/environment distinction of its own. Hence, information is never readily available outside the system (the environment contains no information, von Foerster, 2003a, p. 252)). It is always a selection of particular system states by the system (Luhmann, 1984, pp. 68, 102). In the eye of the beholder, "information—is a difference which makes a difference" (Bateson, 1987, p. 459).

This definition of information as an integral selection process of communication refers back to the seminal work of Shannon & Weaver (1949) on *The Mathematical Theory of Communication*. They write, "information is a message of one's freedom of choice when one selects a message" (Shannon & Weaver, 1949, p. 9, emphasis added). Within this theory, it is possible to measure information in terms of the degree of randomness or choice, which corresponds to the entropy measure of the *Second Law of Thermodynamics* (Boltzmann, 1898, pp. 256–259). Communication is split into the roles of sender (information source and transmitter, to be precise) and receiver (Shannon & Weaver, 1949, p. 7). Following Shannon and Weaver, speech act theory (Austin, 1971; Searle, 1992) likewise employs these two roles in a threefold typology of utterances or speech acts. However, both theories appear problematic as they particularly focus on success or failure of the transmission of information, the respective communication channels, and the reduction of noise thereof. Despite recent advances in communication research, sender-receiver models still dominate management science and organization theory textbooks used in university curricula (e. g., Buchanan & Huczynski, 1997; Hellriegel, Slocum, & Woodman, 2001; McShane & Glinow, 2000). A notable exception is *Organization Theory: Modern, Symbolic, and Postmodern Perspectives* by Hatch (1997).

For communication to emerge, information furthermore requires utterance. Most commonly, language is the medium of choice to convey information. Language is here understood as coded acoustical and optical symbols. It incorporates not only forms of speech but also non-verbal cues, writing, and printing. In principle, utterance is the selection of the form of language. As all social systems are based on the fundamental fact of reproducing communication events, writing and printing are peculiar manifestations of language in that they "have their function in preserving not the events, but their structure-generating power" (Luhmann, 1986, p. 180). In other words, because events cannot be accumulated—"a conscious system does not consist of a collection of all its past and present thoughts, nor does a social system stockpile all its communications" (Luhmann, 1986, p. 180)—writing and printing bring about the temporalization of communication (Luhmann, 1981, p. 125) (Subsection 3.2.3 elaborates on this matter).

With information and utterance on the one hand, and understanding or misunderstanding on the other hand, social systems theory also discerns communication in two alternating roles. Information and utterance are attributed to the communication role of alter, understanding or misunderstanding lies in the realm of ego (Luhmann, 1984, p. 197 ff., who borrows the terms alter and ego from the phenomenology of Schütz and Husserl). Communication only comes into being if ego understands what alter has uttered; the latter is then attributed with information. The plain utterance of information always requires congruent understanding to become communication. For example, the information that "it is cold" and the intention to utter this information (may) imply that alter wants ego to put on a coat when she leaves the house. However, an understanding effort on part of ego is still required to conclude the communication event. If ego leaves the house without getting a coat, she obviously does not understand what alter is trying to tell her. Hence, no communication occurs. (The possibility that ego understands but thereupon ignores alter is neglected in this example.) If ego puts on a coat before leaving, communication successfully concludes at the congruence of information, utterance, and understanding. In case ego turns up the heat in the house, she simply misunderstands the intended meaning that "it is cold outside." Nonetheless, communication takes place.

Alter and ego are communication roles, and nothing else. This must not be confused with individuals, say, Adam and Eve. Communication and consciousness are operationally closed systems. Structurally, however, they are coupled. Depending on the direction of communication, Adam and Eve are either coupled to alter or ego. For the sake of simplicity, the above example attributes both communication roles with the characteristics of individuals. Therefore, it is ego who is addressed to put on a coat when in fact only Eve can do so.

While autopoietic systems are closed in their operations, structural coupling facilitates their mutual interpenetration (Luhmann, 1984, p. 286 ff.). The aforementioned example makes this especially perspicuous. Social systems hardly come into existence without the participation of psychic systems. It is communication that selects information, utterance, and (mis)understanding, not consciousness. However, the two corresponding communication roles, alter and ego, are attributed to human beings; this accounts for the indisputable fact that the mind participates in communication (Luhmann, 2002). Indeed, "the mind has the privileged position of being able to disturb, stimulate, and irritate communication" (Luhmann, 2002, p. 176 f.). But it cannot instruct communication, because communication constructs itself. Communication likewise disturbs, stimulates, and irritates consciousness in its autopoietic reproduction of thoughts. The key to overcoming operational boundaries and establishing a structural link between social and psychic systems is of course observation, that is, observation of consciousness by communication and observation of communication by consciousness.

A single communication event emerges at the congruence of the selections of information, utterance, and (mis)understanding. Social systems evolve as their self-referential production of communication progresses from one communication event to another. The connection between past, present, and the possibility of future operations is well explored in evolutionary science. In economics, for instance, phenomena such as increasing returns, path-dependence, and lock-in effects are all based on the concept of self-reference (Arthur, 1989; Liebowitz & Margolis, 1995). The connectivity (*Anschlußfähigkeit*) between communication events, however, is not implied in a single communication event as such. Understanding does not include the acceptance of communication content. Indeed, "communication always results in an open situation of either acceptance or rejection" (Luhmann, 1986, p. 176). The autopoiesis of social systems is therefore only maintained through holistic networks of communication, that is, through observations of communication by communication in each system. The above example implicitly assumes the acceptance of communication: Ego understands alter's uttered information that "it is cold," the communication roles change, and the former ego (now alter) puts on her coat or turns up the heat, which the former alter (now ego) understands on his part as information of the acceptance of the previous communication situation. In case ego leaves the house with the understanding that "it is cold outside" yet without a coat, she openly rejects the previous communication, slips into the role of alter herself, and conveys ignorance as information to his opposite. In any event, acceptance or rejection bifurcate further communication.

Communication observes communication of the same system, and communication observes communication or consciousness of other systems. The emergence of communication is highly complex, because the self-reference of social systems is based on autopoietic operations which refer to themselves as processing the distinction between themselves and their topics (Luhmann, 1986, p. 175). In other words, social systems separate self-referential and hetero-referential communication; they are structurally self-determined and structurally coupled to other systems at the same time, all by communication, for communication is the only operation they know. The myriad of communication events which emerge simultaneously and consecutively in the networks of communication of social systems are highly interrelated, both in space and time. Communication is not only complex but also contingent; that is to say, single communication events are selectively actualized in a particular way which always could have come off differently. However, communication is not chaotic or in any sense random. The structure of the networks of communication largely determines which communication connects to which, thereby reproducing the very structure of the networks (for similar lines of argument, cf. Castells, 1996, p. 470 f.; Giddens, 1984, p. 16 ff.). The autopoiesis of social systems therefore refers to the reproduction of single communication events as well as the relationship between them. For example, a communication about the weather may involve the uttered information that "it is cold outside." This alone limits the connectivity of further communication. The reply that "roses are red" is of course possible but nonetheless highly unusual. Communication within the (structured) contingency of social systems rather concerns itself with (i. e., it observes) individual action such as putting on a coat or turning up the heat.

Due to the complexity of autopoietic operations, social systems theory regards communication not as a phenomenon but as a problem (Luhmann, 1981). The improbability of communication becomes immediately evident when the problems and obstacles that hinder the emergence of communication are taken into perspective. First, despite "the separateness and individuality of human consciousness, one person can understand what another means. Meaning can be understood only in context, and context for each individual consists primarily of what his own memory supplies" (Luhmann, 1981, p. 123). Consider a communication which conveys the information that the outside temperature is below freezing. While the information is rather unambiguous, the addressee of the communication, say, Eve, may nevertheless think about turning up the heat instead of putting on a coat. In the end, it is the mind and not communication that determines the actualizations of thoughts and thus the actions to be taken.

Second, space and time severely limit the possibility of communication. For instance, interaction between participants of communication generally necessitates physical presence (Luhmann, 1984, p. 560 ff.); and even among those present, communication faces time constraints because individuals have other things to do, too. Particular forms of media (e. g., writing with regard to language) transcend the bounds of immediate presence and face-to-face communication. "They enormously expand the store of memorized data available for additional communication, while at the same time restricting it through selectivity" (Luhmann, 1981, p. 125).

Third, even if communication is understood, there is no assurance of its being accepted; rejection is always possible. Yet only the acceptance of the content of communication (the information) is a premise for further communication along the intended course. Rejection either forces communication in a completely different direction or simply terminates it altogether. The above example already clarifies this matter. In accepting the information that "it is cold," further communication concerns itself with a coat or a heating system depending on whether the previous communication is understood in one or the other way. Rejection, on the other hand, brings about the reply (i. e., new information) that "roses are red" or breaks off the communication in ignorance.

This concept of communication with the distinction of the three components of information, utterance, and mis(understanding) has far reaching consequences for the application of social systems theory. Other theories begin with an understanding of communication in terms of action (e. g., Austin, 1971; Habermas, 1984; Searle, 1992; Shannon & Weaver, 1949) and therefore regard communication as a successful or unsuccessful transmission of messages, information, or suppositions of agreement. Social systems theory, however, emphasizes the very emergence of communication (Luhmann, 1992). Nothing is transferred. Redundancy is produced in the sense that communication stabilizes in expectations which, in turn, provide anchors of reference in the complexity and contingency of the world. In other words, expectations are condensed generalizations of communication (Luhmann, 1984, pp. 139, 448); they endow systems with redundancy and in that ease the selection pressure of further communication. One expects, for example, the weather in the winter to be colder than in the summer. Therefore, communication about the necessity to wear a coat when one leaves the house is framed with just this expectation; it is almost of no question to keep warm in January yet highly suspicious to be asked to wear a coat in July, at least in Europe.

Expectations serve two purposes: (1) the selection of communication within general bounds of possibility and thus the maintenance of complexity in reduced form (one expects the winter to be colder than the summer in all of Europe); (2) the application of this generalized condensate of communication to each situation (in Europe, it is common sense to put on a coat when leaving the house in December; in Australia, however, one rarely wears a coat during Christmas time). The unity of both these aspects allows for the construction of system/environment distinctions without direct access to those distinctions. Systems do not need to construct their environment completely anew with each and every episode of their autopoiesis; they rather rely on the observation of contingency and simply process the uncertainty of expectations with respect to their environment, that is, the possibility that expectations disappoint. Furthermore, expectations pertain to the cognitive structure of social systems. This notion is explicated in Subsection 3.2.1, particularly with regard to the knowledge of social systems.

3.1.4 Organization and Decision

Communication is imperative to the autopoiesis of social systems. Nonetheless, interactions, organizations, and societies each evince characteristics which discern them from one another. Organizations, in particular, are defined by way of four fundamental criteria (Luhmann, 2000, pp. 39–122, 256–301; 2003, pp. 45–47): (1) The membership of individuals who participate in organizational communication, (2) the specific positions of these participants in the communication networks, (3) the programs that determine the viability of organizational communication, and (4) the communication of decisions.

Membership. Individuals and organizations are structurally coupled to one another; consciousness irritates communication, and vice versa. Individuals are members of organizations in that they are motivated to participate in communication. Motivation comes about some sort of economic value (*Nutzen*), contractual commitment, career opportunity, and the like (Herzberg, 2003; March & Simon, 1958, p. 83 ff.); it is left to individual discretion what preferences they pursue, if their behavior conforms to organizational agreements, and how harsh, if at all, they endeavor to push their careers (Luhmann, 2000, p. 110). These factually and temporarily motivated roles distinguish members of organizations from non-members. For example, individuals who perform some agreed upon duty on a day-to-day basis are considered members of an organization; most commonly and in one way or another, they are rewarded for their time spent.

Positions. Organizations differ from other social systems in that their members maintain certain positions in the organizational communication networks. This criterion primarily concerns the formal structure of organizations. In German, Luhmann (2000, p. 231 ff.) uses the term *Stelle*. The English translation, position (Luhmann, 2003, p. 47), is somewhat unfortunate as *Stelle* already conciliates a whole set of ideas which reaches beyond the mere structure of organizations. While originating from the vocabulary of public administration, the expression *Stelle* is nowadays frequently used in private organizations as well. For example, *Stellenbeschreibung* is not simply a description of a position (e. g., who reports to whom in hierarchical organizations) but a detailed specification of authorities, directives, reporting procedures, work processes, and, last but not least, incentives. *Stellenbeschreibungen* are common for documenting organizational structures and processes, and in a less detailed form they are used as job advertisements (*Stellenanzeigen*).

Programs. If not particularly concerned with the programming of computers, research in management science and organization theory refers to an organization's program also as task (March & Simon, 1958, p. 23) or, in case of corporations, as business (Baecker, 1999, p. 151). Any way, programs are observations of system operations in the light of—programs. They are self-referential, and thus they program system operations. Put simply, a program is an organizational task to be performed, the very business of an organization; simultaneously, it marks the point of reference for the accomplishment of the task, for the success of the business. Programs ameliorate the viability of organizational communication with the aid of visions and missions, goals and objectives, policies and purposes. Rather than limiting organizational scope, they extend the repertoire of causal possibilities through operations which occur under no other circumstances (Luhmann, 2000, p. 278).

Decisions. Indeed, decisions are the most prevalent criterion of organizations in theories of organizations and management (Barnard, 1972; Cohen, March, & Olsen, 1972; Cyert & March, 1963; Luhmann, 2000; March & Simon, 1958; Simon, 1976; Weick, 1969). In their 1963 seminal monograph, *A Behavioral Theory of the Firm*, Richard Cyert and James March see organizations as "information-processing and decision-rendering system[s];" thus they question, "how organizations secure information, how that information is communicated through the organization, how authoritative decisions are reached, and finally, how such decisions are implemented in the organization" (Cyert & March, 1963, p. 20). Social systems theory taps into this line of research. Organizations produce and reproduce themselves from communication of decisions (Luhmann, 2000, p. 63). At this, autopoietic organizations process information and render the decisions they consist of in operational closure.

> From this theoretical basis, organised social systems can be understood as systems made up of decisions, and capable of completing the decisions that make them up, through the decisions that make them up. Decision is not understood as a psychological mechanism, but as a matter of communication, not as a psychological event in the form of an internally conscious definition of the self, but as a social event. That makes it impossible to state that decisions already taken still have to be communicated. Decisions are communications; something that clearly does not preclude that one can communicate about decisions. (Luhmann, 2003, p. 32, sic)

With the emphasis on decisions, all other criteria of organizations become secondary; they are but results of the decision-making process of organizations in the first place. Membership encompasses decisions on who is permitted to participate in organizational communication. In principle, this is the primary decision to be made (March & Simon, 1958, p. 83 ff.). Decisions on the specific positions of organizational members bring about the formal structure of organizations, that is, hierarchies, authorities and directives, departments, teams, role concepts, et cetera. Furthermore, the programs that determine the communication of organizations likewise result from decisions. Visions and missions, goals and objectives, policies and purposes are all set, revised, or abrogated in the course of organizational decision making.

The above questions of how information is secured, how that information is communicated, how decisions are reached, and how they are implemented in the organization (originally posed by Cyert & March, 1963, p. 20) extend to questions of who, when, where, and what (e. g., who participates when and where in communication, and what is the topic of that communication). Still, the relation between decisions and membership, positions, and programs is not monocausal. In recursive fashion, past decisions are premises for present decisions which, in turn, become premises for future decisions, and so on. Different organizational structures emerge depending on who participates in decision making, different programs lead to unique results in membership, and different directives affect decisions on programs in a variety of ways. The communication of decisions and the three derivative criteria then not only discern organizations from other social systems, but their evolutionary characteristics account for distinctions among organizations themselves (Luhmann, 2003, p. 39).

As with communication in general, decisions require acceptance or rejection. In contrast to normative communication theories (e. g., Habermas, 1984), social "systems theory replaces the consensus-directed entelechy with another argument: Communication leads to a decision whether the uttered and understood information is to be accepted or not" (Luhmann, 1992, p. 255). Nonetheless, the connectivity of further decisions is maintained only with regard to acceptance or rejection of decisions. Hiring an individual is a decision which receives acceptance with every subsequent decision that incorporates the new employee as an organizational member in the network of communication. While this is the most common situation, rejection is nevertheless a possibility. Instead of acceptance, subsequent decisions may produce rejection in that they revoke the recruitment before it actually takes place; for example, middle management conducts interviews for an open position, decides on a potential candidate, when upper management refuses to sign the final contract. All decisions then produce acceptance or rejection of previous decisions with just the reference to the previous decisions in one way or the other.

"Based on this assumption, one may imagine organizations as continuously oscillating between acceptance and rejection of noise and between loss and reconstitution or redundancy" (Luhmann, 2003, p. 43). In other words, decisions bundle pieces of information, and through this reconstitute the organization anew or with increased redundancy—if they are accepted. In case decisions are rejected, a loss of information occurs. The sheer complexity of decision making, where single decisions refer to numerous others across space and time, is ubiquitous in the communication network of organizations. Therein, "every position may be regarded as a combination of programmatic, web-like and personal decision-making premises" (Luhmann, 2003, p. 47). Positions, in turn, are connected by communication channels which largely determine acceptance and rejection of decisions. Communication channels are either of informal nature, as in personal networks between members of an organization, or they are deliberately established (e. g., through directives, policies, hierarchical structure, or information and communication technology) to permit the circulation of information with a binding impact on the organization (Luhmann, 2003, p. 46; March & Simon, 1958, p. 3).

Organizations operate exclusively on communication or, more precisely, communication of decisions. In autopoietic closure, they produce decisions from decisions. Previous decisions are thus premises to present decisions which are, again, premises to future decisions. However, two kinds of decision premises must be distinguished: decidable decision premises and undecidable decision premises. On the one hand, membership, positions, and programs all come about decisions and affect further decision making; these are decidable decisions premises. Undecidable decision premises, on the other hand, are per definition unquestioned in their existence and often inaccessible to analysis at all (Luhmann, 2000, p. 241). Organizational culture, for example, rests on basic assumptions which are "ultimate, nondebatable, taken-for-granted values" (Schein, 1984, p. 4); organizational culture is thus a set of undecidable decision premises (Luhmann, 2000, p. 145). Moreover, while membership is decidable, members themselves (i. e., individuals occupying particular organizational positions) impose undecidable decision premises upon decision making in organizations. Some individuals intentionally manipulate information for their own good or for the good of the organization, as they may put it; others bind their participation in the communication of decisions to moral standings which oppose organizational programs. Again, this only emphasizes the fact that individuals and organizations are structurally coupled, that there is no communication without consciousness.

3.2 Autopoietic Organization Theory

Organizations are of major interest to Luhmann. From his first published book, *Funktionen und Folgen formaler Organisation* (Functions and Consequences of Formal Organization; Luhmann, 1964), to his posthumously published work, *Organisation und Entscheidung* (Organization and Decision; Luhmann, 2000), Luhmann never loses sight of organizations as a particular instance of social systems. Autopoietic organization theory (Baecker, 1999, 2003; Bakken & Hernes, 2003; Seidl & Becker, 2006) refines social systems theory in many ways. It already covers issues such as (the paradox of) decision making (Andersen, 2003; Czarniawska, 2006; Knudsen, 2006), strategic management (Baecker, 2003, pp. 152–178, 256–292; Vos, 2006), and organizational form and function (Baecker, 1999, pp. 126–168, 198–236). However, autopoietic organization theory lacks appropriate concepts of organizational knowledge, organizational learning, and organizational memory, so far.

3.2.1 Organizational Knowledge

The following contemplations do not constitute a genuinely new philosophy of knowledge; they merely revoke the unsatisfactory definitions used in management science and organization theory (above all, cf. Subsections 2.2.4 and 2.3.4). What follows first is a functional definition of knowledge in general and organizational knowledge in particular. A brief discussion on the matter of tacit as opposed to explicit knowledge then accompanies exemplifications of different types of organizational knowledge. In accordance with social systems theory, epistemological conclusions set the stage for the theoretical advancement and the practical applicability of autopoietic organization theory.

In general, knowledge is the cognitive structure of social and psychic systems (Baecker, 1999, pp. 85–90; Baraldi, Corsi, & Esposito, 1997, pp. 45–49; Cohen & Levinthal, 1990; Luhmann, 1984, pp. 448–452; von Krogh, Roos, & Slocum, 1996; Walsh, 1995). This definition of knowledge bears reference to the above considerations on expectation, communication, and consciousness (Subsection 3.1.3). Expectations organize episodes of the autopoiesis of social and psychic systems. At this, they guarantee the ease of connectivity of communication events and conscious thoughts by means of dedicated system/environment distinctions without immediate reference (the winter is colder than the summer, and this is a fact in the winter as well as in the summer). Social and psychic systems draw either on immediate system/environment distinctions (if it is indeed snowing outside, one better puts on a coat before leaving the house) or on expectations (if it is winter, one should consider putting on a coat before leaving the house; it could be snowing outside) to constitute themselves and their environment in autopoietic fashion. Similarly, system/environment distinctions and expectations are but evidence and conclusions when "In organizational communication evidence is replaced with conclusions drawn from that evidence, and these conclusions then become the ‘facts’ on which the rest of the organizations acts” (March & Simon, 1958, p. 155).

If knowledge is the cognitive structure of social and psychic systems, its (cognitive) function is that of a complex consistency check accompanying all of communication and consciousness (Baecker, 1999, p. 85; Luhmann, 1990, p. 129). First of all, expectations fundamentally ease information processing and thus aid the autopoiesis of social and psychic systems at large. As an integral part of communication and consciousness, information is the necessary first selection of system/environment distinctions with or without immediate reference in the world; information refers either to actual system/environment distinctions or to expectations. When social and psychic systems rely on expectations, environmental contingencies appear within general bounds of possibility. Expectations reduce the pressure to select from everything and all. Then again, they carry an inherent uncertainty with respect to the environment (cf. March & Simon, 1958, p. 165, on the matter of uncertainty absorption); that is to say, there is always a possibility that expectations disappoint (“wearing a coat at the prospect of a cold winter is certainly disappointing when it is in fact an unseasonably warm day outside”). The de-facto disappointment of expectations, however, requires observations of second order. Knowledge as the cognitive structure of communication and consciousness integrates past, present, and future expectations to ensure just this reflexivity of expectations in space and time (Weick, 1999, 2002); in this sense, knowledge condenses in reflexive expectations (Luhmann, 1984, p. 447). Reflexive expectations pay tribute to the cognitive assessment of consistency between actual system/environment distinctions and expectations by way of information. In turn, information is the process by which knowledge is acquired, and knowledge is the processes that integrates past and present experiences (von Foerster, 2003c, p. 200). Baecker concludes,

> knowledge is a structure with which a social system addresses disappointment-ready expectations at its environment. It is a complex examination operation [*komplexe Prüfoperation*] accompanying all communication with the possibility that one is guided by expectations which already cannot be maintained any longer and therefore must be exchanged for new expectations. That is why knowledge is so strenuous. It aims at disappointment. (Baecker, 1999, p. 90, own translation)

Following traditional epistemology on such classical accounts as Plato's *Theaetetus and Phaedo*, Descartes' *Discourse on Method*, Locke's *An Essay Concerning Human Understanding*, Hume's *An Enquiry Concerning Human Understanding*, and Kant's *Critique of Pure Reason*, knowledge management employs a somewhat similar definition of knowledge as justified true belief (e. g., Nonaka, 1994). The justification of beliefs compares favorably to the disappointment of expectations or, rather, the non-disappointment of expectations. Where beliefs are justified, expectations do not disappoint. In contrast, the truthfulness of beliefs as an essential attribute of knowledge is untenable (the philosophy of science addresses this issue as the Gettier problem; cf. Gettier, 1963). Without further discussions of the 19th century's great achievements in theory, already the dialectics of Hegel, Marx, and Darwin vividly illustrate that truth always depends on critique (rejection, conflict, etc.). Truth is never universal, never objective, and never free of paradox. In addition, the functional definition of knowledge as a cognitive structure removes all anthropological connotations of knowledge as justified true belief. Therefore, knowledge is neither universally true, nor does it exclusively correlate with the mental capabilities of individuals.

On the assumption that organizations operate exclusively on the communication of decisions, *organizational knowledge is the cognitive structure of communication (of decisions).* Contrary to popular belief in the literature on knowledge management, it is not "anchored on the commitment and beliefs of its holder [...] as it relates to human action" (Nonaka, 1994, p. 15), it is not "the capability members of an organization have developed to draw distinctions in the process of carrying out their work" (Tsoukas & Vladimirou, 2001, p. 983, emphasis in the original), and it is not embedded in documents, repositories, organizational routines, processes, practices, and norms (Davenport & Prusak, 1998, p. 5). These citations characterize individual knowledge, at best. Organizational knowledge emerges in autopoietic fashion with the communication of decisions; it provides reflexivity with respect to the development, maintenance, and abandonment of expectations (i. e., organizational learning; Subsection 3.2.2).

In general, it is worthwhile to mention that knowledge "is history dependent, context sensitive, and, rather than being oriented towards problem solutions, enables problem definition" (von Krogh, Roos, & Slocum, 1996, p. 163). Problems reflect in the uncertainty of organizational knowledge (Luhmann, 1984, p. 489; 2000, p. 184) as it provides information processing and consequently decision making with reflexive expectations (Baecker, 1999, p. 95). The less certain organizational knowledge is, the more problematic decisions are. Problems are solved, if at all, by the acceptance of decisions. Or they may simply be ignored in hope that they resolve themselves (Cohen, March, & Olsen, 1972). If decisions are made premises for future decisions (i. e., if they are accepted), their quality with respect to the environment remedies the uncertainty of organizational knowledge, at least in retrospective. Quite frequently, however, this leads to postdecision surprises (Harrison & March, 1984); sometimes chosen alternatives turn out to be better than anticipated, sometimes they turn out to be worse. Consider, for instance, the uncertainty about the weather (or the uncertainty of market demands, customer preferences, stock prices, etc.) along with the problem of dressing the appropriate way before leaving the house (or the problem of planning production capacities, designing product features, choosing investment alternatives, etc.). It is common knowledge to wear a coat in the winter, although the weather is forever uncertain; there is always the possibility of an unseasonably warm winter day. But it is immediately evident that the decision to put on a coat was the right one to make when it starts snowing outside, which then confirms the quality of the decision and renders the underlying knowledge certain (until the next decision, that is).

So far, the functional definition of (organizational) knowledge as cognitive structure emphasizes the more procedural, recursive nature of knowledge, though knowledge as condensate of reflexive expectations hints the possibility of temporalization. Understanding knowledge in terms of structure and process, rather than commodity or substance, is best exemplified by the famous distinction between tacit and explicit knowledge (Polanyi, 1958, pp. 55–65) (moreover, cf. Grant, 1996; Nonaka, 1994; Spender, 1996). With regard to human knowledge, tacit knowledge conveys a personal, embodied quality deeply rooted in action, commitment, and involvement; it is hard to formalize and to communicate. Explicit or codified knowledge is transmittable in formal, systematic language. However, tacit and explicit knowledge are never separable from each other (Polanyi, 1958, p. 57 f.). Tacit knowledge includes individuals' schemata, paradigms, viewpoints, believes, know-how, crafts, and skills which apply to specific contexts; its articulation is difficult but nonetheless possible. "By contrast, explicit knowledge is discrete or digital. It is captured in records of the past such as libraries, archives, and databases and is assessed on a sequential basis" (Nonaka, 1994, p. 17, emphasis in the original).

Tacit organizational knowledge is well in line with hitherto contemplations. It is the cognitive structure of communication and condenses in reflexive expectations. It emerges alongside each and every autopoietic episode, that is, each and every decision, whereby "decisions themselves produce the knowledge that can be used by decisions" (Baecker, 1999, p. 96, own translation). Tacit organizational knowledge, too, adheres to schemata, paradigms, viewpoints, and the like, particularly since all of these terms are but different names for—(reflexive) expectations. Bluntly speaking, tacit knowledge is knowledge at work. To a certain extent, it is possible to explicate tacit organizational knowledge in further communication, that is, to make the cognitive structure of past communication subject (topic, theme, content, etc.) to present and future communication. This may then be referred to as explicit organizational knowledge, although it is not of a directly applicable kind, not knowledge at work. Explicit organizational knowledge discloses in communication about knowledge and thus comprises tacit organizational knowledge as well. The cognitive structure of communication underpins communication about knowledge as much as it underpins the communication of decisions. In contrast to the above exemplifications of explicit human knowledge and the here put forth definition of organizational knowledge, explicit organizational knowledge is not captured in libraries, archives, and databases. These and other records of the past such as books, films, lectures, papers, and reports are simply vehicles for information (von Foerster, 2003c, p. 201; von Krogh, Roos, & Slocum, 1996). They may become part of future communication (e. g., when understanding concludes the reading of a book), but records of the past do not constitute communication in themselves, and as such they are not knowledge.

The distinction between tacit and explicit organizational knowledge is nevertheless valuable in that it clearly addresses knowledge as either integral part of all communication or as subject of specific communication. Therefore, tacit organizational knowledge is the single most important issue of organizations with respect to their decision-making capabilities, whereas explicit organizational knowledge is detached from any immediate applicability. Indeed, explicit knowledge is somewhat of a misnomer. Knowledge is explicit only in that it finds explication in the communication about knowledge, not so much in the communication of decisions (arguing along the same line Schoeneborn, 2006, p. 32 ff., contrasts interactions with decisions). For the lack of a better term, for sake of simplicity in this context, and with the further interest in the very dynamics of organizations, it is always tacit organizational knowledge that all of the below contemplations on decision making refer to; explicit organizational knowledge is specifically accounted for with regard to, for instance, the temporalization function of organizational memory (Subsection 3.2.3).

Besides the distinction between tacit and explicit, management science and organization theory offer yet other typologies of organizational knowledge such as autonomous and systemic, complex and simple, and the like (for an overview, cf. Gopalakrishnan & Bierly, 1997). Tacit organizational knowledge, in particular, receives further contextual classification. For instance, Baecker (1999, pp. 70–77) identifies five types of organizational knowledge, two of which are especially critical with regard to managerial practice: (1) Product knowledge, (2) societal knowledge, (3) management knowledge, (4) expert knowledge, and (5) social knowledge.

Product Knowledge. Product knowledge (*Produktwissen*) comprises products as well as corresponding production processes and technologies. Knowledge of this type answers questions which immediately cut to the heart of a business, for example, What problems are solved with a particular type of product?, What technologies are best employed in order to address these problems?, and What production steps in which sequence lead to standardization yet retain sufficient variability in the product? Of the four criteria that distinguish organizations from other social systems (cf. Subsection 3.1.4), the criterion of programs is the one closest to product knowledge.

Societal Knowledge. Societal knowledge (*Gesellschaftswissen*) gives evidence to what organizations are, how they work, what to expect from them, and under which aspects they are accepted by society. This type of knowledge is rarely subject to discussion but simply presupposed knowledge about organizations as institutions (a separate line of research in organization science takes on this particular notion, e. g., DiMaggio & Powell, 1983; Meyer & Rowan, 1977; Pfeffer, 1976). Organizations themselves call upon this knowledge, for example, in their decisions on membership; apart from contractual agreements, organizations assume that individuals know to behave differently in organizational settings than in private situations.

Management Knowledge. Management knowledge (*Führungswissen*) pertains to the management of hierarchies, departments, work groups, expert teams, communities of practice, or, in short, to the division of labor. With regard to generally accepted standards of authority and matching patterns of discipline, management knowledge is part of societal knowledge. Then again, this type of knowledge reflects in the ways organizational members are motivated in their work, in the styles of cooperation among colleagues, and in the pursuits of career opportunities. The next best criterion that distinguishes organizations from other social systems in relation to management knowledge is thus the one of positions. Decisions on who participates in what communication fundamentally determine formal as well as informal organizational structures. Above all, management knowledge is an issue which management science and organization theory deal with in terms of power and politics (e. g., Pfeffer, 1994; Salancik & Pfeffer, 1977).

Expert Knowledge. Expert knowledge (*Expertenwissen*) is all about the environment of organizations. It ensures the quality of decisions on, for instance, purchasing policies and sales techniques, financial reward systems and accounting procedures, strategy development and human resource management. Naturally, the contingency of these and other functional differentiations appears best in the way other organizations do business. To this effect, expert knowledge is always under the scrutiny of organizational performance. Contrastingly to the latent ubiquity of societal and management knowledge, it furthermore develops and maintains expectations with respect to the expertise of but a few individuals (e. g., marketing managers, financial accountants, and business consultants). This puts individual expertise in the spotlight of several knowledge management theories (e. g., Brown & Duguid, 1991; Nonaka, 1994). It is evident that membership is the one criterion to distinguish organizations from other social systems, and that it preeminently associates with expert knowledge.

Social Knowledge. Social knowledge (*Milieuwissen*) deals with the way things usually work in organizations, who to involve in decisions, when to disobey directives, where to get technical advice, what initiatives promise success, and so on, and so forth. Since the 1980s, this type of knowledge is subject to ample discussions revolving around the topic of organizational culture (e. g., Deal & Kennedy, 1982; Schein, 1984). Culture frequently presents the access point for organizational analysis in terms of either a root metaphor or a critical variable (Smircich, 1983). Particularly the latter approach pays tribute to the difficulties of de-contextualizing organizational culture or, as a matter of fact, social knowledge. More than any other type of knowledge, social knowledge resists organizational analysis, functional improvement, and managerial utilization; once isolated and explicated, it resembles management or societal knowledge.

This clear a distinction between any one of the five types of organizational knowledge is of course only possible in theory. In practice, decisions always entail a combination of different types of organizational knowledge. Yet, this theoretical distinctions highlights that production and expert knowledge,

Table 3.1: Epistemological Attributes of Knowledge

Autopoietic Organization Theory	Knowledge Management
complex	complicated
recursive	linear
emergent	reducible
creative	retentive
constructivist	representative
problem defining	problem solving
history dependent, evolutionary	designed, transferable
context sensitive	universal, objective, free of paradox

more than any other type of organizational knowledge, are at managerial discretion (Baecker, 1999, p. 98). Product knowledge reflects best in the way organizations do business (i. e., make decisions) on a day-to-day basis. Routines and procedures, processes and customs, norms and conventions, rules and standards are all attributed with reflexive expectations. Management explores and exploits product knowledge by setting the boundaries for production programs, research agendas, accounting methods, and the like. In the narrowest sense of the term, product knowledge is highly specific to certain organizational settings, which offers management the possibility to exercise exclusive discretion by determining relevant decision premises. Expert knowledge, too, is at particular managerial discretion. By and large, it draws on the membership of individuals. Experts are commonly employed with regard to (facilitating) the definition and solution of problems in their area of expertise, for example, marketing, accounting, or consulting. And since the membership of experts is decided on by management, the employment or dismissal of experts offers leverage for the development of organizational knowledge.

Table 3.1 contrasts epistemological attributes of knowledge from the perspective of social systems theory and autopoietic organization theory with those found in the literature on knowledge management (cf. Subsection 2.3.4). In summary, the functional definition of organizational knowledge stands in contrast to the debate on whether organizations know less than their members (Argyris & Schön, 1978; Hedberg, 1981; Starbuck & Hedberg, 1977), know more than their members (Gopalakrishnan & Bierly, 1997), or know just what their members know (Walsh, 1995). The corresponding technical question is whether systems are less, more, or equal to the sum of their parts. From the previous contemplations it is obvious that in fact neither proposal fits social systems theory and autopoietic organization theory, respectively. Organizational knowledge is not individual knowledge, and individual knowledge is not organizational knowledge. More or less are not the right categories. Luhmann emphasizes that decisions require

> knowledge that the organization itself disposes of, independent of what individuals know. Belonging to the knowledge of the organization is of course knowledge about what persons, who one could ask, could know. Just therefore, organizational knowledge cannot be reduced to personnel sources. As outcome of learning processes, it is stored in the organization itself and can be taken for granted with the activation of communication. (Luhmann, 2000, p. 186, own translation)

Hence, the only thing that matters for organizations is organizational knowledge. More or less provocative statements like this draw frequent critique; some scholar suspiciously regard social systems theory as anti-humanistic (e. g., Blühdorn, 2000; Viskovatoff, 1999), others aim at deconstructing autopoietic organization theory with the claim that the very concept of communication itself is "flawed with an unavoidable mental dimension, namely the component of understanding" (Thyssen, 2003, p. 213) which, in effect, makes it impossible to separate individuals from organizations or consciousness from communication. However, social systems theory does not deny the importance of individuals when it comes to their participation in the communication of decisions (instead of many references, cf. only Luhmann, 2002); as a matter of fact, neither one is possible without the other. What social systems theory, autopoietic organization theory, and this theoretical clarification offer is a clear-cut distinction between individual and organizational knowledge. Both levels of analysis deserve treatment in their own right, particularly with respect to the management of organizational dynamics at large.

3.2.2 Organizational Learning

The above contemplations on organizational knowledge carefully avoid any references to organizational learning. At times, this is quite difficult to achieve. The reflexive nature of organizational knowledge hints the possibility to develop, maintain, or abandon expectations, for example. In a crude sense, this already describes organizational learning. In the following, a more precise definition of (organizational) learning complements the above functional definition of (organizational) knowledge as the cognitive structure of social and psychic systems. The remainder of this subsection links some important aspects of natural and open systems approaches to organizations with autopoietic organization theory. In particular, organizational unlearning, organizational inertia, and organizational knowledge creation are under scrutiny. First of all though, a controversy introduces the topic.

Management science and organization theory attempt to come to grips with the way organizations learn for more than a quarter of a century now (e. g., Argote, 1999; Argyris & Schön, 1978; Senge, 1993) (moreover, cf. Subsection 2.2.4). "The entire field of research seems to continuously validate itself on the initial diagnosis that organizations are not able to learn in the first place," Baecker (2003, p. 179, own translation) remarks. Nonetheless, judging by the sheer amount of literature on organizational learning (for reviews, cf. Dodgson, 1993; Easterby-Smith, Crossan, & Nicolini, 2000; Fiol & Lyles, 1985; Hedberg, 1981; Huber, 1991; Levitt & March, 1988; Miner & Mezias, 1996; Shrivastava, 1983), the problem is obviously more persistent than any of its solutions.

Then again, organizational learning may not be the problem after all. "Perhaps organizations are not built to learn. Instead, they are patterns of means-ends relations deliberately designed to make the same routine response to different stimuli, a pattern which is antithetical to learning in the traditional sense," Weick (1991, p. 119) asserts. Of course, he does not deny that organizations do in fact learn. Weick merely claims that the traditional definition of organizational learning yields a one-sided picture. Consider, for example, Argyris' (1976, p. 365) definition of learning as "the detection and correction of errors, and error as any feature of knowledge or of knowing that makes action ineffective." In contrast to patterns of different stimuli, same response, this traditional definition ascribes to same stimulus, different responses patterns which are rarely the case in organizations. To further illustrate his point, Weick asks his readers to consider the example of learning curves (cf. Epple, Argote, & Devadas, 1991; Shrivastava, 1983, pp. 14–16).

> Suppose that one month after an auto plant opens, a completed car rolls off the assembly line every 10 minutes. Ten months later a completed car rolls off every 6.5 minutes. At first glance it looks like the response remains the same (a car is produced) and the stimulus of material inputs remains the same. Thus, there seems to be no learning behind the learning curve.

> More detailed inspection suggests the possibility of a different story. At the macro level, materials and technology change over the 10 months as suppliers and technicians make adjustments (different stimuli), but cars continue to be produced (same response). A basic routine is broadened to include a wider variety of stimuli. (Weick, 1991, p. 121)

Without further ado, this controversy is only evidence for the need to reconsider organizational learning. Unfortunately, autopoietic organization theory does not provide a readily available definition of organizational learning to be cited or paraphrased. Luhmann (2000, pp. 74–76) himself devotes three initial pages to organizational learning. His elucidations are brief, all in all leaving his readers with a need for more information, whereupon he refers them to the research of March and colleagues (e. g., Herriott, Levinthal, & March, 1985; March, 1991; March & Olsen, 1976). Baecker (2003, p. 179–197) introduces *The Unlearning Organization* in a chapter of its own, strangely enough without the appropriate reference(s) to, at least, Hedberg's article on *How Organizations Learn and Unlearn* (1981). Nevertheless, he offers some inspiring insights on organizational learning which bring a description of how organizations learn a considerable step closer (cf. the below remarks on disappointment, destablization, etc.). Other literature on autopoietic organization theory (e. g., Bakken & Hernes, 2003; Seidl & Becker, 2006) adds no further prospect to matters of learning or unlearning.

Social systems theory is a valuable source of information, once again. It defines *learning as the partial change of the cognitive structure of social and psychic systems* (Luhmann, 1984, p. 158). In this respect, learning is as much the unobservable transition from one system state to another, as it is the observable difference between system states (Maturana & Varela, 1980, p. 35). This simple enough definition is well in line with hitherto discussions and, as a matter of fact, complements the above definition of (organizational) knowledge (Subsection 3.2.1). In pursuit to advance autopoietic organization theory, organizational learning denotes the partial change of the cognitive structure of communication (of decisions). It is both process and outcome (i. e., unobservable transition and observable difference), to use the language of organization theory (Sandelands & Drazin, 1989).

This definition of organizational learning requires some particularizations, of course. A first look follows Weick's (1991) challenge to the traditional definition of organizational learning. His critique rests on the assumption that "either organizational learning is an infrequent event, or it occurs frequently but takes a nontraditional form" (Weick, 1991, p. 116). Consequently, Weick (1991, p. 121) suggests either to retain the same stimulus, different responses pattern or to take the position that "organizational learning occurs when groups of people give the same response to different stimuli." Autopoietic organization theory quickly resolves this controversy.

Same stimulus, different responses. "Stimulus situations in organizations tend to be unstable and changing. This instability makes it hard to establish sufficient stimulus similarity so that it becomes possible to make a different response," Weick (1991, p. 117) claims. Apparently, he assumes that these stimulus situations are unstable and changing as they originate from a likewise unstable and changing environment. However, organizations selectively construct their environment (Subsection 3.1.1) and hereupon decide whether or not their (self-)observations match their operations (Luhmann, 2000, p. 74 f.; incidentally, Weick, 1995, p. 36 ff., adopts this point of view later on, too). Thus, organizations establish sufficient stimulus similarity just fine. Hidden in this argument is the notion of reflexive expectations (Subsection 3.2.1). Expectations are dedicated system/environment distinctions without immediate reference. Their reflexivity ensures the consistency between actual system/environment distinctions and themselves. More specifically, the disappointment of expectations stabilizes a stimulus situation which evokes the partial change of the cognitive structure of social systems. In other words, while the stimulus situation leads back to environmental irritations (disturbances, perturbations, stimulations, etc.), learning occurs when organizations distinguish between success and failure (Luhmann, 2000, p. 75), between match and mismatch (Argyris, 1992, p. 8) of their (self-)observations and their operations. The traditional definition of organizational learning (e. g., "the detection and correction of errors," Argyris, 1976, p. 365) fits well with autopoietic organization theory, after all.

Different stimuli, same response. In contrast to the traditional definition of organizational learning Weick (1991, p. 121, sic) states, "If organizations learn when they develop routines, then this should be visible as different responses become resolved down to a singular response, and an increasingly wide variety of stimuli now trigger this singular response." The development of routines and procedures, processes and customs, norms and conventions, rules and standards likewise pertains to the notion of reflexive expectations (Subsection 3.1.4). Expectations draw their dedicated system/environment distinctions from actual system/environment distinctions (i. e., they are generalizations of communication; cf. Subsection 3.1.3), and their reflexivity ensures subsequent consistency. At the same time, expectations are failure tolerant; they are robust (Luhmann, 2000, p. 250). Their reflexivity accounts for a fuzzy set of actual system/environment distinctions only. In other words, some expectations disappoint, some do not, and others are uncontested altogether. As a result, an increasingly wide variety of stimuli may well trigger the same singular response over and over again, while it never evokes the partial change of the cognitive structure of social systems (again, cf. March & Simon, 1958, p. 165, on the matter of uncertainty absorption). *The Nontraditional Quality of Organizational Learning*, as Weick (1991) puts it, is accordingly close to autopoietic organization theory, too.

The semantic redisposition in the domain of learning embraces both the traditional as well as the nontraditional definition of organizational learning. Organizations detect and correct ineffective actions, and still they respond to errors in routine ways. To continue Weick's (1991) example, consider two competing auto plants that face a bottleneck in supplies. One company takes this situation as a serious threat and consequently changes from a static assembly line to a more flexible work cell production of cars (same stimulus, different responses). The other company leaves the problem largely unattended and simply improves its production routines so to incorporate alternative parts (different stimuli, same response). Both companies learn, but in quite different ways. Moreover, note that neither the very change from assembly line to work cells nor the improvement of production routines is observable in itself. The work cells and alternative parts themselves, however, are observable instances of learning.

So far, the discussion establishes a firm understanding of organizational learning within the realm of autopoietic organization theory as well as in relation to traditional and nontraditional definitions thereof. Two more aspects require closer inspection in order to fully grasp the particularities of this reconsideration. These are organizational inertia (Hannan & Freeman, 1984) and organizational unlearning (Hedberg, 1981).

Organizations solve problems, accomplish tasks, and do business more efficiently than any one of their members could do by himself. They establish programs, procedures, routines, and the like in spite of ubiquitous uncertainties. Hence, organizational knowledge faces continuous (threats from perceived) environmental turbulence. This renders organizational learning ever the more necessary but in a sense precarious, too. Indeed, one must wonder why the literature promotes an overwhelmingly positive image of organizational learning (e. g., Argote, 1999; Senge, 1993). While a change of the cognitive structure of social systems promises a better fit between the communication of decisions and whatever these decisions aim at, there is no guarantee that this is in fact the case. Learning destabilizes organizations (Baecker, 2003, p. 183); it takes time and resources, and in the meantime organizations are quite disoriented or paralyzed (Hedberg, 1981); or it may well be plain disadvantageous (Herriott, Levinthal, & March, 1985; Levinthal & March, 1993; Lounamaa & March, 1987), just consider the possibilities of misinterpreting market demands, of adopting already dying technologies, or the like.

Baecker (2003, p. 195) points out that organizational learning receives its positive connotation almost certainly in retrospect, right when organizations identify their past learning as valuable and thus attribute any future learning as similarly valuable (in this respect, cf. the discussion of postdecision surprises by Harrison & March, 1984). Weick & Westley (1996, p. 440) altogether retreat from positivist thinking and go as far as calling organizing and learning "essentially antithetical processes, which means the phrase 'organizational learning' qualifies as an oxymoron. To learn is to disorganize and increase variety. To organize is to forget and reduce variety."

Organizational learning is certainly precarious in that it may change the cognitive structure of social systems to something less desirable than originally intended. However, reliable organizational knowledge is usually difficult to abandon. "Success reinforces organizations' theories of action," Hedberg (1981, p. 18) writes (moreover, cf. Argyris, 1976; Starbuck & Hedberg, 1977). These long-time successful cognitive structures prevent organizations from disadvantageous learning. Time and again, they become inert and prevent organizations from advantageous learning, too. The Catholic Church, for instance, does not officially acknowledge heliocentrism until 1992, although it accuses Galileo Galilei of heresy for promoting this very world view already in 1633. In order to deal with organizational inertia (i. e., inert cognitive structures, cf. Hannan & Freeman, 1984), organizations require just the converse case of organizational learning, unsurprisingly termed organizational unlearning (Baecker, 2003, pp. 179–197; Hedberg, 1981).

> Organizational unlearning is typically problem-triggered. Funds shortages, falling revenues, actual losses, diminishing popular support, or public criticism from evaluators are some examples. These triggers cause hesitancy and build up distrust in procedures and leaders. A turbulent period then frequently follows. Inconsistent messages are issued by the leaders, and organiza-

> tional members and outside evaluators begin searching for new leadership and alternative strategies and myths. Ultimately the world view and the standard operating procedures break down. The organization has unlearned its yesterday. (Hedberg, 1981, p. 19)

In this sense, it took the Catholic Church 350 years of unlearning before it changed its world view. Although most of today's organizations are certainly far younger then three and a half centuries, they generally maintain expectations over long periods of time, expectations which often enough disappoint (Baecker, 2003, p. 166). As a matter of fact, organizations establish programs, procedures, routines, and the like not merely in spite of ubiquitous uncertainties, but precisely to endure all of the environmental irritations, disturbances, perturbations, stimulations, and so on (cf. Subsection 3.2.1). Organizational knowledge evinces compensating characteristics which success or failure, and subsequently learning or unlearning, steadily construct, deconstruct, and reconstruct. Hence, learning and unlearning are but different labels for still—the partial change of cognitive structures of social and psychic systems.

With the (re)description of organizational learning and unlearning in place, a last issue requires some consideration. An everlasting critique of organizational learning reflects in "the problem of creating the initial body of knowledge that made learning possible" (Spender, 1996, p. 64). Social systems theory quickly dismantles this reproach. The starting point is to "draw a distinction" (Spencer-Brown, 1979, p. 3). In case of social and psychic systems, this is the distinction these systems draw between themselves and their environment (Subsection 3.1.1). The very first distinction then puts a cognitive structure in place which further communication and consciousness relies upon. Luhmann subsumes the emergence of social and psychic systems under the heading of learning, too. However, he creates the initial body of knowledge that makes learning possible by means of a rhetorical trick. For him, agnosia (the state of not knowing; *Nichtwissen*) is as much basis for learning as knowledge is (cf. Luhmann, 1984, p. 448). Luhmann's cumbersome rethoric finds a somewhat more elegant differentiation in the term knowledge creation (cf. Nonaka, 1994; Nonaka & Konno, 1998). Knowledge creation indicates the emergence of the cognitive structure of social and psychic systems (i. e., the very first distinction), whereas (un)learning is (and remains) the partial change thereof.

Much of the discussion builds upon the fundamental concepts of social systems theory (Section 3.1) as well as the functional definition of (organiza-

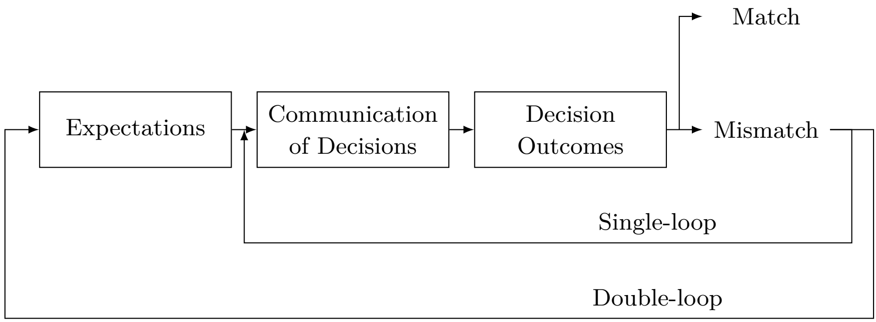

Figure 3.3: Single-loop and Double-loop Learning (Argyris, 1992, p. 5)

tional) knowledge (Subsection 3.2.1). Therefore, the contemplations on organizational learning and unlearning are brief but dense. For the most part, basic concepts of organizational learning, such as Argyris' (1976) model of single-loop and double-loop learning (moreover, cf. Subsection 2.2.4), are valuable as of today. Organizations target their issues with ever new decisions. If they observe a mismatch between a decision and whatever the decision aims at, they simply try to decide differently the next time around (single-loop learning). In case of more profound issues (e. g., continuous organizational failure), organizations inquire into the governing variables of their autopoiesis (double-loop learning), namely, the membership, positions, and programs that guide their decisions (see Figure 3.3).

The two most important takeaways are that (1) each and every autopoietic episode features the possibility of organizational (un)learning, and that (2) organizational (un)learning adheres to intraorganizational problems (tasks, programs, etc.; cf. Subsection 3.1.4) which issue from (observed) environmental irritations (disturbances, perturbations, stimulations, etc.; cf Subsection 3.1.2). In short, (organizational) learning is unavoidable.

3.2.3 Organizational Memory

Organizational knowledge, learning, and memory are interrelated concepts, though management science and organization theory frequently treat them separately (cf. Subsection 2.3.4 on knowledge management and Subsection 2.2.4 on organizational learning for numerous examples). "Like voltage, current and resistance, the terms knowledge, learning and memory must be defined in terms of each other," Spender (1996, p. 75, sic) asserts, otherwise they are forever "three concepts in search of a theory" (Spender, 1996, p. 63). In other words, management science and organization theory lack a comprehensive theoretical framework to integrate these three concepts. Spender himself offers a pluralistic epistemology embracing both positivistic and interpretive positions. Unfortunately, he stops short of constructivist perspectives and simplifies his ambitions in a two-by-two matrix of knowledge types (cf. Spender, 1996, p. 70).

The hitherto contemplations, discussions, and reconsiderations revamp knowledge and learning from the perspective of autopoietic organization theory. This subsection takes up their implicit references to organizational memory; it complements organizational knowledge (Subsection 3.2.1) and organizational (un)learning (Subsection 3.2.2) with a definition of organizational memory. Before the actual definition, though, consider another one of von Foerster's (1981a, p. 92 ff.) peculiar examples.

To begin with, von Foerster confesses that he is a man who has a hard time carrying out multiplications by hand. In spite of multiplying large digit numbers over and over again and getting different results most of the times, he wonders how much paper he would need to print a multiplication table with two entries, one on the left (X) and one at the top (Y) for the two numbers to be multiplied, and with the product (XY) being recorded at the intersection of the appropriate rows and columns. His approximations show that a table with 100 entries fits on a single page. While this is certainly not surprising, a table for multiplications of ten-digit numbers extends to about 100 times the distance between the sun and the earth or about one light-day long. Looking up a single entry in the body of this table takes, on average, half a day—if only one could move at the speed of light.

Multiplication tables are apparently not a very practical way to store data. Luckily, von Foerster (1981a, p. 93) continuous, he found a device made up of 20 little wheels, each with numbers from zero to nine printed on them. The wheels are coupled to each other in an "ingenious way so that, when a crank is turned an appropriate number of times, the desired results of a multiplication can be read off the wheels." It usually requires about 50 turns to reach a result for the multiplication of two ten-digit numbers, which takes a lot less time than traveling at the speed of light for about half a day.

Whether it is the straightforward storage and retrieval of data from multiplication tables, the use of handy devices to compute the results for the multiplication of two numbers on the fly, or the recall of a particular meal from the last overseas flight (cf. von Foerster's vivid illustration of airline food services in Subsection 2.3.1), memory plays an important role in all of these examples. Speaking of memory in terms of either storage and retrieval or recognition and recall (cf. Subsection 2.3.1, once more) requires some more consideration. The first instance inevitably links memory to data, whereas the latter emphasizes information instead. Subsection 2.3.4 on knowledge management reviews data, information, and knowledge, but it is nevertheless necessary to present the stance of autopoietic organization theory on the issue.

Data are artifacts in symbolic code (e. g., numbers in the decimal system or characters in the literary language, just like the above example indicates). They exist in the environment of social and psychic systems and therefore are without meaning of their own. They entail meaning only in the system/environment distinction of information. Literally, information means to put data in form. Using an example from managerial life, von Krogh, Roos, & Slocum clarify this matter.

> Books, movies, lectures, papers, computer programs, memos, etc., are data in the environment of the manager—not information. They are simply fractions and may be vehicles for potential information. Information is dependent on the manager who makes use of it to create knowledge. The only way to describe this process is to say that the manager is simultaneously open and closed. He or she is closed with respect to knowledge (also knowledge about the environment) but open with respect to data from the outside. (von Krogh, Roos, & Slocum, 1996, p. 165, emphasis in the original, sic)

In turn, information is always a selection of a particular system, and in case of organizations, it is the first integral selection of the communication of decisions (Subsection 3.1.3). Organizations occasionally impute mistakes in decision making to a lack of information. From a social systems perspective, however, this statement is simply false. All organizational decisions necessarily comprise information (Subsection 3.1.4). The question is not whether information exists in the first place, but whether sufficient information is conveyed (i. e., if the selection provides the right content for the decision). Consequently, neither are organizations flooded with information as if information exists independent of organizations, nor is there information outside an organization waiting to be recognized. To repeat the words of von Foerster (2003a, p. 252, emphasis in the original), "the environment contains no information; the environment is as it is."

The above conceptual elucidation of data and information points out that books, movies, lectures, papers, computer programs, memos, and the like are not the location of the memory of social and psychic systems. As a matter of fact, memory does not have a location at all, simply because it is not an object. The German translation of memory is very precise here. On the one hand, memory denotes *Gedächtnis*; on the other hand, it translates to *Speicher*. *Gedächtnis* is clearly inherent to psychic systems (consider its etymological Old High German root *kithēhtnissi*, *das Denken an etwas*; i. e., thinking about something). Although social systems cannot think (Subsection 3.1.2), they have a *Gedächtnis*, too (Luhmann, 1996; Luhmann, 2000, pp. 60, 192). It is obvious that books, movies, lectures, papers, computer programs, memos, et cetera do not have a *Gedächtnis*; they are media which cannot think or communicate. Contrastingly, the German term *Speicher* is technical in its nature, like the memory of a computer or, indeed, books, movies, and so on, and so forth. The *Gedächtnis* may employ some form of *Speicher* to keep record, much like the memory of social and psychic systems may use the memory of, say, computers to store data. Still, *Gedächtnis* and *Speicher* are two different things. *Gedächtnis* is a matter of communication and consciousness and thus recognition and recall, whereas *Speicher* emphasizes the storage and retrieval of data.

In recent years, empirical findings in neuroscience put forth a constructivist theory of memory (e. g., Bolhuis, 2000; Brook & Akins, 2005; Roth & Wullimann, 2001; Singer, 2002) which departs from the idea that data and information are in any way repositories of memory. This spawns an interdisciplinary debate on the consequences of such a theory for society at large, particularly in Germany (instead of the many individual contributions, cf. the edited volume by Geyer, 2004). The debate is certainly interesting; still, it offers no conclusive definition of (organizational) memory. About the same time, social systems theory develops its own definition of memory (cf. Esposito, 2002, pp. 24–31; Luhmann, 1996; Luhmann, 1997, pp. 576–594), mostly in reference to von Foerster's (1981a; 2003d) cybernetic point of view. Social systems theory employs a likewise constructivist approach to memory which holds true for all autopoietic systems, not just the human brain that neuroscience focuses on. Esposito (in heavy reliance on Luhmann) claims that memory is merely an abbreviation for the recursivity of operations; it "allows, beyond the steady flow of ever new operations, to capture that what repeats itself and is therefore remembered, whereas everything else falls victim to forgetting" (Esposito, 2002, p. 24, own translation, emphasis in the original).

Social systems theory anchors memory in the operations of social and psychic systems (i. e., communication and consciousness). In each and every autopoietic episode of social and psychic systems, memory serves the "double function of remembering (preservation) and forgetting (interruption)" (Luhmann, 1996, p. 312, own translation), for whatever is remembered is not forgotten, and whatever is not remembered is forgotten. "Forgetting, however, is not, as our everyday understanding suggests, an unfortunate adversity. It is rather the primary function of memory," Luhmann (1996, p. 311, own translation) furthermore explains. Forgetting prevents a deadlock of communication and consciousness whereby the vast amount of observations of past operations quickly overwhelms the information processing capabilities of social and psychic systems. For example, the decision whether or not to put on a coat before leaving the house does not require one to remember how the weather was a week, a month, or even a year ago. One must only remember the present weather situation and decide accordingly.

Apparently, memory is an imperative quality of communication and consciousness, in many ways similar to knowledge and learning. Remembering and forgetting set the boundaries within which possible consistency checks operate (Luhmann, 1997, p. 579); at this, they free up information processing capabilities so that social and psychic systems are open to new irritations (disturbances, perturbations, stimulations, etc.). It is most noteworthy that memory is not a consistency check itself, it merely takes responsibility for the coherence of recursivity; that is, it ensures the order of observations of the past (Esposito, 2002, p. 26). The consistency check that operates within the boundaries of memory is—the cognitive function of knowledge (Baecker, 1999, p. 85; Luhmann, 1990, p. 129) (moreover, cf. Subsection 3.2.1). Therefore, the relation between knowledge and memory is the one of recognition and recall. Knowledge aims at the external consistency between actual system/environment distinctions and expectations, whereas memory guarantees the internal coherence of systems' past operations. In turn, knowledge and memory are premises of learning. "Learning requires an open combination of retainable and changeable knowledge, and only in such a combination are cognitive expectations treated as knowledge," Luhmann (1984, p. 447 f., own translation, emphasis in the original) writes. Memory remembers and forgets the past, learning anticipates the future.

The beginning of this chapter promises a definition of organizational memory which complements the definitions of organizational knowledge and organizational learning. Obviously, this is a demanding task. Social systems theory clearly dissociates itself from object-oriented approaches to memory (e. g., based on data) such as Simon (1991, p. 128) who asserts that "much of the memory of organizations is stored in human heads, and only little of it in procedures put down on paper (or held in computer memories)." Similar statements are frequently found in management science and organization theory (e. g., Anand, Manz, & Glick, 1998; Cohen & Levinthal, 1990; Moorman & Miner, 1998; Olivera, 2000; Walsh & Ungson, 1991). The common belief that information exists in databases (e. g., Bierly, Kessler, & Christensen, 2000; Nonaka, 1994) is also not a belief social systems theory subscribes to. In accordance with information science, it hence speaks of databases, not informationbases. Although Walsh and Ungson ultimately develop a different definition of organizational memory, they correctly remark that the "difference between information and memory lies in their temporal qualities" (Walsh & Ungson, 1991, p. 61). In their work, information reduces decision equivocality, whereas memory refers to stored data which, when retrieved, comes to bear on present decisions.

Now, on the assumption that organizational knowledge is the cognitive structure of social systems (Subsection 3.2.1) and organizational learning is the change thereof (Subsection 3.2.2), *organizational memory is the connectivity of the cognitive structure of social systems in space and time.* Its double function is that of remembering and forgetting whereby the emerging coherence (stability, consistence, etc.) of the cognitive structure underpins the autopoiesis of social systems. Hence, organizations are never without memory. This functional definition of organizational memory incorporates information as the first integral selection of the communication of decisions but necessarily leaves out data. Undeniably, however, data are important to memory (e. g., to obtain the results of a multiplications of two large digit numbers, one may carry out the calculation by hand, try to remember the results from a previous calculation, or simply read them off a multiplication table). Subsection 3.1.3 lightly touches upon the issue of verbal, non-verbal, written, and printed communication. Writing and printing, in particular, are agencies of communication which "enormously expand the store of memorized data available for additional communication, while at the same time restricting it through selectivity" (Luhmann, 1981, p. 125). Writing and printing temporalize communication. For instance, information and utterance are necessarily bound to the communication role of alter, while understanding on part of the communication role of ego completes communication immediately in case of the physical co-presence of psychic systems (i. e., face-to-face communication); but ego may perfectly well complete communication at a later time (i. e., without the need of physical co-presence) when reading whatever alter selectively wrote beforehand. "Memory, and then writing, have their function in preserving—not the events, but their structure-generating power" (Luhmann, 1986, p. 180). In this light, reconsider von Krogh, Roos, and Slocum's above example of a manager who makes use of books, movies, lectures, papers, computer programs, memos, et cetera to build knowledge himself.

The definition of organizational memory complements the two previous definitions of organizational knowledge and organizational learning. As always, there is limited space to elaborate on the issue. With an interest in writing and printing, issue of media richness (Daft & Lengel, 1984, 1986) arise, for example. Other interesting perspectives describe the memory of the economy (Baecker, 1987), develop a contemporary analysis of the group mind in terms of transactive memory (Wegner, 1986), and postulate that information systems actually destroy memory (Osten, 2004).

3.3 Summary and Application Potential

In hope of an easier access to the paradigmatic value of social systems theory, this section summarizes the distinction between system and environment, and between operation and observation, as well as the complementing concepts of communication and expectation, and of organization and decision.

The starting premise of social systems theory is that there are self-referential systems. Self-referential systems constitute their elements and basic operations in autopoietic (self-producing) fashion; that is to say, they recursively generate their elements through the very operations that generate just the elements. As composite units in space and time, such networks of operations furthermore constitute the systems' boundaries to their environment. The distinction between systems and environment not only marks the self-referential closure of system operations but serves as a point of reference for system observations. This structural coupling between systems and environment yields the principle source of information.

Systems are operationally closed but structurally coupled to each other. Their operations separate them from the environment, whereas their observations overcome the ensuing endogenous system boundary. Social systems use communication as their particular mode of autopoietic reproduction; their elements are communication events which are recursively produced by a network of communication. The elements of psychic systems are thoughts which bring forth consciousness through a network of thoughts (the mind). Operational closure deprives systems of any immediate influence on other systems in their environment; after all, no system can operate outside its boundary. However, social and psychic systems incorporate observations of their environment into further communication and consciousness, respectively. As a consequence, the environment appears dynamic with mutually influential system/environment distinctions at the level of observations.

While the autopoiesis of social systems evolves highly complex networks of communication, single communication events are indecomposable for social systems. Nonetheless, communication comes about a precisely defined process: It is the selection of information, the selection of utterance of this information, and the selective understanding or misunderstanding of this utterance and its information. With information and utterance on the one hand and understanding or misunderstanding on the other, social systems theory furthermore discerns communication in two alternating roles. Information and utterance are selections of alter, understanding or misunderstanding are selections of ego. Psychic systems participate in communication in either one of the two communication roles; technically speaking, however, the participation of consciousness restricts to social systems' operations at the boundary of alter and ego.

The complexity of social systems refers to the impossibility of simultaneously connecting all communication events within space and time and thus the temporal selection of particular networks of communication. The autopoiesis of social systems is neither completely random nor perfectly ordered; and social systems are necessarily less complex than their environment, for communication about everything and all in the environment is simply infeasible. Social systems run counter to the complexity and contingency of the environment in that communication produces redundancy through expectations. Expectations are condensed generalizations of communication which provide stable anchors of reference in lieu of actual system/environment distinctions. Expectations furthermore assist cognitive structures by easing the pressure of selecting communication to pursue the autopoiesis of social systems in the face of a dynamic environment.

Interactions, organizations, and societies are social systems based on communication. Organizations, in particular, are defined by way of (1) the membership of individuals who participate in organizational communication, (2) the specific positions these participants occupy in the communication network, (3) the programs that determine the viability of organizational communication, and (4) the communication of decisions. The last criterion is the most prevalent one, because social systems theory understands organizations as systems made up of decisions and decisions as communication events. Membership, positions, and programs are all but results of organizational decisions in the first place. However, these three derivative criteria affect the decision-making process of organizations (i. e., the communication of decisions) in recursive fashion; once they are decided upon, and if they are accepted, then they are premises for future decisions.

The fundamental concepts of social systems theory provide the basis for autopoietic organization theory. Organizational knowledge, organizational learning, and organizational memory then present reconsiderations of comparable concepts from the rational, natural, and open systems perspective on organizations in themselves. Moreover, they are metaphorical concepts altogether. That is to say, knowledge, learning, and memory apply to both psychic and social systems alike, while autopoietic organization theory keeps the clear-cut distinction between individuals and organizations.

There is no further need to summarize this works' core theoretical development apart from the definition that knowledge is the cognitive structure of psychic and social systems, learning is the partial change, and memory the connectivity of this structure. These definitions are presented in straightforward manner. Their workings, however, largely deny immediate (empirical) study. "One can imagine the inside of a system [...] as very complex and opaque (at best subject to simulation)," Luhmann (1984, p. 275, own translation) writes. Following his latter suggestion, the next chapter introduces social science simulation as a scientific methodology to inquire into complex theoretical issues before Chapter 5 finally operationalizes autopoietic organizations theory.

4 Social Science Simulation

Computational simulation is used in a variety of scientific fields (e. g., biology, chemistry, physics). Unfortunately, simulation in the social sciences exists at the margin of scientific research. This situation is changing gradually. Social science simulation frequently piggybacks on the emerging science of complexity (Bruderer & Maiers, 1997) and with it reaches a wider audience. The remainder of this chapter presents a formal definition of computational simulation, introduces social science simulation as a specific form of scientific inquiry, and finally discusses its purposes and limitations.

4.1 Simulation as Scientific Endeavor

Etymology traces the origin of the term simulation back to the Latin word *simulatus*, the past participle of *simulare*, meaning to copy, represent, or feign. Simulations are imitative representations (i. e., theories or models) of the dynamics of one system or process by means of the dynamics of another (e. g., a computational simulation of an industrial workflow or a chemical reaction). They are not ends in themselves, however. Simulations furthermore comprise experimental frameworks which allow for the manipulation of system inputs and functions, and the observation of corresponding outputs and behaviors.

Traditional scientific research relies on theoretical and empirical analysis (i. e., deduction and induction). Simulation can be understood as a third way of scientific inquiry, as a blend of both deduction and induction, "standing halfway between theory and experiment" (Waldrop, 1992, p. 63). Three major landmarks identify the process of scientific research by means of simulation; these are (1) the deductive development of a theory or model, (2) its implementation in an experimental design, and (3) the inductive analysis of the simulation results (Axelrod, 1997).

Deductive Development of Theory or Model. Some researchers start from scratch and observe (natural) systems themselves to build genuine theory. Most simulations, however, are based on existing theory. Umbrella sciences or scientific paradigms such as complex adaptive systems (Holland, 1975) or

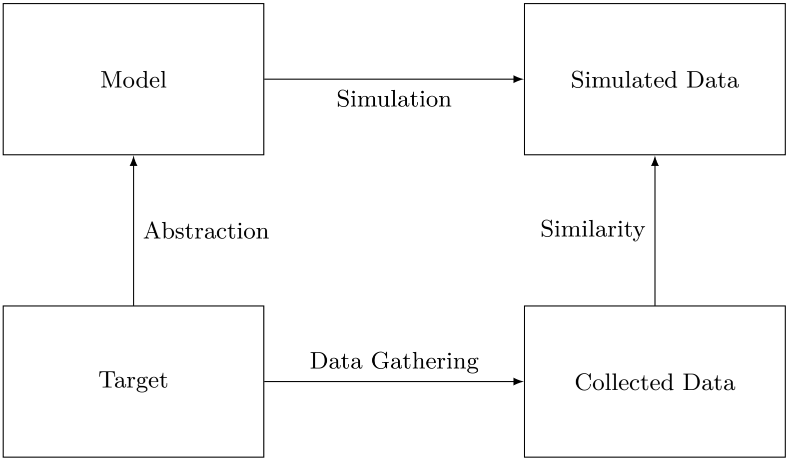

Figure 4.1: The Logic of Simulation (adapted from Gilbert & Troitzsch, 1999, p. 16)

social systems theory (Luhmann, 1984) provide rich theoretical frameworks to the development of models which, in turn, answer particular theoretical and practical questions in greater detail. For example, *NK* models (Kauffman, 1995, pp. 169–175) and *Echo* systems (Holland, 1995, pp. 101–107) answer questions concerning the fitness and survival of organisms at the edge of chaos, whereas simulations of *The Problem of Double and Multi Contingency Following Luhmann* (Barber, Blanchard, Buchinger, Cessac, & Streit, 2006; Dittrich, Kron, & Banzhaf, 2003) address the emergence of social order. The deductive development (abstraction; see Figure 4.1) of a theory or model requires the careful study and fundamental understanding of the system of interest (target; see Figure 4.1), nevertheless. Only then it is possible to formulate necessary simplifications without losing the essence of real-world dynamics.

Implementation of Theory or Model in Experimental Design. The implementation of a theory or model depends on the research questions to begin with. In general, simulations address two different issues. The first one is to find an optimal solution to a specific problem, an approach most engineering or operation research models use. The second issue is to understand system dynamics per se. Here, research inquires into the theoretical model without any need to maximize or minimize for best performance. The following section elaborates further on these issues and the various purposes of social science simulations.

Inductive Analysis of Simulation Results. Once simulations are carried out (e. g., a simulation is run on a computer), their results are studied in similar fashion (and in similarity; see Figure 4.1) to the analyses of empirical data. This typically includes standard mathematical techniques such as descriptive statistics, hypotheses tests, or regression analyses. In addition, sensitivity analyses (Axtell, Axelrod, Epstein, & Cohen, 1996; Chattoe, Saam, & Möhring, 2000) are imperative to simulation research nowadays. These tools and methods explore how sensitive simulation results (outputs and behaviors) are to changes in simulation variables and parameters (inputs and functions). *Active Nonlinear Tests* (Miller, 1998) are one way to probe key weaknesses in simulation models, for example. Standard mathematical techniques and sensitivity analyses apply to the majority of simulations. However, the more complex systems are, the less likely they are to exhibit linear behavior (Waldrop, 1992, p. 64). The results of complex simulation models thus call for new ways of analysis. Bedau & Packard (1992), for instance, develop a measurement of evolutionary activity to discern whether or not, and to what degree, evolution takes place in an observed system.

Simulation is a scientific endeavor beyond theoretical and empirical analysis, though it replaces neither one of these traditional research methods. Simulation rather integrates deduction and induction to predict, prove, discover, explain, critique, and prescribe (Section 4.3) some features of the real world which are often enough inaccessible to traditional theoretical and empirical analysis.

4.2 A Brief History of Social Science Simulation

Contemporary approaches to simulation date back to the development of differential equations (e. g., Newton's *Second Law of Motion*) and stochastic processes (Brownian motions, random walks, etc.) during the 18th and 19th century. The use of simulation in the social sciences, however, only coincides with the advent of computers in university research in the early 1960s (Troitzsch, 1997). Although there is a strand of non-computational simulations such as *The Beer Distribution Game*, first developed at the Massachusetts Institute of Technology's Sloan School of Management (cf. Senge, 1993, pp. 27–54, for a hands-on introduction to this interactive simulation), computer-based simulation is the hallmark of today's third way of scientific inquiry.

> On the one hand, it continues mathematical modelling and is no more than the numerical treatment of difference equations or the various kinds of differential equations (including partial and stochastical differential equations). Here, a machine is used to manipulate the symbols of the symbol system of mathematics, and this manipulation is more or less restricted to numerical treatment (although some computer help in symbolic computation is sometimes desirable, too). On the other hand, computer simulation is used in its own right, not as a substitution for more elegant mathematical solution algorithms, but as a means of manipulating the symbols of the symbol system of programming languages. (Troitzsch, 1997, p. 41, sic)

A well-known example of a computer simulation of a mathematical model is system dynamics (Forrester, 1961, 1969, 1971). System dynamics is an ambitious theoretical and practical attempt to describe, model, and simulate state or behavioral changes of large-scale systems such as industries, economies, societies, or the world as a whole. It operates on a macro level; the equations in use map relationships between and among individuals, groups, organizations, et cetera. In other words, systems dynamics cannot address individuals, groups, or organizations independent of each other, as entities in their own right. This fact severely limits the widespread adoption of simulation in the social sciences throughout the 1980s. In addition, Gilbert & Troitzsch reason that some instances of system dynamics, for example,

> The Club of Rome simulations [e. g., growth in world models (Meadows, Meadows, Randers, & Behrens, 1972, pp. 88–128)] which predicted global environmental catastrophe[,] made a major impact, but also gave simulation an undeservably poor reputation as it became clear that the results depended very heavily on the specific quantitative assumptions made about the model's parameters. Many of these assumptions were backed by little evidence. (Gilbert & Troitzsch, 1999, p. 6)

As a remedy to the limitations of system dynamics, microanalytical, discrete event, and multilevel models, as well as models of cellular automata, game theory, and artificial intelligence surface in social science research

(Brassel, Möhring, Schumacher, & Troitzsch, 1997; Troitzsch, 1997). The simulations thereof address a wide variety of issues, among them issues of workflow management and business process reenginering. Most commonly, they yield an optimal solution in form of a stable distribution (e. g., the optimal sequential order of tasks in a particular workflow). Table 4.1 (in part adapted from Brassel, Möhring, Schumacher, & Troitzsch, 1997, p. 59) provides a taxonomy and classification of these social science approaches to simulation (the entries are the prevailing characteristics).

All of these social science approaches to simulation certainly deserve an in-depth discussion of their own. However, they are of little paradigmatic value for this and subsequent sections, mainly because they cannot fully depict organizational knowledge, learning, and memory (Section 3.2). Therefore, they are omitted from individual treatment. For more comprehensive reviews, see Troitzsch (1997), Gilbert & Troitzsch (1999), Suleiman, Troitzsch, & Gilbert (2000).

In the 1990s, the social sciences shift their focus to agent-based simulation (Davidsson, 2002). Backed by the theory of complex adaptive systems (Holland, 1975) and follow-up research (e. g., at the Santa Fe Institute), agent-based simulation currently presents the leading simulation paradigm in the social sciences. Agent-based simulation shares a relatively loose relationship with classic mathematical modeling. For the most part, it is based on developments in the computer sciences, particularly tools and methods used in artificial intelligence research such as genetic algorithms, neural networks, and simulated annealing (Goldberg, 1989; Holland, 1995; Mitchell, 1996). Agent-based simulation describes real-world phenomena as interacting agents in a common environment. In contrast to mathematical approaches to simulation, these agents are guided by a set of rules rather than differential equations. There is no agreed upon definition of what constitutes an agent, but social science research commonly distinguishes between reactive, intentional, and social agents (Brassel, Möhring, Schumacher, & Troitzsch, 1997).

Reactive agents receive messages from their environment and, in turn, send messages to other agents based on fixed rules. System dynamics is essentially a single, reactive agent; its single set of equations processes incoming messages (input from the environment) and communicates results (outcome) back to the environment. Intentional agents share the same basic capabilities with reactive agents, but their rule system additionally comprises meta-rules which allow them to define goals depending on their motivation or needs. Moreover, they are capable of designing strategies to achieve these goals or solve conflicts between them. Intentional agents may

Table 4.1: Taxonomy and Classification of Common Social Science Approaches to Simulation

	System Dynamics	Microanalytical Simulation Models	Discrete Event Models	Multilevel Models	Cellular Automata, Game Theory, Artificial Intelligence
Main Purpose	prediction	prediction	prediction	explanation	explanation
Time	approximately continuous	discrete	event oriented	continuous or discrete	discrete
State Change	deterministic	stochastic	stochastic	deterministic and stochastic	deterministic and stochastic
Level(s)	macro	micro and macro, without feedback	micro	micro and macro, with feedback	micro

also inform each other about their goals. On top of all of these capabilities, social agents hold explicit models of other agents. They may thus reflect on their relationships to others and incorporate these in their own plans. Social science research furthermore distinguishes between indivisible and aggregate (or systemic) agents (Brassel, Möhring, Schumacher, & Troitzsch, 1997). Indivisible agents are single sets of rules; they do not consist of other agents. In contrast, aggregate agents are made up of other agents, though they interact with their environment in the same manner as indivisible agents (i. e., they appear as indivisible agents to their environment).

Agent-based simulation subsumes earlier mathematical approaches to simulation. Any mathematical model of systems dynamics is an indivisible, reactive agent, for instance. Although microanalytical simulation, discrete event, and multi-level models consist of multiple agents, these agents interact with each other based on differential equations, too. Consider an industrial workflow including several dependent production teams. Each team may be modeled either as an indivisible agent or as an aggregate agent. In the latter case, team members are indivisible agents which make up an aggregate team agent. Agents (teams or team members) receive inputs and send outputs to others based on fixed workflows. The whole industrial workflow is in fact an aggregate of agents. To the environment (e. g., a production plant), it may thus appear as an indivisible agent, again.

In any case, agent-based simulation solves the differential equations to account for state or behavioral changes in single and systemic agents, respectively. Still, the agents are simply reactive in their nature. Intentional or social agents loosen the restrictive (and, at times, problematic) use of large sets of differential equations. Here, sets of rules account for the dynamics of systems. These rules come as mathematical functions or computational instructions (e. g., if-then-else statements). Moreover, rules may change over time as a consequence of either themselves (i. e., dependent on whatever the rules state) or other agents (i. e., other rules). This yields much more qualitative solutions to simulation. Chapter 5 exemplifies this matter with respect to knowledge, learning, and memory.

A good example of the limitations of mathematical modeling is the traveling salesman problem, in mathematics also known as the *Hamiltonian Walk* (Robinson, 1949). The problem involves a salesman who needs to do business in a number of cities. He knows the cost (or time) of travel between the cities and now wants to find the cheapest (or shortest) route to visit all of them and return home. Given a finite number of cities, one approach to the problem is to determine all possible trips and compare their respective costs (or times). The overall solution yields the cheapest (or shortest) route, of course. However, an increase in the number of cities comes at the cost of an exponential growth of potential trips. There are 181,440 ways to visit ten cities, more than 43 billion possible routes through 15 cities, but already the one best solution for 20 cities amounts to more than six quadrillion possible trips! To attack the traveling salesman problem with sheer force (i. e., computing power) means to compute all of $(n-1)!/2$ routes (where n is the number of cities). Currently, the largest solved traving salesman problem is a tour through 24,978 cities in Sweden (for a multimedia illustration by the research team of Applegate, Bixby, Chvátal, Cook, and Helsgaun, see their website at http://www.tsp.gatech.edu/sweden). The tour was found using an algorithm known as Lin-Kernighan heuristic (LKH).

Mathematical approaches to the traveling salesman and other large-scale problems are often infeasible or at least problematic in their execution. While there are certainly more sophisticated mathematical algorithms (e. g., branch-and-bound, cutting-plane, tabu search, LKH) than the complete computation of all possible routes, agent-based simulation offers an elegant alternative to the brute force attack. For example, in analogy to the way ant colonies function, Dorigo, Maniezzo, & Colorni (1996) introduce an agent-based model which solves the traveling salesman problem, job-shop scheduling issues, and the like. The main characteristics of the model are the distributed computation of local optima by agents and the positive feedback between them.

There are numerous other applications of agent-based simulation besides the traveling salesman problem. They are commonly employed in case mathematical modeling does not yield an analytical solution, which is often the case in nonlinear, partial, and stochastic equations, or when a mathematical treatment of such equations leads to infeasible computing times. The following sections take a closer look at the purposes and limitations of agent-based (and, to some extent, other) simulation.

4.3 Purposes of Social Science Simulation

"There is nothing unusual about the logic of research using simulation models," Hanneman & Patrick (1997, 3.7) write. Simulation is simply another way of scientific inquiry beyond strictly theoretical and empirical analysis (Section 4.1).

> Observation, insight, and prior work give rise to a tentative theory which is stated quite formally and specifically in a model; the model is studied in itself as a way of working out (logi-

> cally deducing) the implications of the theory across a range of scenarios. Comparing the results of simulation predictions in particular empirical cases to empirical data tests the theory. Failure to make accurate predictions results in rejection of the model and/or theory; success in making predictions results in tentative acceptance of the theory and model. (Hanneman & Patrick, 1997, 3.7)

But social science simulation is more than just prediction. It answers a myriad of research questions, particularly those that traditional research methods cannot address. Axelrod (1997, p. 23, sic) suggests "diverse purposes to which social science simulation can be put. These purposes include: prediction, performance, training, entertainment, education, proof and discovery." Following Quinn (2000), however, performance, training, entertainment, and education may be discredited as little related to scientific research. Hence, they receive no further discussion. In addition to (1) prediction, (2) proof, and (3) discovery, there are at least three more valuable uses of simulation. These are (4) explanation, (5) critique, and (6) prescription.

Prediction. Agents process inputs (e. g., data or other resources) either from their environment or from themselves, depending on the rules they are made up of. The outcomes (e. g., decisions or other consequences) of their cooperation and competition are the basis for prediction. Prediction is thus the declaration or indication of outcomes in advance. For example, if the goal is to predict the world population ten years from now, simulation is the one best technique at hand. Given a formal model of world dynamics (e. g., Forrester, 1971), simulation easily predicts a number of scenarios which may or may not occur. All of these future scenarios are within the limitations of the model itself, initial conditions, and random disturbances.

Besides basic research, businesses frequently make use of the predictive power of simulation, too. In the late 1990s, Boeing sets out to seal a multi-billion-dollar deal on a fleet of 737 airplanes with a small company called Ryanair. Understandably, Boeing is most anxious when it comes to the credit-worthiness of its relative unknown partner. Its sales department sets up a computer simulation of Ryanair's business model and runs multiple scenarios to test for flaws in the system. Parameter settings such as demand, exchange rate, and fuel price are varied, but predictions from the simulation show profitable earnings through and through. Needless to say, Boeing sells its airplanes to Ryanair who is among the most profitable airlines in Europe today (Bowley, 2003).

Proof. The issue of proof is actually the issue of existence proof. This stands in contrast to the rigorous mathematical proof of a theorem (i. e., mathematical deduction). Rather, simulation validates the possibility of a theory or model to generate certain behavior. In other words, it tests the feasibility of a theory or model and demonstrates that system dynamics confirm to specified conditions such as boundary limitations. Cellular automata (Wolfram, 1986) and Conway's Game of Life (Gardner, 1970) are two agent-based simulations that prove that simple rules may nonetheless produce complex system behavior. The Game of Life is played on a field of cells, for example. Each cell has eight adjacent cells (i. e., the field of cells is actually a torus, removing edge effects) and may or may not host an agent. The initial conditions include the particular setup of the field and the number of agents randomly placed in the cells. Only three rules govern the game: (1) If an agent has no or one neighboring agent, he dies of loneliness; (2) two or three neighbors let the agent survive; (3) if an unoccupied cell has three adjacent cells with agents on them, it becomes occupied. The game itself displays endless sorts of patterns. Lumps of cells move over the field, bounce of walls, die away, produce offspring, or just freeze up—complex behavior based on simple rules, once again.

Discovery. The scientific value of simulation most commonly associates with prediction and proof. But discovery is likewise important to research, if not more important in social science simulation. The natural sciences (e. g., physics) often rely on precise models to predict or prove system dynamics. Engineers may simulate the oscillation of a pendulum, for instance. Without difficulty, they verify that the pendulum in motion will never leave its trajectory, that is, if it is not disturbed in any other way, of course. In contrast, the social sciences hardly ever fall back on precise models. Even the most elaborated simulation cannot fully account for the complexity of mass hysteria (Helbing, Farkas, & Vicsek, 2000), the spread of epidemic diseases (Bagni, Berchi, & Cariello, 2002), or organizational learning (Subsection 3.2.2). Nevertheless, social scientists are successful in discovering connections, principles, relationships, and the like from simple models. Axelrod (1997, p. 24) points out, "the simpler the model, the easier it may be to discover and understand the subtle effects of its hypothesized mechanisms." A good illustration is Carroll & Harrison's (1998) simulation of rival populations of organizations. Their simple model provides important insights into the general process of competition. One discovery Carroll and Harrison make is that path-dependent effects sometimes enable weak populations to win out over populations that are competitively superior.

Explanation. Scientific inquiry into natural systems frequently yields unexplained empirical phenomena. Simulation helps understanding the origins of these observed facts. Explanation relates to proof, but it typically extends beyond the mere demonstration of certain system dynamics, outcomes, and limitations. Indeed, explanation is of a more qualitative nature than prediction, proof, and discovery. Waldrop (1992, p. 39) puts this notion in rather casual words when he says, "predictions are nice, if you can make them. But the essence of science lies in explanation, laying bare the fundamental mechanisms of nature." Later on, he depicts a computer simulation of a thunderstorm (Waldrop, 1992, p. 63 f.) which produces astonishingly complex behavior from a set of simple equations. The equations of the thunderstorm describe how water vapor condenses and evaporates, how air pushes air, and numerous other small-scale matters. A computer integrates the equations over space and time and produces, for example, "a rising column of air with rain freezing into hailstones" or "a cold, rainy downdraft bursting from the bottom of the cloud and spreading along the ground" (Waldrop, 1992, p. 63). The analysis of the data produced by simulation establishes a firm ground for explanations about the causes of updrafts and downdrafts, what happens when temperature and humidity changes, and the factors that are important to the dynamics of a storm in general.

Critique. Simulation is a way to critique theory. In this sense, critique is the opposite of proof. Simulation either uncovers the flaws in a theory or proves the theory (at least theoretically) to be right. Moreover, simulation is a way to critique other simulations. This critique then rests on replication. Although replication is rarely done, it is nevertheless an important step in the research process (Axelrod, 1997; Axtell, Axelrod, Epstein, & Cohen, 1996; Edmonds & Hales, 2003). Replication confirms whether the claimed results are reliable and can be (re)produced by other researchers from scratch. Furthermore, it is a test of the robustness of inferences from simulations (Chattoe, Saam, & Möhring, 2000). In an effort to align prominent simulation models, Axtell, Axelrod, Epstein, & Cohen (1996) summarize a number of important lessons, including standards for evaluating replication results. They distinguish three levels of replication.

Table 4.2: Payoff Matrix for Prisoner's Dilemma

	Cooperate	Defect
Cooperate	1 year, 1 year	0 years (free), 20 years
Defect	20 years, 0 years (free)	10 years, 10 years

First, if replication reproduces the exact same results of the original simulation, one may speak of numerical identity. Second, replication achieves distributional equivalence with the original simulation in case their results are statistically indistinguishable. Distributional equivalence is a sufficient enough level of replication in most cases. Lastly, there is relational equivalence, which means that replication and simulation share the same internal dynamics.

Prescription. Discovery, explanation, and prescription are closely related. Discovery highlights previously undetermined connections, principles, and relationships in theories and models, and explanation adds a basic understanding of how these connections, principles, and relationships produce particular system behaviors. Prescription follows discovery and explanation. When discovery and explanation lay bare the dynamics of a theory or model, the theory or model may be modified (e.g, via parameter settings) to optimize system behaviors. This modification is part of prescription, which eventually leads to the definition of a best way to organize, to pick a strategy, et cetera.

An example of the prescriptive powers of simulation originates from game theory (Axelrod, 1984; Dresher, 1961). Game theory studies the conditions under which cooperation between agents emerges. Consider the famous *Prisoner's Dilemma* (Poundstone, 1992; Rapoport & Chammah, 1965). Two individuals commit a crime together and both get caught. The police questions them separately. Now, each one of them may either cooperate with or defect against the respective other. If both cooperate (i. e., neither one of them confesses the crime), then they face one year in prison each; in case one of them instead defects, he goes free and the other gets sentenced to 20 years; if both defect, then each one of them serves ten years in prison (Table 4.2).

The highest payoff in a single game is the cooperate/cooperate strategy. It still puts both individuals in prison, but the overall sentence is only two years. Unfortunately, this logic is not stable to defection. Since neither individual knows what strategy the other one pursues, each one of them defects in hope of getting free. This leads to an inferior defect/defect strategy with an overall sentence of 20 years.

Obviously, there is nothing much to discover and to explain in a single game. Iterated Prisoner's Dilemmas, however, are different. Simulation shows that the highest payoff is no longer a cooperate/cooperate strategy but a strategy called *TIT FOR TAT* (Axelrod, 1984, pp. 27–54). Here, both individuals cooperate until one of them defects against the other. The respective other then defects the next time around but immediately resumes cooperation thereafter. The discovery and explanation of this strategy provide the basis for prescription. Simulations of the Prisoner's Dilemma with modifications to the payoff matrix, the size of individuals' memory (i. e., how many iterations of the game they may recall), and the like eventually lead to the prescription of conditions under which TIT FOR TAT is likely to be the best strategy.

4.4 Limitations of Social Science Simulation

Simulation is a valuable methodology for scientific inquiry. Its purposes and potential benefits clearly speak for themselves (Section 4.3). However, simulation remains at the margin of social science research. Bruderer & Maiers (1997) identify four major problems why the social sciences reject simulation, whereas the natural sciences, for example, embrace simulation. First, poorly designed user interfaces restrict the use of simulations to a small community of scientists. Second, intricacies of computer code are too high an entry barrier for most researchers. Third, difficulties in replicating results rarely allow for the verification of scientific discoveries. And fourth, simulations are not being used as educational tools. In addition, there are at least four issues which likewise pose limitations to (the widespread adoption of) simulation in the social sciences. These are (1) simplicity versus complexity, (2) built-in results, (3) sensitivity to initial conditions, and (4) programming bugs.

Simplicity Versus Complexity. Real-world phenomena exhibit levels of complexity which simulation cannot fully account for (cf. Section 4.3 on discovery), no matter how elaborated it is in the end. Yet, simplicity and complexity are not necessarily two sides of a coin. It does not need a complicated model to generate complexity. Conway's Game of Life (Gardner, 1970) (moreover, cf. Section 4.3 on proof) illustrates that simple rules indeed produce complex system behavior. Another example is residential tipping (Schelling, 1978, pp. 155–166) where a single rule governs the dynamics of migration. The simulation model assumes that a family moves to a new area if more than a third of its immediate neighbors are somehow different (e. g., the neighbors are of another ethnicity). The simulation results show heavily segregated neighborhoods, even though everyone is initially placed at random, and everyone is somewhat tolerant. These and numerous other agent-based simulation models follow Axelrod's plea for the KISS principle

> which stands for the army slogan "keep it simple, stupid." [Its] point is that while the topic being investigated may be complicated, the assumptions underlying the agent-based model should be simple. The complexity of agent-based modeling should be in the simulated results, not in the assumptions of the model. (Axelrod, 1997, p. 26)

However, any simulation runs the risk of unwittingly omitting important system aspects. In other words, a simulation model may be just too simple. The most difficult question is thus, which aspects of the system of interest to include in the simulation model and which ones to neglect. The deductive development of the simulation model, its implementation in an experimental design, and the inductive analysis of the simulation results are necessary first steps (Section 4.1) to assess simplicity versus complexity. More specifically, whether or not the simulation results compare favorably to empirical time series data is a sign for the reliability of simplification claims (Jacobsen & Bronson, 1997).

Built-in Results. Discovery is one benefit simulation provides. But scientific research needs to be careful with the interpretation (i. e., explanation) of the discovered connections, principles, and relationships. Sometimes outcomes are unintentionally pre-programmed into a simulation. These built-in results are consequences of model design, rather than emerging from system dynamics. In order to avoid false inferences, thorough sensitivity analyses (Section 4.1) are required. One way to support the assumption of true emergence is to run a simulation in a variety of scenarios (i. e., for a range of parameter settings) and find a set of conditions for which the main results disappear.

Sensitivity to Initial Conditions. Most simulations are rather sensitive to initial conditions (Fung & Vemuri, 2003). That is to say, quantitative results largely depend on specified inputs. The obvious remedy to matters of this sort is to repeat a simulation several (hundred, if not thousand) times and average the results. Consider a public survey among companies from a particular regional area. The questionnaire is sent out to a large number of firms to guarantee a representative random sample, of course. Likewise, a simulation is iterated over and over again as if each individual run represents the answers of single company. Naturally, the survey answers as well as the simulation outcomes need to be analyzed statistically.

Simulation takes up time. This is a problem when computational time and power is not readily available. Today this matter seems somewhat irrelevant. Most desktop computers are sufficiently equipped to run fairly complicated simulations in a matter of minutes or hours. In addition, social science researchers usually have access to powerful workstations via university laboratories or other research facilities. Thus, sensitivity to initial conditions is manageable problem.

Programming Bugs. Simulations are implemented in computer code, generally written in a higher programming language, for example, C++ or Java. Some researchers develop their simulations from scratch, others use simulation frameworks such as NetLogo, SWARM, or Repast (for reviews and recommendations, cf. Railsback, Lytinen, & Jackson, 2006). Moreover, several commercial software packages exist which may be employed for simulation purposes (e. g., MATLAB). No matter what the choice of technique is, programming bugs are subject to all implementations of simulation models. (This stands in contrast to built-in results which are issues of modeling in the first place.) Apparent flaws such as spelling errors or incorrect mathematical signs and symbols are quickly removed by hand, if not automatically corrected by the programming editor. A more dangerous situation arises if the procedural programming itself is buggy (e. g., conditional statements are erroneous). These bugs may cause unexplainable simulation results (e. g., explosions in population growth). Even worse, simulation results may appear correct, when in fact they are nearly untraceable programming bugs. Carefully debugging the simulation code is often a burdensome, but nevertheless necessary, part of the implementation of simulation models.

5 Simulation of Organizational Structures and Dynamics

Computational simulation allows for the study of social systems beyond the restrictions of theoretical and empirical analysis. Still, it replaces neither one of these traditional research methods but rather complements them. Several studies in management science and organization theory employ computational simulation, indeed. One of the most prominent examples from management science is the *Garbage Can Model of Organizational Choice* by Cohen, March, & Olsen (1972). The simulation inquires into the decision-making process of organizations and yields predictions with respect to the effect of adversity. Other well-known computational simulations from organization theory are March's (1991) *Exploration and Exploitation in Organizational Learning* and Carley's (1992) *Organizational Learning and Personnel Turnover*, both of which revolve around issues of organizational learning, obviously. Moreover, they particularly well compare to social systems theory (Blaschke & Schoeneborn, 2006). The below model of autopoietic organization theory and the computational simulation thereof draw heavily on both March and Carley, therefore.

Computational organization theory (Lomi & Larsen, 2001; Prietula & Carley, 1994; Prietula, Carley, & Gasser, 1998) offers numerous other models and simulations which predict, prove, discover, explain, critique, and prescribe organizational issues such as culture (Canessa & Riolo, 2003; Carroll & Harrison, 1998; Harrison & Carroll, 1991, 2002), design (Ashworth & Carley, 2006; Carley & Lin, 1997; Ouksel & Vyhmeister, 2000; Zhu, Prietula, & Hsu, 1997), and trust (Prietula & Carley, 1999), just to name a few. These references indicate the vanguard of American research. Nevertheless, European research actively employes computational simulation, too, although its perspective is not so much with organizations in particular but more with social phenomena in general. Socionics (Malsch, 2001; Müller, Malsch, & Schulz-Schaeffer, 1998) is an emerging scientific discipline which presents itself at the border between sociology and distributed artificial intelligence (or, rather, informatics, hence the name). Its concern is with issues such as social order (Dittrich, Kron, & Banzhaf, 2003), social self-organization (Köhler, Langer, von Lüde, Moldt, Rölke, & Valk, 2007), and communication-oriented modeling (Malsch & Schlieder, 2004; Malsch, Schlieder, Kiefer, Lübcke, Perschke, Schmitt, & Stein, 2007). The latter model and simulation is most noteworthy for its description of large-scale communication events in terms of the inception and reception of messages, that is, communication without agents. It is considerably close to social systems theory yet falls short of defining organizations. As a step towards communication-centric organization theory, however, communication-oriented modeling is an invaluable substantiation of social systems theory and thus autopoietic organization theory.

The following model ties together social systems theory and autopoietic organization theory with respect to their understanding of social systems (organizations, networks of communication), psychic systems (individuals, organizational members), and the respective environments (Section 5.1). Both social and psychic systems are computational agents to begin with (cf. Brassel, Möhring, Schumacher, & Troitzsch, 1997) and come with the dynamics of knowledge, learning, and memory (Section 5.2). Note that these two chapters give few references to the literature except for those that add new perspectives or clarify matters. All appropriate groundings are laid out in Chapter 3 on organizations as social systems and referenced in the following only when needed. Section 5.3 reviews the findings from the computational simulation of organizational structures and dynamics. It reveals insights on the difference between organizational and individual knowledge, learning, and memory, highlights the effects of personnel turnover and layoff on the emergence of organizational knowledge, and finally sheds new light on an ongoing discord in theories of communities of practice.

5.1 Agent Types

Social systems use communication, psychic systems use consciousness as their particular mode of autopoietic reproduction. These operations constitute their boundaries to an environment and then the environment itself. In turn, the environment is everything and all social and psychic systems are not, including respective other systems (Subsection 3.1.1). With this works' primary interest in organizational dynamics, three types of agents are considered; these are (1) organizational environments, (2) psychic systems, and (3) social systems. The agent types are described in a very general sense, at first. Most of their dynamics are later introduced in Section 5.2.

Table 5.1: Organizational Environment

m	1	2	3	4	5	6	7	8	...	30
Environment	1	−1	1	1	1	1	1	1	...	−1

5.1.1 Organizational Environments

Agent-based simulations in the social sciences frequently model an environment as a point of reference to compare their agents to. For instance, March (1991, p. 75) defines "an external reality that is independent of beliefs about it. Reality is described as having m dimensions, each of which has a value of 1 or −1." Carley (1992, p. 25) suggests a very general task "involving elements of both pattern matching, and determining statistical relationships. The organization must determine which configuration of 1's and 0's in a binary word of length N goes with a yes or no answer." Other simulations install problem spaces (Cohen, March, & Olsen, 1972; Zhu, Prietula, & Hsu, 1997), warehouse tasks (Prietula & Carley, 1994, 1999), and the like as their environmental points of reference.

Following the first two examples, the model employs a binary vector of length m with which a network of communication constitutes its organizational environment. The default length of the vector is set at 30, the binary values are either 1 or −1, and the initial independent probability that any one dimension will have a value of 1 is 0.5 (cf. March, 1991). Table 5.1 exemplifies such a binary vector.

Note that the employment of this and other binary vectors (cf. Subsections 5.1.2 and 5.1.3) does not only follow the common practice of agent-based simulation but well reflects the binary codes of symbolic generalized communication media (Luhmann, 1984, p. 222 ff.), too. Symbolic generalized communication media are specific cognitive structures (Subsection 3.1.3) which enhance the probability of communication success (Baraldi, Corsi, & Esposito, 1997, p. 189 ff.). For example, law as a communication medium operates on the binary code of legal/illegal, politics on progressive/conservative, and science on true/false.

Say, the binary vector represents a task of m elements (Carley, 1992). An element with a value of 1 then reflects a certain quality of the task, while the same element with value of −1 reflects a respective other quality. The elements of the task are attributions (i. e., system/environment distinctions) of communication to the environment (Subsection 3.1.1), much like aspects of a guiding vision, mission statements to follow, or operations to perform. Just as March's reality and Carley's task, the environment facilitates information processing, too. If the task is to prepare for the cold outside, then one of its simplest elements is turning up (1) or down (−1) the heat in the house. Another element is whether or not (1 or −1) the preparation for the cold outside requires putting on a coat when leaving the house (Subsection 3.1.3). Likewise, symbolized generalized communication media operate on binary codes. Law argues the many aspects of a case to be either legal or illegal, politics dissects a dispute into progressive or conservative matters, and true or false reasonings define a scientific theory.

Alternatively, one may think of the binary vector as a set of business opportunities, market demands, or the like. In any case, the environment always comprises more possibilities than a system is able to selectively constitute as its environment (Subsection 3.1.1). It is therefore the necessarily more complex side of the system/environment distinction. The binary vector carries this complexity asymmetry to extremes. The environment is complex only in that the task of m elements is simple (cf. Carley, 1992, pp. 25–27, for a discussion of task complexity) (moreover, cf. Section 4.4 on the issue of complexity versus simplicity in social science simulations).

Whether the binary vector represents a task or anything else is a contextual issue. Its technical implementation is free of any such discussion. Agent-based simulations in the social sciences generally implement the environment as a grid of cells, patches, and the like (instead of many examples, cf. Klüver & Schmidt, 1999, for an introduction to the topology and metric of social systems). In like manner, the model maps the binary vector onto a grid of patches. The default grid size is set at 11×11 patches (see Figure 5.1). The grid itself wraps around horizontally and vertically (i. e., it is actually a torus) so that each one of the 121 patches has eight adjacent patches, no matter where it is located. Consider the white patch in the middle of the top row. It has one adjacent patch on its left, one on its right, three in the row below it, and three in the middle of the bottom row.

The grid of patches presents system/environment distinctions; therefore, it is everything and all communication is not. In addition, the grid of patches is host to n psychic systems (the default number of psychic systems is set at 50; cf. Subsection 5.1.2), whereby each patch may host only one psychic system at a time. The size of the grid of patches then correlates with the number of psychic systems in the organizational environment, for it may host no more than 121 psychic systems at a time. Nonetheless, it is a simulation parameter to begin with and may thus be modified according to, for instance, contextual issues.

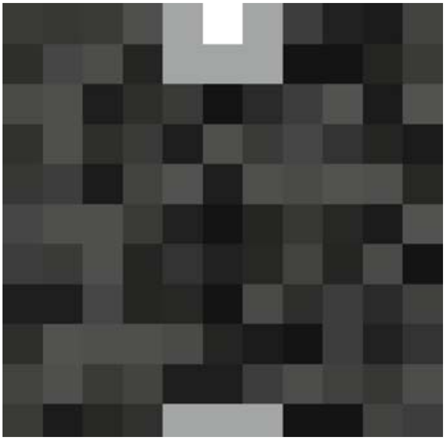

Figure 5.1: Organizational Environment

If communication constitutes a single task to operate on, all patches hold the same binary vector. This task is global, much like a strategic vision. However, communication may well constitute several local tasks. In this case, each patch holds a different binary vector. Limited subtasks, categorized problems, and the like are beyond the scope of the model and its subsequent simulation, although their implementation is rather simple, obviously.

5.1.2 Psychic Systems

Psychic systems are systems of consciousness. Their basic operational units are thoughts which are recursively produced and reproduced by a network of consciousness and which cannot exist outside such a network. A single thought is indecomposable for psychic systems, much like a single communication event is indecomposable for social systems (Subsection 3.1.3). However, communication comes about the synthesis of three selections, namely, information and utterance on part of the communication role of alter, and understanding or misunderstanding on part of the communication role of ego. Consciousness is likewise informed by selection, namely, conception.

Note that conception finds no immediate reference in social systems theory (and for that matter, in any other theory). Notwithstanding, it is an indispensable construct to have psychic systems operate in similar ways social systems do. Conception is consciousness' equivalent to communication's information and, to the extent that thoughts take the symbolic form of language, utterance (cf. Subsections 3.1.3 and 5.1.3). There is no understanding in consciousness, of course. Even a peculiarity of the mind such as an inner dialogue is anything but a communication with oneself. The mind simply cannot consciously communicate, and communication cannot think (Luhmann, 2002, p. 169).

The model keeps the terminology of social systems theory. It merely introduces conception in complement of consciousness and expectation. Other agent-based simulations employ their own language, too. A quick comparison is certainly worthwhile, if only for examplification reasons. March (1991, p. 74) considers expectations of psychic and social systems alike when he says that "beliefs about reality are held by each of n individuals in an organization and by an organizational code of received truth. For each of the m dimensions of reality, each belief has a value of 1, 0, or -1. This value may change over time." In translation, the beliefs are dedicated system/environment distinctions without immediate reference to reality (i. e., expectations; Subsection 3.2.1), each individual is a psychic system, and the organizational code is a social system. Carley, likewise, endows her agents with expectations. "As the DM [decision maker] encounters subproblems it builds up, for each class of subproblems, an expectation as to whether its decision when it sees a problem in that class is a 0 or a 1," she writes (Carley, 1992, p. 27). The concept of expectation is important to both March and Carley. It covers conception, consciousness, and expectation. Expectations change or build up unanimously with respect to reality or problems of a task. Hence, operations and observations of individuals or decision makers are one and the same.

In contrast to March's individuals and Carley's decision makers, psychic systems are operationally closed yet structurally coupled to social systems. In other words, psychic systems produce and reproduce consciousness yet observe the communication of social systems. Conception, consciousness, and expectation are separate but complementary system operations. The model then attributes each of n psychic systems with a binary vector of length m for conception and a ternary vector of the same length for consciousness and expectation, respectively. In line with March (1991, p. 75), the default number of psychic systems is set at 50. Figure 5.2 displays these 50 psychic systems (in the shape of a person) randomly distributed in the organizational environment.

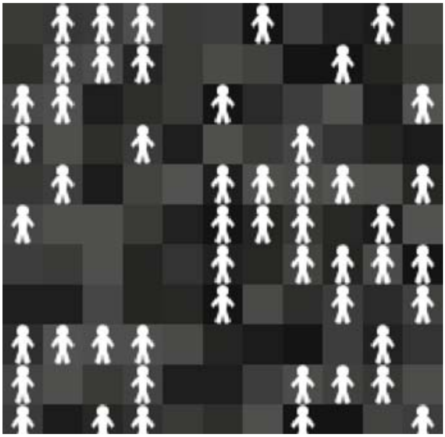

Figure 5.2: Organizational Environment including Psychic Systems

Conception. The first integral selection process of communication is information; it is the observant selection of system/environment distinctions with or without immediate references (i. e., consciousness or expectation; Subsections 3.1.3 and 3.2.1). In like manner, conception brings forth consciousness in that it selects observations either of communication or of expectation. The model employs a binary vector of length m to do so. (Subsection 5.1.3 clarifies this either/or selectivity of conception in analogy to information, utterance, and understanding.) Neither one of the n psychic systems observes the environment at large. This neglect rests safely with this work's primary interest in organizations; hence, the grid of patches is the organizational environment at large (cf. Subsection 5.1.1). For each of the m dimensions, the conception has a value of 1 (selection) or 0 (no selection). The initial independent probability that any one dimension will have a value of 1 is 0.5. This value may change over time (cf. Subsection 5.2.3 on remembering and forgetting).

Consciousness. Information, utterance, and understanding synthesize in communication (Subsection 3.1.3). Similarly, conception spawns consciousness. It selects observations of communication if only there is communication at hand; otherwise, it selects observations of expectation. This way psychic systems incorporate observations of their environment in their own operations, yet they do not need to construct their environment completely anew (in Europe, one expects the winter to be colder than the summer, and this is a fact to rely upon in the winter as well as in the summer; Subsection 3.2.1). A ternary vector of length m represents (the content of) consciousness. Each of the m dimensions has a value of 1, 0, or -1 (cf. March, 1991, p. 74). A value of 1 indicates a certain quality of consciousness with respect to the m elements of the task (i. e., the organizational environment; Subsection 5.1.1), while a value of -1 indicates a respective other quality. A value of 0 leaves any quality of consciousness unspecified. The reason for a value of 0 is either a lack of conception altogether or a lack of observable communication and expectation.

Expectation. Communication stabilizes in expectation (Subsection 3.1.3). The same holds true for consciousness. Expectation serves conception where there is no communication to refer to. It provides system/environment distinctions without immediate reference (Subsection 3.2.1). In turn, expectation is a generalized condensate of consciousness. It emerges, changes, and decays with conception (cf. Subsection 5.2.2 on learning and unlearning). A ternary vector of length m represents expectation. Similar to consciousness, a value of 1 indicates a certain quality of expectation with respect to the m elements of the environmental task, while a value of -1 indicates a respective other quality. If the value is 0, the quality of expectation is left unspecified. The initial independent probability that any one dimension will have a value of 1, 0, or -1 is equal for all values (cf. March, 1991, p. 74). These values may change over time as psychic systems (un)learn.

Conception, consciousness, and expectation are the very operations and observations of psychic systems. In a technical sense, these binary and ternary vectors characterize each one of the n psychic systems. Besides conception, consciousness, and expectation, psychic systems hold (tracking) variables for knowledge and competence, learning and unlearning, and remembering and forgetting, as well as vectors for reliability, coherence, and age. These variables and vectors are elaborated on in Section 5.2 on agent dynamics. Of lesser interest are additional variables necessary to the simulation itself (e. g., nodes' IDs, x and y coordinates on the grid of patches, color); they are not explicitly discussed.

5.1.3 Social Systems

Social systems are networks of communication which produce and reproduce communication events. They are interactions, organizations, or societies (see Figure 3.1). Four fundamental criteria define organizations, which are (1) the membership of individuals who participate in organizational communication, (2) the specific positions of these participants in the networks of communication, (3) the programs that determine the viability of organizational communication, and (4) the communication of decisions (Subsection 3.1.4). The model maps all of the defining criteria onto $n \times (n-1)$ sets of information, utterance, and understanding, communication, and expectation. Together, these sets constitute a social system, a network of communication, an organization. And although the primary interest of this work is with organizations in general, it considers a single organization in particular.

Information, Utterance, and (Mis)understanding. Communication "arises through a synthesis of three different selections, namely, selection of *information*, selection of *utterance* of this information, and a selective *understanding or misunderstanding* of this utterance and its information" (Luhmann, 1992, p. 252). These three different selections synthesize in a binary vector of length m with values of either 1 (selection) or 0 (no selection). The initial independent probability that any one dimension will have a value of 1 is 0.5 (again, this value may change over time; cf. Subsection 5.2.3 on remembering and forgetting). Information is the observant selection of system/environment distinctions with or without immediate reference (Subsections 3.1.3 and 3.2.1). That is to say, it selects observations of consciousness, if there is indeed consciousness to observe, or observations of expectation. Utterance is the subsequent selection of a form of language (speech, non-verbal cues, writing, printing, or other media) to express information (Subsections 3.1.3 and 3.2.3). Information and utterance give rise to the communication role of alter. In turn, the communication role of ego associates with the selective understanding or misunderstanding of uttered information (Subsection 3.1.3).

Communication. Communication comes about the synthesis of information, utterance, and understanding. In the model, it is a ternary vector of length m. Each of the m dimensions has a value of 1, 0, or -1 (cf. March, 1991, p. 74), very similar to consciousness (cf. Subsection 5.1.2), not the least because social and psychic systems are both of autopoietic nature (Subsection 3.1.2). Again, a value of 1 indicates a certain quality of communication with respect to the m elements of the environmental task (Subsection 5.1.1), while a value of -1 indicates a respective other quality.

Table 5.2: Synthesis of Communication

m	1	2	3	4	5	6	7	8	...	30
Expectation	0	0	1	0	1	0	0	1	...	0
Consciousness	1	0	1	−1	0	−1	1	−1	...	0
Inf., Utt., Und.	0	1	1	0	0	0	0	1	...	0
Communication	0	0	1	0	0	0	0	−1	...	0

If the value is 0, communication features no such quality. A value of 0 is due to either the lack of congruent information, utterance, and understanding or the lack of consciousness and expectation to observe. In reference to the last of the four fundamental criteria that define organizations, communication not only takes up one or the other quality that describes the elements of the task, but it furthermore bears (the topic, theme, content of) a decision on how to go about this task.

Expectation. Communication stabilizes in expectation. In turn, expectation is a generalized condensate of communication which endows social systems with redundancy (Subsection 3.1.3). Expectation emerges, changes, and decays with communication (cf. Subsection 5.2.2 on learning and unlearning). Once more, a ternary vector of length m represents expectation as a whole. For each of the m dimensions, a value of 1 indicates a certain quality of expectation, while a value of −1 indicates a respective other quality, and a value of 0 the lack thereof. All dimensions have an initial value of 0 (cf. March, 1991, p. 74), that is, they are unaffected by organizational learning.

Table 5.2 exemplifies the synthesis of communication through information, utterance, and understanding with respect to observations of consciousness and expectation. Consider the second dimension ($m = 2$). Although information, utterance, and understanding are congruent at a value of 1, there is neither consciousness nor expectation to fuel communication. Think of this as any open situation where problems are well apparent yet communication simply cannot attain to them. The third dimension ($m = 3$) displays only values of 1. Communication emerges from a selection of an observation of consciousness despite expectation at hand. This instance is subject to interpretation rather than an issue of simulation. It matters little to the simulation whether or not information, utterance, and understanding select an observation of expectation or an observation of consciousness; both observations have a value of 1, after all. (In similar vein, it matters little whether or not psychic systems conceive expectation or communication; cf. Subsection 5.1.2.) However, "information—is a difference which makes a difference" (Bateson, 1987, p. 459), and expected consciousness certainly never makes a difference. Luhmann explains,

> An information that is repeated is no longer information. It retains its meaning in the repetition but loses its value as information. One reads in the paper: the DM [*Deutschmark*] has risen in value. If one reads this a second time in another paper, this activity no longer has value as information (it no longer changes the state of one's own system), although structurally it presents the same selection. The information is not lost, although it disappears as an event. It has changed the state of the system, thereby leaving behind a structural effect, and the system then reacts to and with these changed structures. (Luhmann, 1984, p. 102, own translation)

Such information appears in dimension eight ($m = 8$). Information, utterance, and understanding synthesize communication with a value of -1 although expectation holds a value of 1. The conveyed information is a difference which makes a difference and may well change the cognitive structure of communication (cf. Subsection 5.2.2 on learning and unlearning).

At this point, note that the model uses understanding to conclude communication, although misunderstanding is by far the more common selection (Luhmann, 1981). Misunderstanding is the inverse selection of uttered information. Its technical implementation is rather simple: Any one of the m dimensions of information, utterance, and understanding takes on a value of -1 instead of 1. In order to keep the basic model as simple as possible (cf. Section 4.4), misunderstanding receives no further attention, however.

The binary and ternary vectors of information, utterance, and understanding, communication, and expectation substantiate the last of the four fundamental criteria that define organizations, that is, the communication of decisions. The other three criteria are undiscussed, so far. To that effect, the model describes the organization of interest in terms of $n \times (n - 1)$ binary vectors of length m for information, utterance, and understanding, and and equal number of ternary vectors of the same length for communication and expectation. Given the default number of psychic systems ($n = 50$) in the organizational environment (Subsection 5.1.2), a perfectly

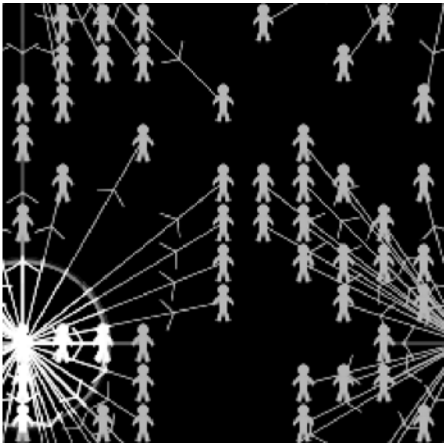

Figure 5.3: Structural Coupling Between Communication and Consciousness

connected network of communication totals 2,450 sets of these binary and ternary vectors. Here, each psychic system is structurally coupled to as many communication events of the social system as there are other psychic systems, whereas each communication event is structurally coupled to but two psychic systems. Figure 5.3 displays 49 communications at a particular point in time, each one in the shape of a link (arrow, edge, etc.). This shape resonates with the structural coupling of the communication roles of alter and ego (cf. Subsection 3.1.3). In contrast to sender/receiver models (e. g., Austin, 1971; Searle, 1992) and social network theory (Scott, 1991; Wasserman & Faust, 1999), however, it depicts neither the flow of messages nor the edges that connect nodes. Communication is an agent in its own right, and so is each and every link.

All of the displayed communication events of the social system are structurally coupled to one and the same psychic system, on the one hand. This psychic system assumes the communication role of alter. On the other hand, the communication events are structurally coupled to 49 other psychic systems. These psychic systems assume the communication role(s) of ego. The situation as such is that communication reaches more than one consciousness at a time (e. g., in lectures, performances, or presentations). However, the communication events are likely to be different among each other, despite the fact that their uttered information is the same. A lecture conveys uniform information, but its reception may be quite controversial, for instance. After all, there is only a single lecturer who addresses an entire audience of recipients.

Communication is directed, obviously. It attributes one end to the communication role of alter and the other end to the communication role of ego. This reflects the first two criteria that define organizations. Communication events localize (1) the membership of individuals and concurrently determine (2) the positions these individuals occupy in the network of communication. Now, a perfectly connected network leaves no doubt about the membership and positions of individuals or psychic systems, respectively. Every consciousness simply participates in communication with every other consciousness (i. e., every psychic systems links to every other psychic system). This is rarely the case, of course. It is safe to say that organizations are always structured in one way or another (last but not least, cf. Section 2.1). Some psychic systems share several links with others, some are sparsely connected in the network of communication. Indeed, at the default number of psychic systems ($n = 50$), a perfectly connected network of 2,450 communications cannot emerge in a single time period at all, for psychic systems cannot participate in communication in both the role of alter and ego simultaneously.

Nonetheless, the later simulation keeps track of each and every one of the sets of binary and ternary vectors. This stands in contrast to the visual display of links that reflects only the very (re)production of the respective communication events and therefore presents only the current topology of the network of communication. In other words, the $n \times (n-1)$ sets of binary and ternary vectors characterize the latent structure of the organization, while only their production and reproduction is salient as the organization as such.

The model limits the emergence of communication and thus the visible topology of the network of communication in three ways. The first limitation rests with the necessity of synthesized information, utterance, and understanding. Technically speaking, it is a matter of selection (or, rather, non-selection; i. e., all dimensions are 0) within the respective binary vector. The second limitation is due to the programmatic nature of the organizational structure. Subsection 5.2.2 elaborates on this latter limitation in more detail, particularly with respect to the third defining criterion of organizations (i. e., the programs that determine the viability of organizational communication). The third and last limitation on the emergence of communication succumbs to space and time. As to this matter, recall that social systems theory views communication not as a phenomenon but as a problem. Space and time are among the "problems and obstacles [that] have to be surmounted before communication can come about" (Luhmann, 1981, p. 123) (moreover, cf. Subsection 3.1.3).

In general, communication requires the co-presence of consciousness. The model implements this condition in terms of a spatial limitation on communication events. Only those psychic systems that are on adjacent patches from each other may participate in communication to begin with. Moreover, the simulation puts a time constraint on communication, too. While psychic systems in the communication role of alter may participate in more than one communication event at a time, psychic systems in the communication role of ego may only participate in a one such event. The reasoning behind this twofold limitation is simple. For example, in a situation where a lecturer addresses a room full of recipients, none of the recipients may simultaneously be in another room to listen to another lecture. To exemplify this matter, Figure 5.4 focuses on the same psychic system as Figure 5.3, though the psychic system now participates in communication with only one other psychic system one on the opposite side of the grid of patches (keep in mind that the grid wraps around horizontally as well as vertically). All other psychic systems still occupy the same patches they did in Figure 5.3. Some of them participate in communication in the role of alter (as does the psychic system in focus), some of them in the role of ego (e. g., the psychic system below the psychic system in focus), and some do not participate in communication at all (e. g., the psychic system in the middle of the third row).

The spatial and temporal limitations on structural coupling between communication and consciousness are somewhat artificial, of course. The use of media lifts these constraints, for the most part at least. For example, telephones and computers overcome spatial (via calls and chats) or temporal boundaries (via voice mail or e-mail). However, telephones and computers are prone to issues of media richness (Daft & Lengel, 1984, 1986). For now, the model remains as simple as possible and therefore leaves these particular issues out of the question.

Besides information, utterance, and understanding, communication, and expectation, the social system holds $n \times (n-1)$ (tracking) variables for knowledge and competence, learning and unlearning, and remembering and forgetting, as well as vectors for reliability, coherence, and age. Similar to psychic systems' variables and vectors, they are elaborated on in Section 5.2 on agent dynamics. Moreover, there are a number of additional variables necessary to the simulation itself (e. g., communication events' IDs, x and y coordinates on the grid of patches, color); they are of lesser interest and not explicitly discussed.

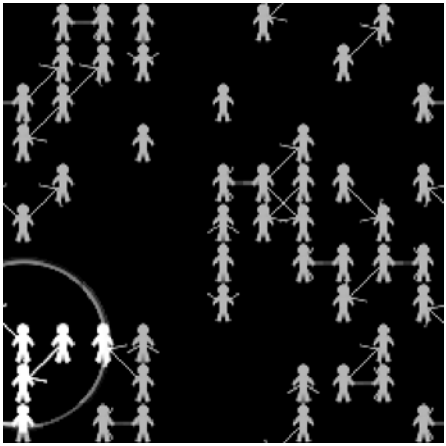

Figure 5.4: Spatial and Temporal Limitations on Structural Coupling

Lastly, a brief note on the terminology in use. The above singular terms communication, consciousness, and expectation refer to entire vectors, while the respective plural terms communications (i. e., communication events), thoughts, and expectations mark the dimensions of these vectors. Unfortunately, there is a linguistic fuzziness involved in the use of these terms. A network of communication with $n \times (n-1)$ single communications has all the more communication events, for example. The same holds true for the expectation(s) of a social system. Whether the plural of communication and expectation refers to entire vectors or the dimensions thereof reveals itself only in the context in that these terms are used.

5.2 Agent Dynamics

The previous section introduces organizational environments, psychic systems, and social systems as computational agents. Next, the dynamics of these agents are operationalized as already hinted by autopoietic organization theory (cf. Section 3.2). Knowledge and decision, learning and unlearning, and remembering and forgetting mark the constituting operations and observations of both psychic and social systems, then.

5.2.1 Knowledge and Decision

Knowledge is the cognitive structure of social and psychic systems; it accompanies all of communication and consciousness (Section 3.2.1). It is the structure with which social and psychic systems address disappointment-ready expectations at their environment, as Baecker (1999, p. 90) puts it. Unfortunately, there is no readily available measure of such a cognitive structure. March (1991, p. 75) suggests that "the proportion of reality that is correctly represented in the organizational code can be calculated for any period. This is the knowledge level of the code for that period." In like manner, Carley assesses organizational knowledge in terms of expectation-based decisions made by organizational members with respect to the problems of the task these decision makers face or, in her own words, the "knowledge of what pattern corresponds to which solution" (Carley, 1992, p. 25). In several of her later works, Carley employs similar measures to capture organizational performance (Carley & Lin, 1997), individual knowledge (Carley & Hill, 2001), shared knowledge between individuals (Carley & Krackhardt, 1996), and cultural homogeneity among individuals (Carley, 1995). Computational simulations within the realm of social systems theory address knowledge in one way or the other, too. For example, Duong & Grefenstette (2005) use Shannon's concept of mutual information (cf. Shannon & Weaver, 1949) to measure the amount of knowledge held in a society, and Barber, Blanchard, Buchinger, Cessac, & Streit (2006, 4.8) see the complementary knowledge of two agents as "the distance or overlap between two memories."

Apparently, the above examples of computational simulations parallel each other in their measures of knowledge. There is always a vector or matrix on behalf of an agent which compares to another vector or matrix on behalf of another agent or the environment, respectively. The proportion of the one vector or matrix correctly represented in the other vector or matrix hence reflects knowledge. All of these measures hinge on the particular definition of knowledge in use, of course. Alas, they are not directly applicable to autopoietic organization theory (cf. Subsections 2.3.4 and 3.2.1).

Knowledge condenses in reflexive expectations (Subsection 3.2.1). That is not to say that expectations are knowledge; after all, knowledge is but the cognitive structure of communication and consciousness. Consequently, the proportion of the environment that is correctly represented in expectation is not an adequate measure of knowledge, although this is well in line with March's (cf. 1991, p. 75) suggestion. Knowledge condenses in reflexive expectations for as long as these remain consistent with actual system/environment distinctions. Therefore, the cognitive structure of communication and consciousness discloses a value in just those communication events and conscious thoughts that do not disappoint and accordingly bear the chance to condense in (reflexive) expectations. A more suitable measure of knowledge is thus the proportion of the environment that is correctly represented in communication and consciousness (i. e., in effective decisions, so to speak; cf. Subsection 3.1.4). In technical terms, this measure of knowledge is best described by means of a Heaviside step function (Equation 5.1),

$$H(x) = \begin{cases} 0, & x \leq 0 \\ 1, & x > 0 \end{cases} , \tag{5.1}$$

whose value is 0 for a negative argument and 1 for a positive argument. Following the notation of the above Heaviside step function, Equation 5.2 denotes organizational knowledge, $OrgKnw(t)$, at time t,

$$OrgKnw(t) = \frac{1}{n \times (n-1)} \sum_{i=1}^{n \times (n-1)} \frac{1}{m} \sum_{j=1}^{m} H(Com_{i,j}(t) \times Env_{i,j}(t)), \tag{5.2}$$

where $Com_{i,j}(t)$ returns the value the ternary vector for communication i holds in dimension j, and $Env_{i,j}(t)$ returns the value the binary vector for the environment of communication i holds in dimension j. Note that although the index variable i runs from 1 to $n \times (n-1)$, there are at the utmost $n-1$ communications, just as there at the utmost $n-1$ psychic systems in the communication role of ego to busy themselves with understanding at time t. The index variable j runs from 1 to m, then.

Similarly, the model assesses (average) individual knowledge, $IndKnw(t)$ (Equation 5.3). The only notable differences to organizational knowledge are that $Com_{i,j}(t)$ is replaced with $Con_{i,j}(t)$ which returns the value the ternary vector for consciousness i holds in the dimension j, and that the index variable i runs from 1 to n,

$$IndKnw(t) = \frac{1}{n} \sum_{i=1}^{n} \frac{1}{m} \sum_{j=1}^{m} H\left(Con_{i,j}(t) \times Env_{i,j}(t)\right). \tag{5.3}$$

The equation only considers the knowledge (re)produced by psychic systems in the communication role of ego, because only those psychic systems (re)produce consciousness at time t. The consciousness of psychic systems in the communication role of alter is of informational relevance to the social system (cf. Subsection 5.1.3), still, but (re)produced at an earlier time (cf. Section 5.3). Hence, individual knowledge, $IndKnw(t)$, is somewhat of a misnomer. Equation 5.3 in fact denotes the knowledge of psychic systems (i. e., individuals) as if the social system (i. e., the organization) is to judge it, although the social system can never do so (Subsection 3.1.2). The model and then the simulation use organizational and individual knowledge to track the effects of learning and unlearning (Subsections 3.2.2 and 5.2.2), as well as remembering and forgetting (Subsections 3.2.3 and 5.2.3).

5.2.2 Learning and Unlearning

Learning and unlearning both refer to the partial change of the cognitive structure (i. e., knowledge) of communication and consciousness. In the light of this definition, consider the two most important conclusions from Subsection 3.2.2. First, each and every autopoietic episode of social and psychic systems features the possibility of learning or unlearning; second, learning and unlearning adhere to intrasystem problems (tasks, programs, etc.) which issue from (observed) environmental irritations (disturbances, perturbations, stimulations, etc.).

The cognitive structure of communication and consciousness condenses in reflexive expectations. Any partial change of this cognitive structure may bring about a likewise partial change in the ternary vectors for expectation, and vice versa. As social and psychic systems incorporate observations of each other in their respective operations, their cognitive structure may be said to change in just that they select new or different system/environment distinctions. However, this instance of change associates neither with learning nor with unlearning; it is simply a matter of observation, not operation. Nonetheless, new or different system/environment distinctions certainly present the possibility to learn or unlearn, and thus it may evoke the partial change of the cognitive structure of communication and consciousness from within social and psychic systems. Table 5.3 exemplifies the possibility of organizational (un)learning.

Consider the first ($m = 1$) and the seventh ($m = 7$) dimension. Here, the values of the ternary vector for expectation may change from 0 to 1. That is to say, it is possible that on both dimensions the lack of a particular quality of expectation (indicated by a value of 0) is remedied by a likewise particular quality of communication (indicated by a value of 1). In other words, (the cognitive structure of) communication may condense in expectation.

Table 5.3: Possibility of Organizational Learning and Unlearning

m	1	2	3	4	5	6	7	8	...	30
Expectation	0	0	1	0	1	0	0	1	...	0
Communication	1	0	1	−1	0	−1	1	−1	...	0

Dimensions four ($m = 4$) and six ($m = 6$) highlight similar possibilities of change, in this case a change of values from 0 to −1.

At this point, note that the possibility of organizational learning is not the probability of organizational learning. The probability with which a partial change of the cognitive structure of communication (and, for that matter, consciousness) may or may not take place coincides with intrasystem problems (tasks, programs, etc.); this is clarified below. For now, learning is as much the unobservable transition from one system state to another (e. g., when the values of the ternary vector for expectation change from 0 to 1 or −1), as it is the observable difference between system states (e. g., between values of 1 or −1 and 0, where only the ternary vector for expectation accounts for the difference) (cf. Subsection 3.2.2). Unlearning is thus unobservable transition and observable difference, too. Consider the value of communication in dimension eight ($m = 8$). The ternary vector for expectation already holds a value of 1 which may change to a value of −1. Whether the change of the cognitive structure of communication and consciousness is a case of learning or unlearning reflects in the observable difference between system states (i. e., the values of the ternary vector for expectation before and after the change), as well as the observable difference between these very system states with respect to their environment. For example, if the quality of expectation changes from a value of 1 to a value of −1, and if the corresponding element of the task that communication aims at (i. e., the environment) holds a value of likewise −1, then this change marks an instance of learning; conversely, if the quality of expectation changes form 1 to −1 yet the environment holds a value of 1, then this change indicates a case of unlearning. Learning develops knowledge, whereas unlearning abandons it (cf. the previous subsection). The remaining contemplations address the change of the cognitive structure of communication and consciousness as learning in general (i. e., without any qualitative connotation; cf. Subsection 3.2.2) and as unlearning only in particular.

The possibility of organizational and individual learning is free of any adaptive need. Neither knowledge nor the lack thereof constitutes a case of learning all by itself. The cognitive structure of communication and consciousness simply gives rise to the chance of change. The probability of organizational and individual learning, however, rests with the causal attribution of just the cognitive structure of communication and consciousness to environmental irritations (disturbances, perturbations, stimulations, etc.). This causal attribution, in turn, yields problems (tasks, programs, etc.), whereby problems are but residual relations between knowledge and the lack thereof; they may only be solved, if at all, by changes in this relation (Luhmann, 1984, p. 489), that is, learning. The probability of organizational learning specifically roots in the programs that ameliorate the viability of organizational communication (i.e, the third of the four criteria that define organizations; cf. Subsection 3.1.4). The causal attribution of the programmatic nature of the communication of decisions to the environment that these decisions aim at (here, the elements of the task; cf. Subsection 5.1.1) "is form and condition for all adaptation" (Luhmann, 1984, p. 478, own translation) (moreover, cf. Subsection 3.1.1). Technically speaking, for each dimension of the ternary vector for (organizational) expectation, organizational learning occurs with a probability, $pOrgChg_{i,j}$, with which any quality of expectation changes to that of communication. Individual learning occurs with a similar probability, $pIndChg_{i,j}$, with which any quality of (individual) expectation changes to that of consciousness.

The computational simulations of March (1991) and Carley (1992) are inspiring in terms of operationalizing the probability of learning, too, despite the fact that their definitions and consequent implications of learning do not fit this work. March (1991, p. 74) has individual beliefs change to that of the organizational code with probability $p1$, while "at the same time, the organizational code adapts to the beliefs of those individuals whose beliefs correspond with reality on more dimensions than does the code" with probability $p2$. Both these probabilities are global static parameters of the computational simulation, however. March then draws critique from an agent-based perspective, wherein learning probabilities are dynamics of the agents, not the simulation these are part of. Carley avoids any such critique in that she has decision makers build expectations on the basis of local conditional probabilities. Specifically, a "DM's [decision maker's] expectation that its answer is a 0 (1) is defined as the proportion of times in this DM's experience that, given [a] class of subproblems, the true decision was a 0 (1)" (Carley, 1992, p. 27). In the terminology of autopoietic systems theory, expectations change as soon as they are disappointed more times than not. Thus, Carley's computational simulation must bear the critique that learning is deterministic, at least from an agent-based perspective; learning simply depends on (the count of) observations of system/environment distinctions.

Neither March nor Carley's computational simulation meets the needs of autopoietic systems theory right away. Together with hints from Subsection 3.2.2 on the role of inert cognitive structures in (organizational) learning, they point in the right direction, nonetheless. First of all, a brief account of inertia and change is necessary. Hannan and Freeman's seminal article on *Structural Inertia and Organizational Change* (1984) takes the perspective of population ecology on organizations (Carroll & Hannan, 2000a; Hannan & Freeman, 1977, 1989), yet it receives a considerable amount of attention from all of management science and organization theory (e. g., Feldman & Pentland, 2003; Kelly & Amburgey, 1991; Weick & Quinn, 1999). Hannan & Freeman (1984, p. 151) define structural inertia and learning in a dynamic context, whereby "inertia, like fitness, refers to a correspondence between the behavioral capabilities of a class of organizations and their environments." In particular, they consider the concept of structural inertia in the light of organizational age, size, and experience, whereupon they derive assumptions as to what extent organizations are capable of change. Indeed, inertia is often enough the unintended consequence of successful performance (cf. Miller, 1993, 1994).

Following Hannan and Freeman, Larsen and Lomi (1999, 2002) offer a compelling (computational) representation of organizational change (for an alternative representation, cf. Sastry, 1997). In their system dynamics computational simulation, they operationalize structural inertia, pressure for change, and organizational reliability, all of which favorably compare to concepts of autopoietic organization theory.

> As inertia increases, the threshold for change also increases because the organization becomes more resistant to change. Pressure for change cumulates over time as the actual level of performance diverges from the expected level of performance expressed in terms of reliability. (Larsen & Lomi, 2002, p. 280)

The key aspect with respect to the organizational and individual probabilities of learning, $pOrgChg_{i,j}(t)$ and $pIndChg_{i,j}(t)$, is reliability. In this respect, recall that social and psychic systems comprise two additional vectors, namely, one for age and another one for reliability (Subsections 5.1.2 and 5.1.3). Age presents itself as a vector of length m with an initial value of 2 in all dimensions (the choice of a value of 2 is elaborated on below). It furthermore accounts for the number of times that the cognitive structure of communication and consciousness emerges with a particular quality (i. e., a value of either 1 or −1) in any one dimension. Equation 5.4 specifies this count for organizational age,

$$OrgAge_{i,j}(t+1) = Age_{i,j}(t) + \left|Com_{i,j}(t)\right|, \tag{5.4}$$

where $OrgAge_{i,j}(t)$ returns the value the vector for age i holds in the dimension j, and $Com_{i,j}(t)$ returns the value the ternary vector for communication i holds in the same dimension ($i = 1, \ldots, n \times (n-1); j = 1, \ldots, m$).

In like manner, the model assesses the age for the cognitive structure of consciousness. The only difference is that it replaces $Com_{i,j}(t)$ by $Con_{i,j}(t)$ which returns the value the vector for consciousness i holds in the dimension j ($i = 1, \ldots, n$, of course; cf. the previous subsection). The vector for reliability (m dimensions, all of which hold an initial value of 1) accounts for the number of times that communication and consciousness prove reliable with respect to the environment. In other words, each time communication or consciousness emerges with a quality which matches the quality of the corresponding element of the environmental task, reliability increases by a value of 1 (note the similarity to Carley, 1992). Equation 5.5 specifies this increase of organizational reliability,

$$OrgRlb_{i,j}(t+1) = OrgRlb_{i,j}(t) + H\left(Com_{i,j}(t) \times Env_{i,j}(t)\right), \tag{5.5}$$

where $OrgRlb_{i,j}(t)$, $Com_{i,j}(t)$, and $Env_{i,j}(t)$ return the values the vectors for reliability i, communication i, and environment i hold in the dimension j at time t ($i = 1, \ldots, n \times (n-1); j = 1, \ldots, m$). Again, individual reliability is assessed just as well, only with $Com_{i,j}(t)$ replaced by $Con_{i,j}(t)$ which returns the value the vector for consciousness i holds in the dimension j ($i = 1, \ldots, n; j = 1, \ldots, m$).

Larsen and Lomi (2002, p. 280 f.) include several other aspects of Hannan and Freeman's discussion in their computational simulation, for example, expected reliability, variability as an inverse of reliability, and an exogenous baseline variable thereof. These operationalizations further complicate matters, however. Already the relation between age and reliability credits pressure for change. The less reliable communication and consciousness become over time, the more social and psychic systems pressure themselves to change or, in other words, the more organizations and individuals are likely to learn. Conversely, the more reliable communication and consciousness become over time, the less likely is a partial change in the cognitive structure of organizations and individuals. Equation 5.6 denotes the probability of organizational (un)learning, $pOrgChg_{i,j}(t)$, of communication i in the dimension j at time t,

$$pOrgChg_{i,j}(t) = 1 - \frac{OrgRlb_{i,j}(t)}{OrgAge_{i,j}(t)}, \tag{5.6}$$

where $OrgRlb_{i,j}(t)$ returns the value the vector for reliability i holds in the dimension j, and $OrgAge_{i,j}(t)$ returns the value the vector for age i holds in the same dimension ($i = 1, \ldots, n \times (n-1); j = 1, \ldots, m$). Accordingly, the initial probability of organizational learning and unlearning is 0.5 since the vector for reliability holds a value of 1 and the vector of age a value of 2 in all dimensions.

The model furthermore assesses the probability of individual learning, $pIndChg_{i,j}(t)$, though the actual equation is omitted (the only difference to Equation 5.6 is that the index variable i now runs from 1 to n). Note that the probability of individual learning is as much a misnomer as is the measure of individual knowledge (cf. Subsection 5.2.1); it is a mere assumption of how psychic systems learn if they are to face to environment of the social system they participate in. Again, this simplification is a tribute to the model's focus on organizations.

5.2.3 Remembering and Forgetting

If knowledge is the cognitive structure of communication and consciousness, and if learning is the partial change thereof, then memory is the connectivity of this cognitive structure (Subsection 3.2.3). In each and every autopoietic episode of social and psychic systems, memory serves the double function of remembering and forgetting, of preserving and interrupting the cognitive structure of communication and consciousness. Autopoietic organization theory departs from other definitions of memory (e. g., memory in terms of a repository; again, cf. Subsection 3.2.3). Indeed, the above leading examples of computational simulations (i. e., Carley, 1992; March, 1991) well define knowledge and learning, yet they do so without any (explicit) consideration of memory (Blaschke & Schoeneborn, 2006). Computational simulations of social systems theory (e. g., Kron, 2002) offer little to no information about operationalizations of memory. For the most part, these simulations are not concerned with (organizational) knowledge, learning, and memory at all. A notable exception is Dittrich, Kron, & Banzhaf's (2003) article on the *Scalability of Social Order*. "Our agents possess memory in order to store observed events. Stored observations are subsequently used to predict future events," they write (Dittrich, Kron, & Banzhaf, 2003, 2.7). Moreover, they note

> that forgetting is an important feature of the memory. Only if agents forget events, they free capacity for new situations. If they would store everything, the capacity of information processing would run down quickly or the simulation experiments would require unproportional computational resources. So, memorized objects emerge by the repression of forgetting. One can say that the memory in general connects activities. (Dittrich, Kron, & Banzhaf, 2003, 2.8)

Apparently, their definition of memory is well in line with autopoietic organization theory. Their subsequent operationalization of memory, however, simply stores events in a finite matrix, whereby forgetting acknowledges that events long passed are counted less than recent events. Dittrich, Kron, and Banzhaf then specify a forgetting rate (much like March specifies probabilities of organizational and individual learning; cf. Subsection 5.2.2) at which events are removed from the memory matrix altogether. In the end, memory is but a repository of observed events.

In autopoietic organization theory, memory is not a repository (cf. Subsection 3.2.3 on the difference between Gedächtnis and Speicher). Memory accompanies each and every autopoietic episode of social and psychic systems, in many ways similar to learning and unlearning. There is one crucial difference, though. Social and psychic systems are never without memory (apart from an unlikely state of total amnesia), whereas learning and unlearning are just not possible all of the time (e. g., if there is no communication or consciousness to observe; cf. the second dimension ($m = 2$) in Table 5.3). In other words, remembering and forgetting come about a particular probability, yet memory is always certain; learning and unlearning come about a likewise particular probability (cf. the previous subsection), yet the partial change of the cognitive structure of communication and consciousness reflects an instantaneous possibility. The probability that memory remembers and forgets the past roots in the coherence of this cognitive structure (Subsection 3.2.3).

Coherence is much like reliability. It sustains the connectivity of the cognitive structure of communication and consciousness. In this respect, recall that social and psychic systems comprise a vector for coherence (cf. Subsections 5.1.3 and 5.1.2, respectively). This vector (again, m dimensions, all of which are initially 1) accounts for the number of times that communication and consciousness emerge with a quality which matches the quality of expectation. Equation 5.7 denotes this increase of organizational coherence by a value of 1 in the dimension j,

$$OrgCoh_{i,j}(t+1) = OrgCoh_{i,j}(t) + H\left(Com_{i,j}(t) \times Env_{i,j}(t)\right), \qquad (5.7)$$

with $OrgCoh_{i,j}(t)$, $Exp_{i,j}(t)$, and $Com_{i,j}(t)$ returning the values the vectors for coherence i, expectation i, and communication i hold in the dimension j at time t ($i = 1, \ldots, n \times (n-1)$; $j = 1, \ldots, m$). Of course, the model assesses individual coherence, too; it simply substitutes $Com_{i,j}(t)$ by $Con_{i,j}(t)$ which returns the values the vector for consciousness i holds in the dimension j ($i = 1, \ldots, n$; $j = 1, \ldots, m$).

The previous subsection establishes a firm relation between age and reliability which implies a particular probability of a partial change of the cognitive structure of communication and consciousness. The relation between age and coherence then yields a likewise probability of either remembering or forgetting. Equation 5.8 specifies the probability of organizational remembering,

$$pOrgRmb_{i,j}(t) = 1 - \frac{OrgCoh_{i,j}(t)}{OrgAge_{i,j}(t)}. \qquad (5.8)$$

As always, $OrgCoh_{i,j}(t)$ and $OrgAge_{i,j}(t)$ return the value the vectors for coherence i and age i hold in the dimension j, and individual remembering and forgetting, $pIndRmb_{i,j}(t)$, requires but an index variable i which runs from 1 to n_{ego}. Following the above equation, organizational forgetting, $pOrgFgt_{i,j}(t)$, is but the inverse of organizational remembering, that is, $1 - pOrgRmb_{i,j}(t)$, just as well as individual forgetting, $pIndFgt_{i,j}(t)$, is but the inverse of individual remembering, that is, $1 - pIndRmb_{i,j}(t)$ (cf. Blaschke & Schoeneborn, 2006). After all, for whatever is remembered is not forgotten, and whatever is not remembered is forgotten (cf. Subsection 3.2.3). The initial probability of both remembering and forgetting is accordingly 0.5 (again, coherence with all values of 1 over age with all values of 2).

The consequent interpretation of the probability that organizational and individual memory operates on is straight foward. The less coherent expectation becomes over time, the more social and psychic systems are likely to forget (i. e., to interrupt the connectivity of communication and consciousness). Conversely, the more coherent expectation becomes over time, the less likely is forgetting (i. e., an interruption of this connectivity or, the other way around, the more likely social and psychic systems are to remember). For example, one expects January to be colder than July, and this generally holds true for all of Europe. In Australia, however, a cold January quickly proves wrong, and over time, memory ensures that this cold January is forgotten altogether.

In technical terms, organizational memory preserves communication by maintaining or developing the selection of information, selection of utterance of this information, and selective understanding of this utterance and its information (Subsections 3.1.3 and 3.2.3) at probability $pOrgRmb_{i,j}(t)$. Remembering thus maintains a value of 1 (selection) where the binary vector for information, utterance, and understanding already holds such a value, or it develops a value of 1 (selection) where a value of 0 (no selection) is present. If no remembering takes place, memory interrupts communication instead. Forgetting thus abandons a value of 1 in favor of a value of 0 or keeps an already existing value of 0. Individual memory operates in like manner, of course. It preserves or interrupts consciousness by maintaining, developing, or abandoning values in any dimension of the binary vector for conception. The cognitive structure of communication and consciousness therefore reactivates (remembers) or deactivates (forgets) its connectivity (cf. Luhmann, 1996, p. 314, in particular) according to the probability with which remembering or forgetting occurs.

On a final note, memory does not remember or forget expectation in the sense that expectation itself changes. A change of the cognitive structure of communication and consciousness comes about learning or unlearning only. Rather, memory preserves or interrupts the way communication and consciousness (re)produce based on expectation. Remembering is social and psychic systems' mode of connecting communication and consciousness to something familiar, whereas forgetting is their mode of connecting to something else or, indeed, nothing at all.

5.3 Simulation Findings

Computational simulation may be developed from scratch in a programming language such as C++, Java, or the like. This is a cumbersome procedure, however. Data handling, user interface design, and other issues require attention, too, which leaves all the less time for developing the simulation itself. Nowadays, most research relies on simulation frameworks which usually offer a comprehensive development environment with a set of ready-made object classes and a powerful application programming interface (cf. Railsback, Lytinen, & Jackson, 2006, for a review of simulation frameworks).

The computational simulation of organizational structures and dynamics is implemented in such a simulation framework, namely, NetLogo (Wilensky, 1999). NetLogo is free of charge, available for all major operating systems, and comes with an extensive documentation. It is particularly well suited for agent-based simulation and therefore allows for the exploration of the connection between the micro-level behavior of agents (e. g., psychic and social systems) and the macro-level patterns that emerge from the interaction of agents (e. g., organizational learning).

The basic simulation borrows parameter settings from the computational simulations of March (1991) and Carley (1992), mostly. The number of psychic systems (n) is set at 50, whereby the social system (i. e., the network of communication) features a maximum of 49 communication events at a time and 2,450 such events overall (Subsections 5.1.2 and 5.1.3). The length of the binary and ternary vectors for communication, consciousness, expectation, information, utterance, and understanding, and conception (m) is set at 30. The simulation runs for 2,500 time periods (t), each of which may be thought of as a decision cycle (cf. Carley, 1992). "The quantitative levels of the results and the magnitude of the stochastic fluctuations reported depend on these specifications, but the qualitative results are insensitive to values of m and n," March (1991, p. 75) writes. To average these stochastic fluctuations, the simulation is repeated 100 times from different initial conditions (cf. Fung & Vemuri, 2003, for a discussion of the significance of initial conditions).

At each time period, psychic systems on adjacent patches from each other participate in communication. The communication role(s) of alter and ego are determined at random. Technically speaking, communication emerges from a selection of an observation of consciousness in the communication role of alter or expectation, if there is no consciousness to refer to, and a concluding understanding on part of the communication role of ego (Subsection 5.1.3). Consciousness in the communication role of ego subsequently emerges from a selection of an observation of this communication or expectation, if there is no communication to refer to (Subsection 5.1.2). Note that the recursivity of social and psychic systems yields a causality dilemma, namely, the issue of which comes first, communication or consciousness. The simulation solves this dilemma by discretizing the emergence of communication and consciousness in terms of time spells (cf. Carroll & Hannan, 2000a, pp. 141–143, for an introduction to spell splitting). Figure 5.5 exemplifies the spell splitting of events in the simulation.

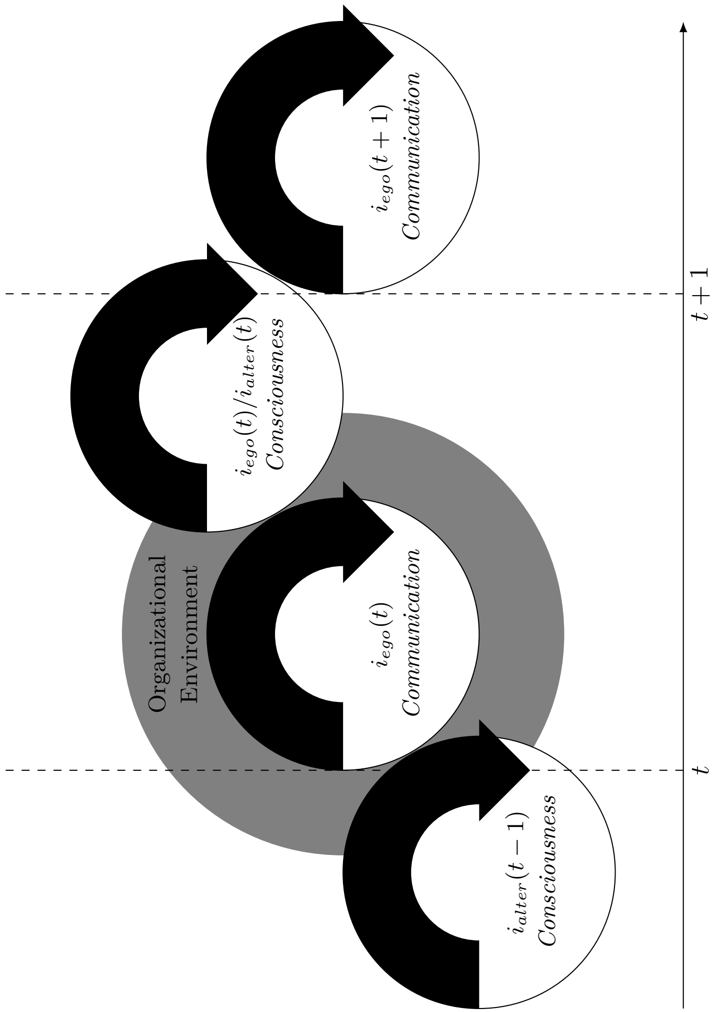

Figure 5.5: Spell Splitting in Simulation

At time t, communication emerges from a selection of information, a selection of utterance of that information on part of the communication role of alter, $i_{alter}(t-1)$, and a selection of understanding on part of the communication role of ego, $i_{ego}(t)$. Consciousness on part of ego, $i_{ego}(t)$, then emerges from a selection of conception of communication, $i_{ego}(t)$, too. At time $t+1$, communication, $i_{ego}(t+1)$ emerges from information and utterance on part of alter, $i_{alter}(t)$, who is but ego to the previous communication.

At the end of each time spell, psychic systems furthermore move around the grid of patches at will. Their movement is guided by a single, simple rule: Psychic systems may only move onto unoccupied adjacent patches. That is to say, each one of the n psychic systems moves onto a randomly determined, unoccupied adjacent patch; if all adjacent patches are occupied, the psychic system stays put. The order of movement is likewise determined at random. Albeit simple, the movement of psychic systems around the grid of patches introduces complexity (i. e., environmental dynamics) to the organization.

In the following, the findings from the computational simulation of autopoietic organization theory are presented. The perfectly connected network of communication marks the baseline organization, followed by an inquiry into the emergence of knowledge, learning, and memory in other organizational structures (i. e., less than perfectly connected or, better, loosely coupled networks). Personnel turnover and layoff then introduce further dynamics into the simulation. Finally, communities of practice are put to question. All findings are discussed in brief, though the appendix lists detailed descriptive statistics and records of two-tailed t-test. A ready-to-run Java applet and the source code of the simulation are available from the website accompanying this work (http://www.blaschke.biz).

5.3.1 Knowledge, Learning, and Memory of Social and Psychic Systems

Knowledge, learning, and memory accompany communication and consciousness, and in the simulation they do just in this order. That is to say, with communication and consciousness comes the cognitive structure that the above measure aims at (Subsection 5.2.1), the partial change thereof (Subsection 5.2.2), and its connectivity to further communication and consciousness (Subsection 5.2.3). Learning and unlearning, remembering and forgetting thus take effect only in the recursive production and reproduction of communication and consciousness. In technical terms, communication may already change (the connectivity of) its cognitive structure in foresight of what is to come, while consciousness still observes the genuine communication at the start of the time period, whereupon it may change (the

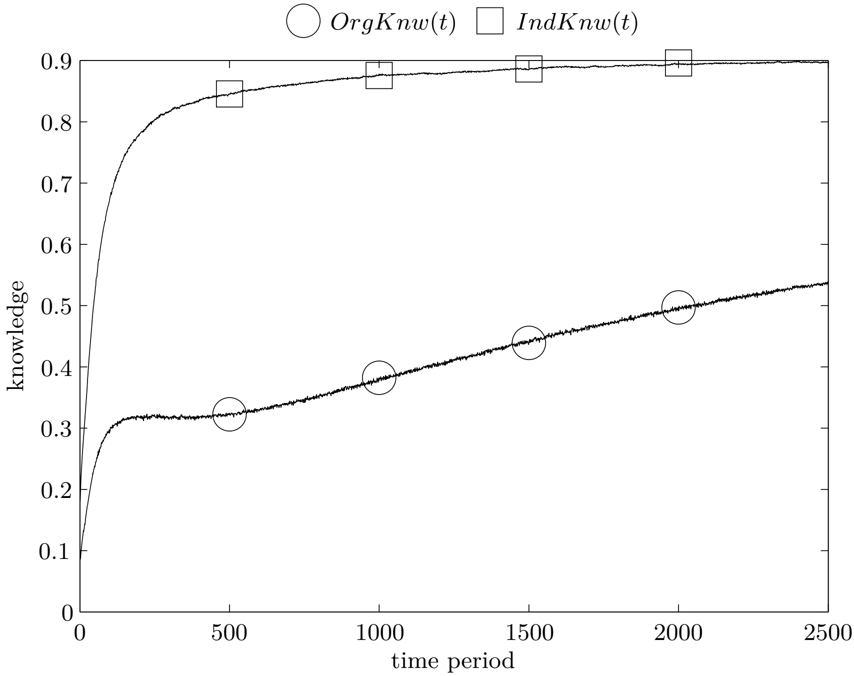

Figure 5.6: Organizational and Individual Knowledge

connectivity of) its own cognitive structure. The following results reflect the knowledge (re)produced by communication, $OrgKnw(t)$, and consciousness, $IndKnw(t)$, at any given time period, t (see Figure 5.6).

The first 500 time periods see an exponential growth of both organizational and individual knowledge. While the organization continues its steady acquisition of knowledge, individual knowledge quickly reaches a ceiling. This difference accounts for the fact that the consciousness of the 50 psychic systems produces and reproduces itself in more frequent manner than do the 2,450 communication events of the social system. However, organizational and individual knowledge eventually converge, whereby all communication and consciousness share the same, yet not necessarily correct, expectation. The results are relationally equivalent (Axelrod, 1997) to those of March (1991), Carley (1992), and others (e. g., Mezias & Glynn, 1993; Ouksel & Vyhmeister, 2000; Vriend, 2000), particularly individual knowledge which other research refers to as organizational knowledge.

Besides knowledge, learning and memory are of further interest to the simulation. The three concepts are defined in terms of each other, after all. Organizational learning is the change of the cognitive structure of communication, whereas individual learning is the change of the cognitive structure of consciousness (Subsection 3.2.2). Therefore, learning is best described by a rate at which social and psychic systems change their expectation over time (Subsection 5.2.2). For example, an organizational learning rate of 0.1 indicates a ten-percent change of the cognitive structure of communication. If the length of the vector for expectation (m) is set at 30, then learning brings about a change of values in three dimensions, that is, a change from a value of 1 to -1, a value -1 to 1, or a value of 0 to 1 or -1 (Subsection 5.2.2, in particular Table 5.3). Recall that the initial probability of organizational (un)learning, $pOrgChg_{i,j}(t)$, is 0.5 (the vector for reliability comes with a value of 1 in all dimensions against which the vector for age holds a value of 2; Subsection 5.2.2). Notwithstanding, the (overall) rate of organizational (un)learning, $pOrgChg(t)$, depends on both the probability and the possibility of organizational learning; therefore, it is likely to be less than the probability or the possibility thereof. The same holds true for the consciousness of psychic systems, of course. The change of the cognitive structure of communication and consciousness may be further characterized by a change of expectation to a value which correctly represents the environment (learning) or just the other way around (unlearning). With a more general interest in change, however, the below results indicate both learning and unlearning in one.

In Figure 5.7, organizational learning steadily declines over the 2,500 simulation periods. Conversely, individual learning quickly levels off within the first 500 time periods. This reflects the steady acquisition of knowledge by the social system as opposed to the exponential growth of individual knowledge. The explanation is analogous, then. It takes more time for the 2,450 communication events to emerge and reemerge than for the 50 psychic systems to produce and reproduce consciousness.

Following the above discussion of learning and unlearning, memory is best described by a rate at which social and psychic systems alter the connectivity of communication and consciousness over time, too. The initial probability of organizational remembering, $pOrgRmb_{i,j}(t)$, is 0.5 (at the beginning of the simulation, the vector for coherence features a value of 1 in all dimensions against which the vector for age holds a value of 2; Subsection 5.2.3). The initial probability of forgetting, $pOrgFgt_{i,j}(t)$, is 0.5, too (Subsection 5.2.3, once more). Since memory accompanies all of communication and consciousness, the probability of organizational remembering

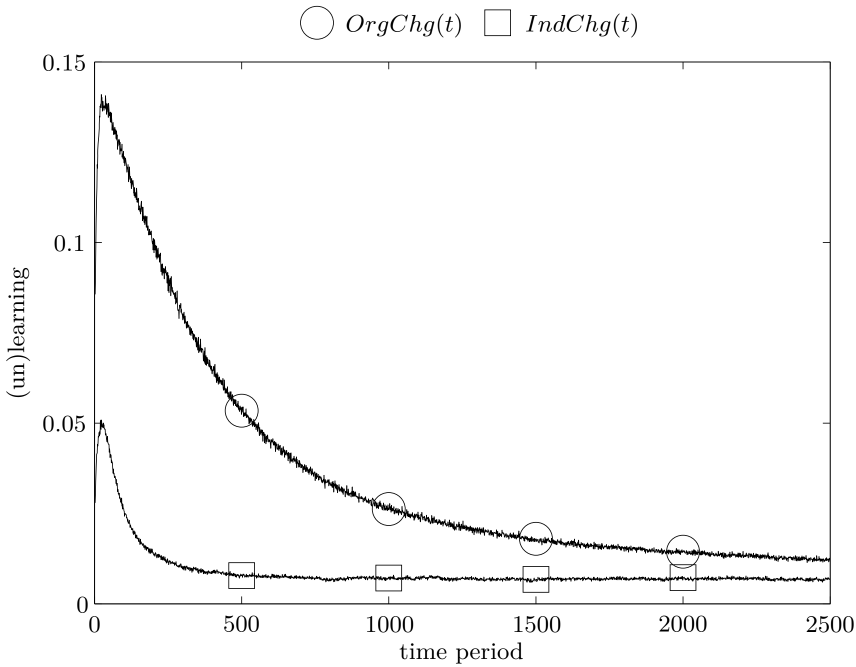

Figure 5.7: Organizational and Individual Learning

immediately reflects in the (overall) rate of organizational remembering, $OrgRmb(t)$, just as the probability of organizational forgetting immediately reflects in the (overall) rate of organizational forgetting, $OrgFgt(t)$. For example, organizational remembering at a rate of 0.1 maintains a value of 1 in three of the 30 dimensions (m), if the binary vector for information, utterance, and understanding already holds such a value; or it develops a value of 1, if a value of 0 is present. At the same time, forgetting abandons a value of 1 in favor of a value of 0 or keeps an already existing value of 0 in the other 27 dimensions. Needless to say, individual memory operates in like manner.

With the claim that forgetting is the primary function of memory, (Luhmann, 1996), Figure 5.8 shows organizational and individual forgetting rather than remembering. Forgetting on part of the psychic systems immediately levels off. This well complements the likewise quick decrease in individual learning as well as the conversely exponential growth in individ-

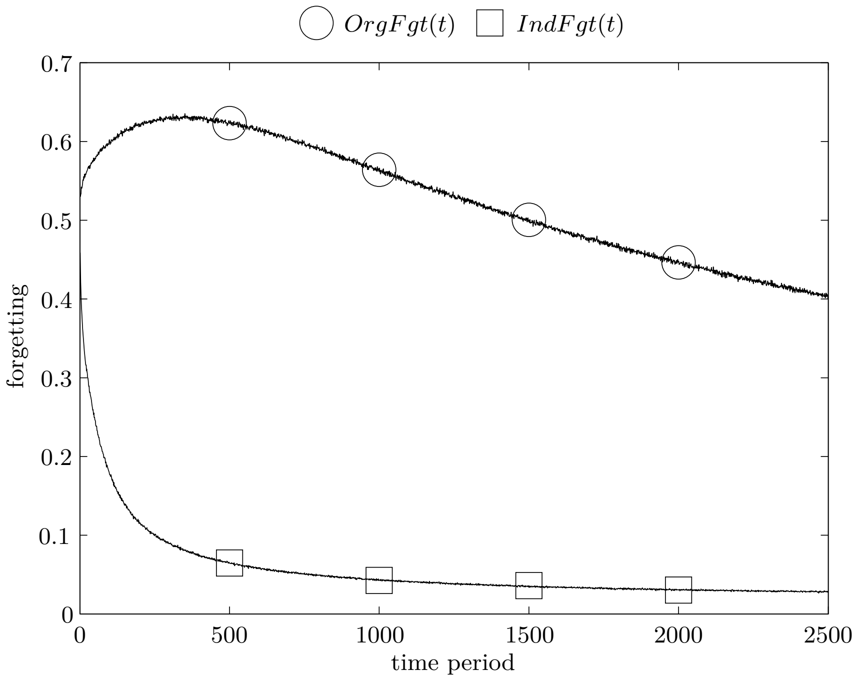

Figure 5.8: Organizational and Individual Forgetting

ual knowledge. Interestingly enough, organizational forgetting accelerates at first, then slowly decreases over all simulation periods. Forgetting as the (initially) primary function of memory indicates the necessity to dispose of incoherent communication (i. e., communication which bears no or, worse, a negative value with respect to expectation). For example, communication with a value of 1 is as much incoherent in comparison to expectation with a value of 0 (recall that the binary vector for expectation holds a value of 0 in all dimensions to begin with) as it is to expectation with a value of −1. With the acquisition of knowledge over time, however, remembering takes over as the primary function of memory.

5.3.2 Organizational Structure

The above simulation findings result from a perfectly connected network of communication with the number of psychic systems (n) set at 50 and

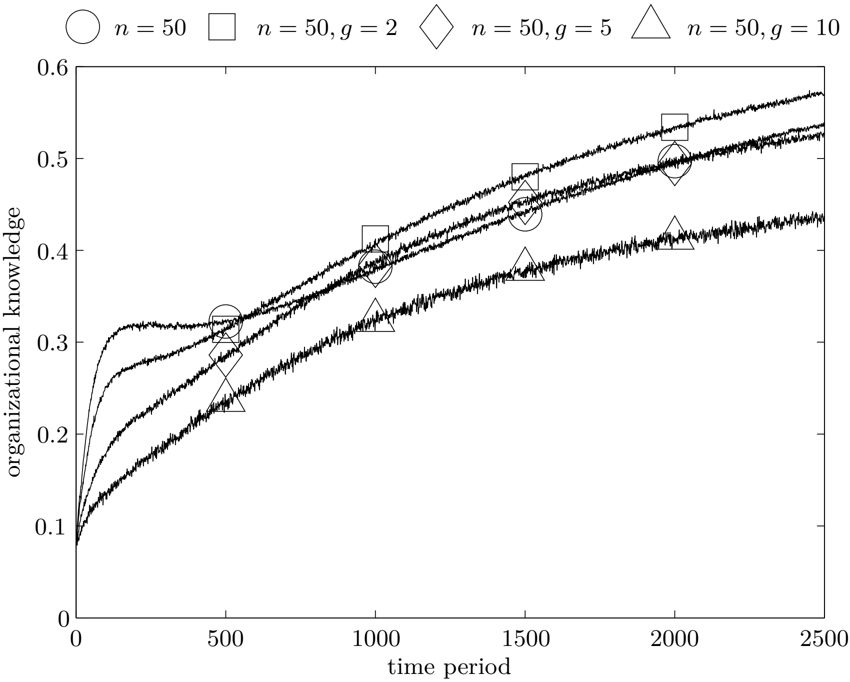

Figure 5.9: Organizational Knowledge for Different Organizational Structures

accordingly a number of 2,450 overall communication events. Of course, there are numerous other organizational structures (i. e., network topologies) which limit the emergence of communication in further ways. Less than perfectly connected networks exhibit a smaller overall number of communication events to begin with. Think of departmental hierarchies, work groups, or communities of practice (as for the latter, cf. Subsection 5.3.5) which restrict communication to just a department, group, and community. For instance, if 50 psychic systems are divided into two work groups so that only members of a group may participate in communication with each other, then this organizational structure limits the overall number of communication events to 1,200 (with $n/g \times (n/g - 1) \times g$, where n is the number of psychic systems and g is the number of groups). At organizational structures of ten psychic systems in five groups ($n = 50, g = 5$) and five psychic systems in ten groups ($n = 50, g = 10$), the overall number of communication events drops to 450 and 200. Figure 5.9 compares the emergence of organizational knowledge over time for structures of one, two, five, and ten groups.

Organizational structure limits the emergence of organizational knowledge. Organizations with a structure of 25 psychic systems in two groups ($n = 50, g = 2$) outperform any other organizational structure in terms of knowledge, while communication among five psychic systems in ten groups ($n = 50, g = 10$) ultimately develops the lowest level of organizational knowledge. Perfectly connected networks of communication ($n = 50, g = 1$) exhibit significantly higher final levels of knowledge than organizational structures of ten psychic systems in five groups ($n = 50, g = 5$), which a two-tailed t-test for the accordingly paired average organizational knowledge levels over the last 200 time periods of the simulation confirms ($p = 0.019, t = 2.371, df = 198$). Larger, more densely connected networks of communication experience irritations (disturbances, perturbations, stimulations) from which they learn in less frequent manner than do smaller, less densely (or more loosely coupled) networks. It simply takes more time for 2,450 communication events to emerge and reemerge than for networks with fewer communication events. However, larger networks face a more variety of irritations than do smaller networks. A single group of 50 psychic systems thus provides more connectivity than ten groups of five psychic systems each. With respect to the emergence of organizational knowledge, this trade-off between the frequency and variety of irritations suggests an ideal group size of anywhere between ten and 50 psychic systems (i. e., an ideal network size of anywhere between 450 and 2,450 communication events).

Although organizations with a structure of 25 psychic systems in two groups develop an overall superior level of knowledge, their rate of organizational learning stays below the one of perfectly connected networks of communication (see Figure 5.10).

In turn, organizations with a structure of ten psychic systems in five groups change a significantly less percentage of expectation than perfectly connected networks of communication, although they are indistinguishable from each other in terms of organizational knowledge. Organizational learning alone cannot explain organizational knowledge, obviously. Figure 5.11 complements learning and knowledge with a display of organizational forgetting over time for structures of one, two, five, and ten groups.

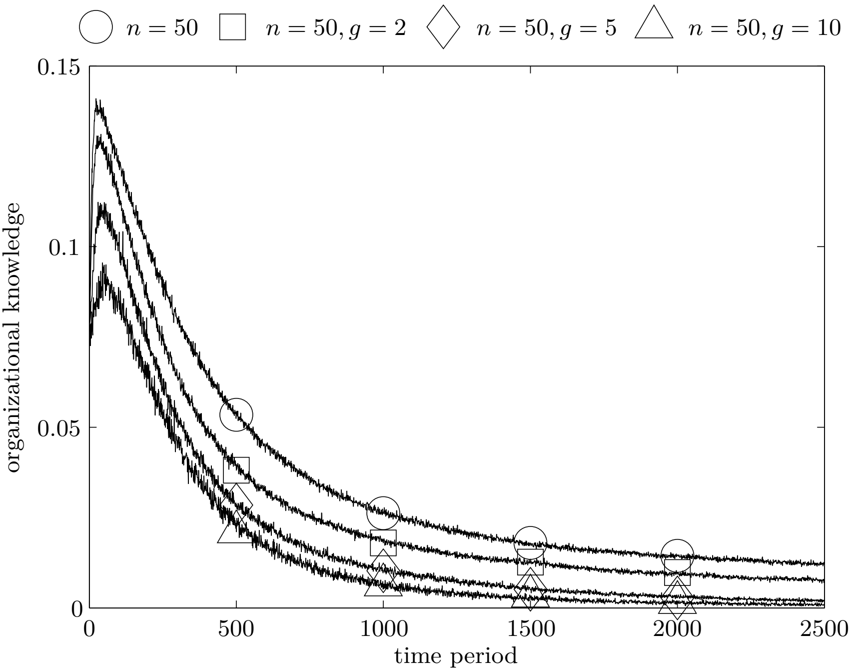

Figure 5.10: Organizational Learning for Different Organizational Structures

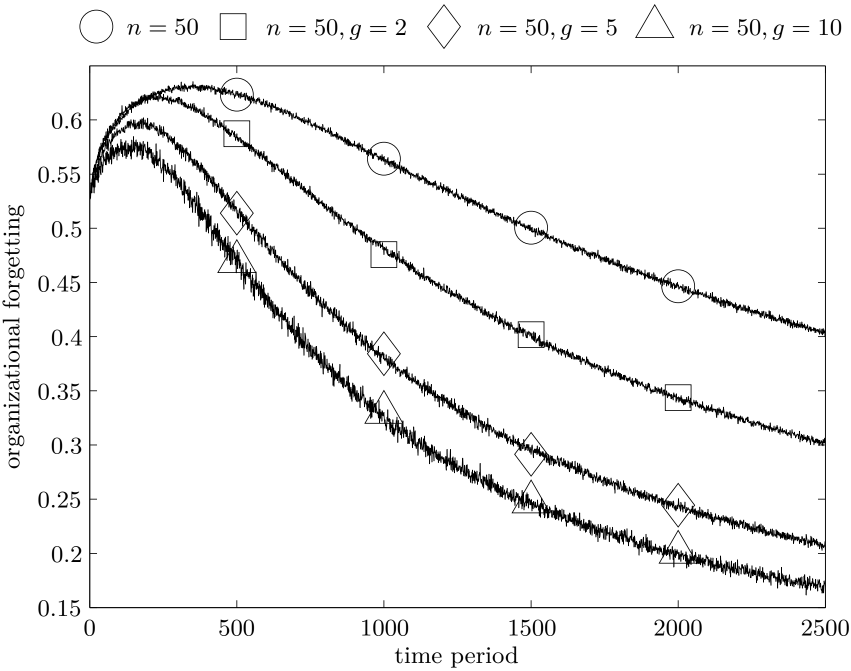

Figure 5.11: Organizational Forgetting for Different Organizational Structures

Recall that organizational forgetting interrupts the connectivity of the cognitive structure of communication by abandoning information, utterance, and understanding. The rate of forgetting then indicates the (in)coherence of communication. At a high rate, communication is well incoherent and thus forgotten, whereas at a low rate, communication is well coherent and thus remembered. As with organizational learning, larger networks of communication experience irritations which they remember (and therefore may still learn from) in less frequent manner than do smaller networks, particularly since all expectation is unaffected by organizational learning to begin with (Subsection 5.1.3). The variety of irritations these larger networks of communication face is just the source of the (in)coherence of communication, however. This finding further specifies Luhmann's (1996) claim that forgetting is the primary function of memory. While this is certainly the case for an initial period of the simulation, remembering is the primary function of memory in the end. In other words, with less and less irritations, forgetting gives way to remembering for all organizational structures. Bluntly speaking, organizations are trapped in their own past.

5.3.3 Personnel Turnover

Personnel turnover is a widely debated topic in management science and organization theory (e. g., Haveman, 1995; Jaros, Jermier, Koehler, & Sincich, 1993; O'Reilly, Caldwell, & Barnett, 1989; Wagner, Pfeffer, & O'Reilly, 1984) (cf. Morrell, Loan-Clarke, & Wilkinson, 2001, for a review of the literature). Computational simulation, too, inquires into the effects of personnel turnover on product development costs (Abdel-Hamid, 1989), production times (Hutchinson, Villalobos, & Beruvides, 1997), economic unemployement rates (Pries, 2004), organizational culture (Harrison & Carroll, 1991), and, last but not least, organizational learning (Carley, 1992; March, 1991).

"Organizational turnover occurs when members of the organization leave and are replaced by new personnel," Carley writes and right away defines "the rate of turnover as 1 over the mean number of of decision periods between these exits/entrances (mean interarrival time)" (Carley, 1992, p. 28). Turnover is implemented by having an individual leave and another immediately enter the organization periodically over time as a Poisson process. It brings about the naïve expectation (i. e., unaffected by organizational knowledge, learning, memory) of new psychic systems as well as the naïve expectation (i. e., likewise unaffected by organizational knowledge, learning, and memory) of new communication events in which these psychic systems may participate in the role of ego in. The simulation considers four turnover

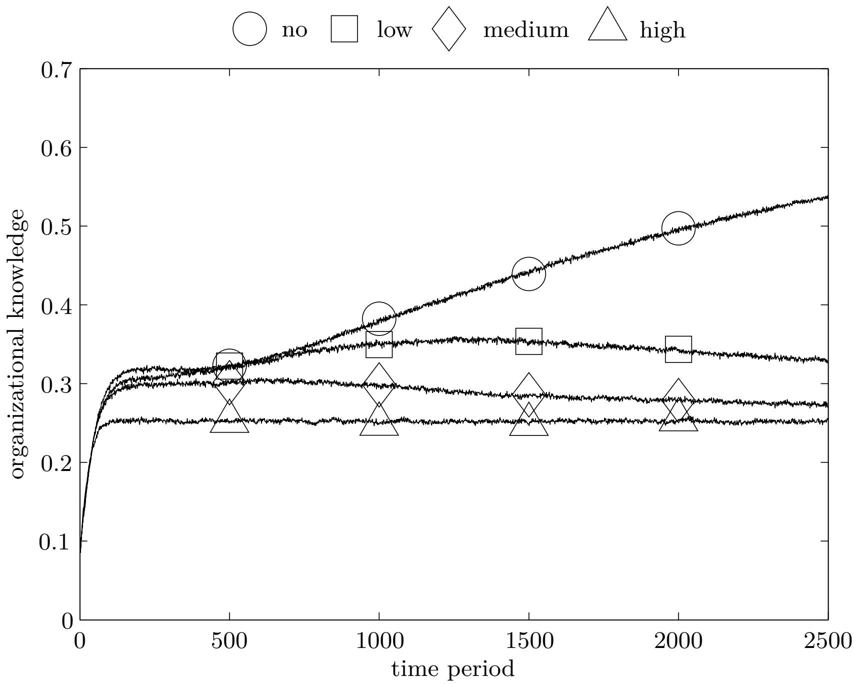

Figure 5.12: Organizational Knowledge for Perfectly Connected Organizational Structures at No, Low, Medium, and High Personnel Turnover

rates, (1) no turnover, (2) low turnover at 0.0033, (3) medium turnover at 0.0067, and (4) high turnover at 0.033 arrivals per time period (again, cf. Carley, 1992). Figure 5.12 displays the emergence of organizational knowledge, $OrgKnw(t)$, in perfectly connected networks of communication for these four rates of turnover over time.

Organizations with low, medium, and high personnel turnover experience a first exponential growth of knowledge much like organizations without turnover. The rate of personnel turnover caps the level of organizational knowledge, however. This finding is well described by Carley's (1992, p. 34) statement that "organizations learn less the higher the turnover." Organizational learning, unlearning, forgetting, and remembering lead to an equilibrium level of organizational knowledge (i. e., at least without personnel turnover; cf. above). In general, the autopoiesis of social systems is path dependent; without further irritations (disturbances, perturbations, stim-

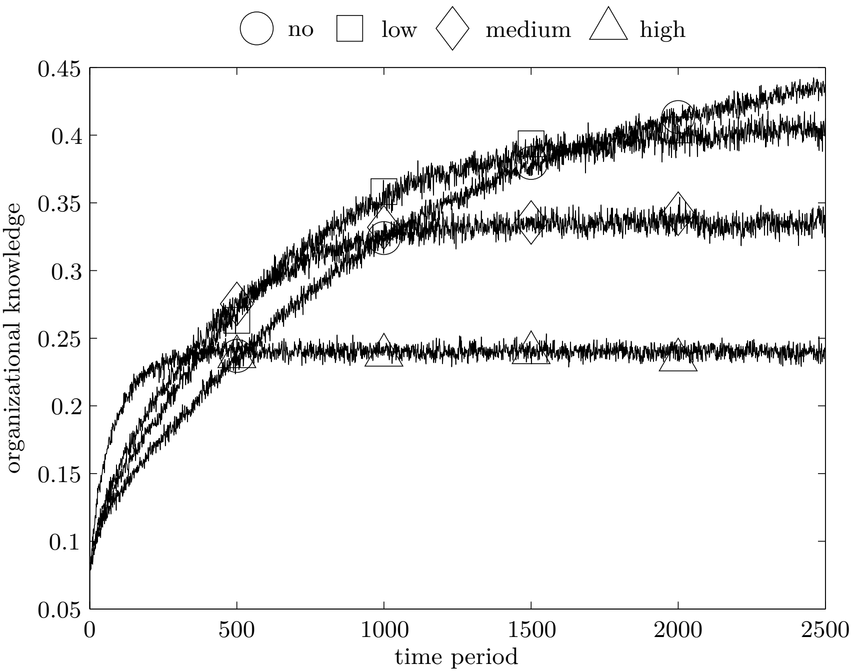

Figure 5.13: Organizational Knowledge for Loose Coupled Organizational Structures at No, Low, Medium, and High Personnel Turnover

ulations, etc.), organizations ultimately encounter a lock-in (Arthur, 1989; Liebowitz & Margolis, 1995) of communication. Personnel turnover is a chance to escape this lock-in by exposing organizations to irritations in the form of newcomers who's consciousness deviates from communication in a favorable way (March, 1991). Indeed, not all entry and exit of individuals is detrimental to the emergence of organizational knowledge. Figure 5.13 compares the emergent knowledge of organizations with a structure of five psychic systems in ten groups ($n = 50, g = 10$) at no, low, medium, and high personnel turnover over time.

While the final levels of organizational knowledge at low, medium, and high personnel turnover are all below the level at no turnover, there is an interim period of time which yields a considerably higher level of organizational knowledge at low personnel turnover. Here, turnover brings about just enough irritations for organizations to accelerate their produc-

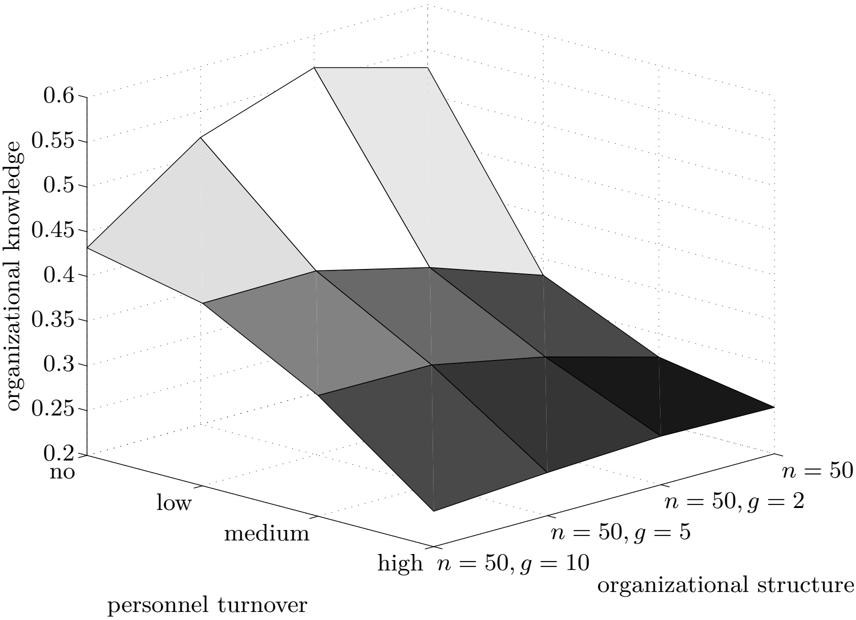

Figure 5.14: Final Organizational Knowledge for Different Organizational Structures at No, Low, Medium, and Large Personnel Turnover

tion and reproduction of knowledge. Smaller, loosely coupled networks of communication sustain low personnel turnover more easily, therefore. Figure 5.14 confirms this finding in reference to organizations with structures of 25 and ten psychic systems in two and five groups, respectively. Note the drop in organizational knowledge from no to low personnel turnover. Again, smaller networks of communication compensate their loss of communication and consciousness in far better ways than do larger networks. At low and medium turnover, they are even able to develop (statistically significant) higher final levels of organizational knowledge (for t-tests reports, cf. Table A.6 in the appendix). The results deny the statement that "organizations learn less the higher the turnover" (Carley, 1992, p. 34) any general validity. In particular, low and medium personnel turnover may well positively affect organizational knowledge, learning, and memory.

5.3.4 Personnel Layoff

A closely related phenomenon to personnel turnover is layoff. Turnover is the rather continuous process of individuals (often enough, voluntarily) leaving an organization in small numbers (hence, the above implementation as a Poisson process), whereas layoff is the more or less episodic dismissal of personnel in large numbers. There are no computational simulations in management science and organization theory which consider personnel layoff, so far. March (1991), Carley (1992), and others (cf. the references given in Subsection 5.3.3) study turnover exclusively, although it is certainly worthwhile to inquire into layoff, too. Layoff is implemented by having a particular number of randomly chosen individuals leave the organization all at once without them being replaced by any other individuals. The simulation considers (1) the layoff of ten psychic systems on the one hand, and (2) the layoff of 25 psychic systems on the other hand, both at time period 1,000.

Figure 5.15 shows the effects of layoff on the emergence of organizational knowledge of perfectly connected networks of communication ($n = 50, g = 1$) over time. Organizations suffer no apparent loss of knowledge as one may expect, neither for laying off ten individuals nor for laying off even half of their members. On the contrary, the smaller the remaining network size (i. e., the fewer the opportunities of communication) the quicker the acquisition of knowledge after the layoff. Large networks of communication may well sustain a significant cutback in the variety of irritations and indeed profit from an increase in the frequency of irritations.

Then again, less densely connected or, the other way around, more loosely coupled networks of communication experience layoff somewhat differently. Figure 5.16 shows the effects of personnel layoff on the emergence of knowledge for organizations with a structure of five psychic systems in a group ($n = 50, g = 10$) over time. A layoff of ten individuals has little effect on the overall emergence of organizational knowledge, although the difference between no layoff and a layoff of ten individuals is statistically significant in favor of no layoff (two-tailed t-test of paired average organizational knowledge levels over the last 200 time periods at $p = 0.009, t = 2.651, df = 198$). A layoff of 25 individuals, however, clearly affects the emergence of organizational knowledge. While smaller networks of communication sustain personnel turnover more easily than do larger networks (cf. above), they suffer a heavy loss of organizational knowledge from too large a layoff. Depending on the organizational structure, there is a trade-off between the

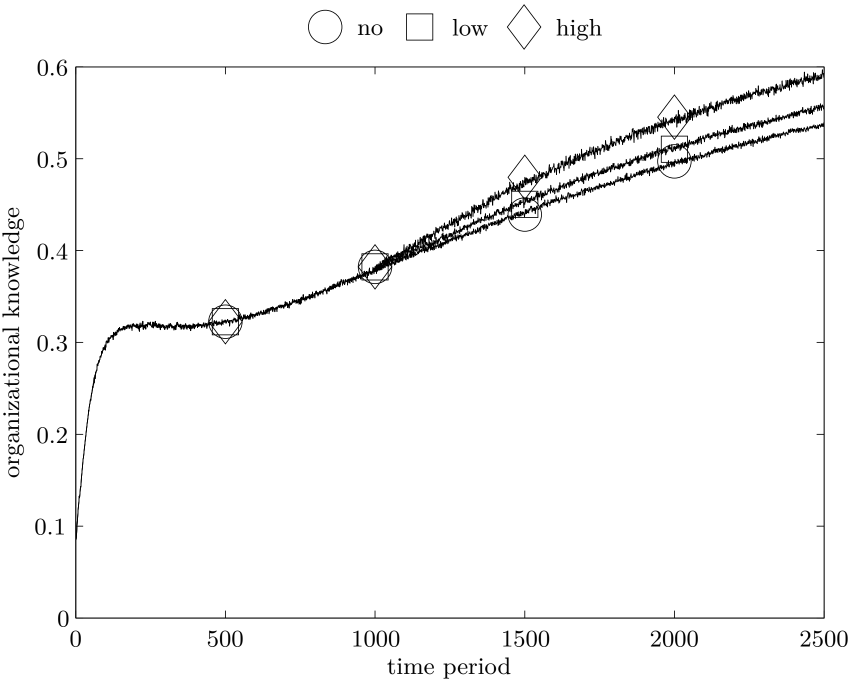

Figure 5.15: Organizational Knowledge for Perfectly Connected Organizational Structures at No, Low, and High Personnel Layoff

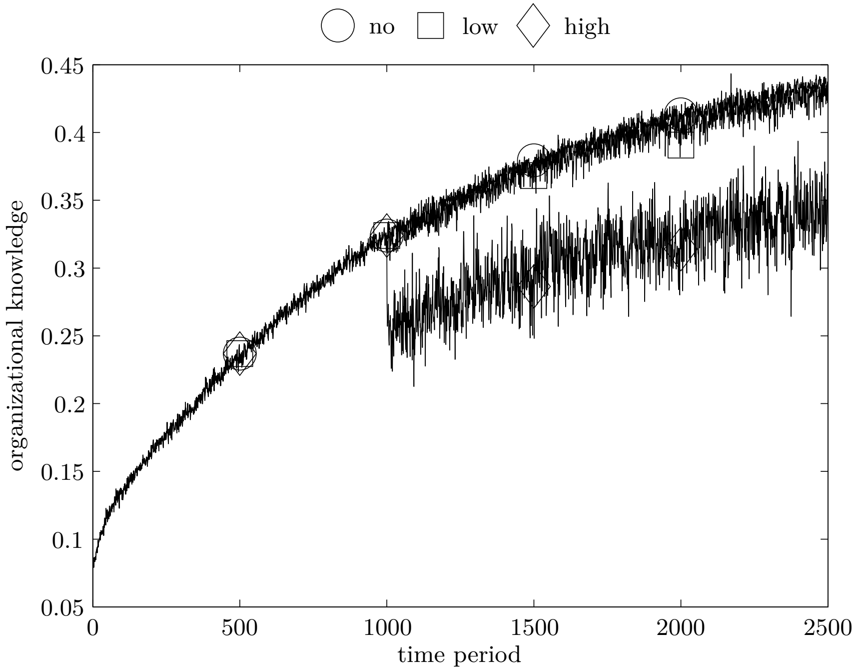

Figure 5.16: Organizational Knowledge for Loosely Coupled Organizational Structures at No, Low, and High Personnel Layoff

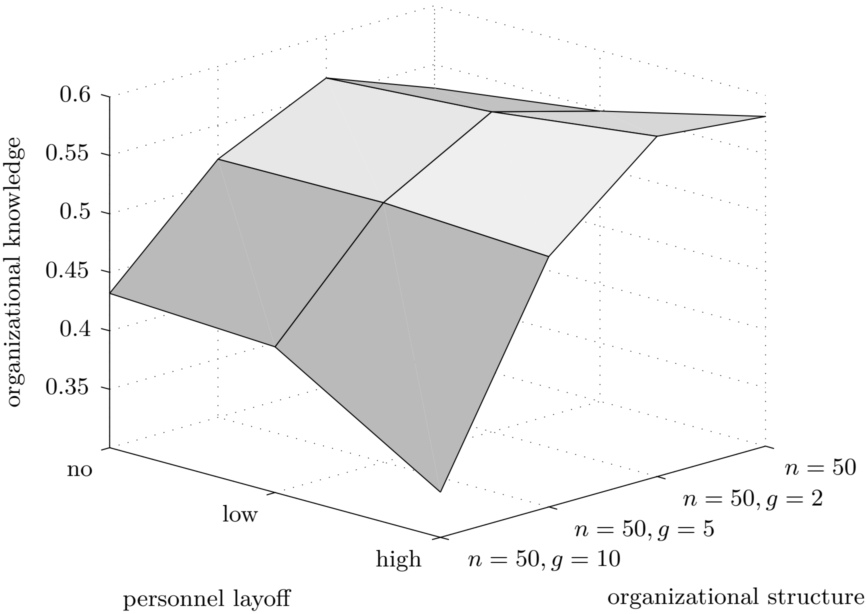

Figure 5.17: Final Organizational Knowledge for Different Organizational Structures at No, Low, and High Personnel Layoff

number of individuals to dismiss and the organizational knowledge that remains (see Figure 5.17).

Organizations with a structure of 25 psychic systems in two groups ($n = 50, g = 2$) still profit from a cutback in opportunities of communication, whereas organizations with a structure of ten psychic systems in five groups ($n = 50, g = 5$) suffer a loss in organizational knowledge as layoff comes about in large numbers. This finding implies that, once again, a group size of anywhere between ten and 50 psychic systems may not only sustain a layoff as large as half of all organizational members but in fact profit in terms of emergent organizational knowledge.

5.3.5 Communities of Practice

Since the early 1990s, management science and organization theory show an increasing interest in communities of practice (e. g., Brown & Duguid, 1991; Fox, 2000; Lave & Wenger, 1991; McDermott, 1999; Mutch, 2003), most frequently under the heading of knowledge management (cf. Subsection 2.3.4). In contrast to work groups, project teams, and informal networks, communities of practice serve the primary purpose of developing their member's capabilities instead of delivering products or services, accomplishing specific tasks, or collecting and passing on information (Wenger & Snyder, 2000). Wenger defines them along three dimensions, which are,

> [the] joint enterprise as understood and continually renegotiated by its members, the relationship of mutual engagement that binds members together into a social entity, the shared repertoire of communal resources (routines, sensibilities, artefacts, vocabulary, styles, etc.) that members have developed over time. (Wenger, 1999, p. 2)

While the literature agrees on the overall positive effects of communities of practice on organizational knowledge, learning, and memory, there is a discord on exactly how (or if at all) they may be managed. McDermott, for instance, grants that the dynamics of communities may be designed for intentional purposes; he argues for "an individual or small group [taking] on the job of holding the community together, keeping people informed about what others are doing and creating opportunities for people to get together to share ideas" (McDermott, 1999, p. 113). Along the same line are calls for a community "coordinator" and a "core group" (Wenger & Snyder, 2000, p. 144), both of which can and should be identified by management. In contrast, Brown and Duguid stress that knowledge, learning, and memory may neither be demanded nor controlled. Communities are in fact emergent, self-sustaining, and continually formed and reformed by their members. "Their shape and membership emerges in the process of the activity, as opposed to being created to carry out a task. [...] The central question more involves the detection and support of emergent or existing communities" (Brown & Duguid, 1991, p. 49).

More recent research proposes *Structural and Epistemic Parameters in Communities of Practice* (Thompson, 2005) which may further organizations to seed and subsequently control the structures that communities emerge from and thrive on. These parameters downright lend themselves to computational simulation which, in turn, may shed another light on the discord in management science and organization theory. In reference to the simulation so far, (re)consider organizations with a structure of five psychic systems in ten groups ($n = 50, g = 10$) and thus an overall 200 opportunities of communication. First and foremost, communities of practice extend the scale of communication in that some individuals take on a boundary spanning role (Katz & Tushman, 1983; Tushman, 1977) by belonging both to a group and a community. In other words, individuals participate in communication with members of their own group and members of their community of practice, if only they are member of such a community to begin with. On the assumption that one out of five psychic systems of each one of the ten groups belongs to a community of practice, too, networks increase by a number of 90 to an overall 290 opportunities of communication (with $n/g \times (n/g - 1) \times g + g \times (g - 1)$, where n is the number of psychic systems and g is the number of groups).

In terms of "indirectly seeding future collaboration" (Thompson, 2005, p. 162, emphasis in the original), the simulation considers three types of communities of practice, namely, a (1) gatekeeper community, a (2) random community, and an (3) expert community.

Gatekeeper Community. A single psychic system is randomly drawn from a uniform distribution of all organizational members. This is just the gatekeeper who invites $g - 1$ peers, one out of every other work group, to join the community of practice. Peer selection is based on social identity (Tajfel & Turner, 1986; Turner, 1982) or, more precisely, shared expectation (cf. Carley & Krackhardt, 1996, for a similar approach). The gatekeeper anticipates the others' expectation and picks the respective peers that fit his own expectation best. Think of this as a programmer asking colleagues with similar experiences (i. e., similar educational background, programming skills, etc.) to communicate on a particular topic of interest, for example. The gatekeeper reflects the individual who takes on the job of holding the community together (McDermott, 1999) and thus acts as a community coordinator (Wenger & Snyder, 2000).

Random Community. From each one of the ten groups, a single individual is chosen at random (again, from a uniform distribution) to participate in the community of practice. This type of community mimicks the membership that emerges in the process of the activity (Brown & Duguid, 1991) rather than being picked by a superior instance (e. g., management).

Expert Community. Communities of practice are frequently said to consist of experts (cf. Gongla & Rizzuto, 2001; Lesser & Storck, 2001). In this case, organizations are assumed to deliberately design a community to facilitate knowledge, learning, and memory among its most knowledgeable members.

From each one of the ten groups, the individual with the best suited expectation in terms of the organizational environment is selected as a member of the community of practice, then. In case of a draw between or among members of a group, the expert is chosen at random.

The number of groups and communities in an organization and the number of individuals in these groups and communities differ from organization to organization, of course. Reportedly, active membership in communities ranges from a handful (Mutch, 2003), to about fifty (Storck & Hill, 2000), and even several thousand networked individuals (Gongla & Rizzuto, 2001). The size and topology of networks of communication does not affect the nature of knowledge, learning, and memory, however. Size and topology rather account for the general opportunity of communication. Figure 5.18 shows the emergence of organizational knowledge over time for baseline organizations without a community in contrast to organizations with a gatekeeper, a random, and an expert community of practice.

Organizations benefit from any type of community of practice, evidently. This positive effect of communities roots in the relationship between a lowered frequency of irritations (i. e., from 200 to 290 opportunities of communication) and a widened variety of irritations. Communities of practice span departmental hierarchies, work groups, and project teams at little cost of extra communication. At the same time, they provide organizations with an almost instant access to the entire spectrum of irritations from individuals. On the individual level, members of a community relay expectation to members of their group, whereas on the organizational level, communities of practice diffuse expectation across all groups. The positive effect of communities on knowledge, learning, and memory is thus of second-order.

As for the difference in knowledge among organizations with a community of practice, an expert community facilitates a (statistically significant) higher final level of organizational knowledge than both a gatekeeper community (two-tailed t-test of paired average organizational knowledge levels over the last 200 time periods at $p = 0.068, t = 1.837, df = 198$) and a random community ($p = 0.045, t = 2.020, df = 198$). In turn, organizations with a gatekeeper community are indistinguishable from organizations with a random community ($p = 0.735, t = 0.339, df = 198$). This suggests that organizations may particularly benefit from communities of practice which consist of experts. Questions concerning the identification of experts, their motivation to participate in the community, and so on are left unanswered, unfortunately. Still, the findings imply that if organizations are to seed the initial structure that communities emerge from, as Thompson (again, cf.

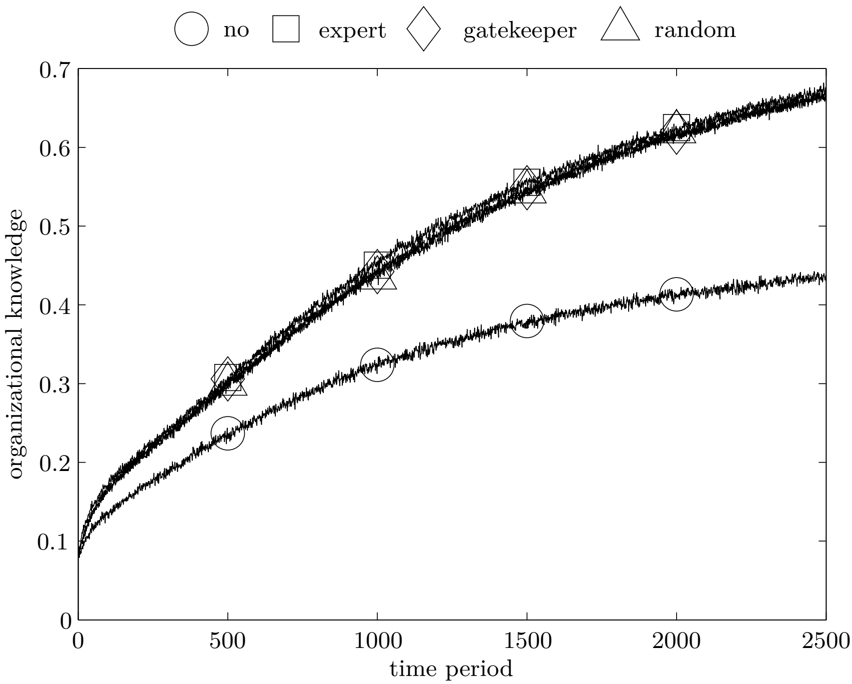

Figure 5.18: Organizational Knowledge for Loosely Coupled Organizational Structures With and Without Communities of Practice

2005) argues, they may as well find a way to have their most knowledgable members join.

5.4 Summary and Implication Potential

Computational simulation as a third way of scientific inquiry stands as a blend of deduction and induction. Autopoietic organization theory represents the foundation upon which the previous chapters develop a model and simulation of agent types and dynamics. Psychic and social systems (individuals and organizations) are computational agents in their own right. They come with a set of binary and ternary vectors for consciousness, conception, and expectation in case of individuals, and communication, information, utterance, and understanding, and expectation in case of organizations. In addition, both hold vectors for coherence, reliability, and age, as well as several (tracking) variables. Knowledge, learning, and memory emerge with each and every autopoietic episode of psychic and social systems, then.

The implementation of the model in an experimental design is elaborated on in detail, yet without reference to the program code itself. (The latter is available from the website accompanying this work, http://www.blaschke.biz) The simulation treats time as discrete and fate as stochastic. Psychic systems participate in communication under the given limitations (space, time, organizational structure); at this, interaction is decentralized and local only. Moreover, they move around the grid of patches. The simulation does not consider, for example, virtual networks of communication, although the necessary adjustments are easy to come by (loosen spatial and temporal boundaries, to begin with).

The simulation runs for 2,500 time periods and is repeated 100 times from different initial conditions. These latter random seed variations are part of the sensitivity analysis (cf. Section 4.1). In addition, this work modifies several parameter settings such as the number of psychic systems (with n set at ten or 100) and the length of the binary and ternary vectors (with m set at ten or 100, too). The quantitative levels of the results depend on these settings, but the qualitative results are in fact insensitive to values of m and n (cf. March, 1991). Note that the sensitivity analysis yields results similar to the above; apart from this brief recount, they are omitted, though. Other modifications to the simulation include starting social systems out with random instead of no expectation, not the least because there is rarely (if ever) communication without expectation (e. g., any communication on topics of winter and summer inevitably relies on expectations of coldness and warmth), and starting out social systems with expectation similar to psychic systems so that communication relies on the same expectation as does the psychic system in the communication role of alter. Again, qualitative results are insensitive to these modifications.

The sensitivity analysis backs the theoretical validity of the simulation findings. In turn, the simulations findings bear resemblance to the ones of March (1991), Carley (1992), and others (cf. the above given references), which confirms their practical validity, too. However, some findings stand in contrast to the literature. For example, depending on organizational structure, low and medium personnel turnover may well positively affect organizational knowledge, learning, and memory, whereas Carley claims that the higher the turnover the less organizations learn.

The most interesting results concern previously unexplored territory, nevertheless. The effects of personnel layoff and seeding structures of communities of practice are two such issues. As for large, densely connected networks of communication, personnel layoff in small numbers may benefit organizations in terms of knowledge, learning, and memory for it breaks up inert structures and ultimately speeds up the frequency of irritations. Small, loosely coupled networks sustain low layoff, as well, yet they are severely hit by increasing numbers. In terms of communities of practice, seeding experts may prove the best strategy at hand, although seeding a structure is generally beneficial to organizational knowledge, learning, and memory. These findings implicate a need for considerate managerial practice when it comes to laying off personnel and seeding communities of practice.

6 Conclusion

In conclusion of the opening theme, knowing the dancer from the dance, even though they are inseparable in practice, is helpfully understood when conceived in the following theoretical fashion (cf. Gill, 1975). First, attend to the particular positions and movements of the dancer. These mediate an awareness of a richer dimension called the dance, in turn. As the latter subsidiarily awareness comes in focus, the positions and movements of the dancer remain but subsidiary themselves. Thus, the distinction between the dancer and the dance emerges. Moving back and forth between the particularities of the dancer and the broader significance of the dance amplifies the experiential knowledge gained through aesthetic awareness.

Knowing individuals from organizations is similar to knowing the dancer from the dance. The operations and observations of individuals call for an awareness of organization(s), not the least because there is no conscious link between individuals. Organizations as networks of communication are necessarily distinct from individuals as networks of consciousness, then. The conceptual metaphors of organizational knowledge, organizational learning, and organizational memory bridge the divide between individuals and organizations, allowing for an enhanced understanding of both ontologically distinct entities in one perceptual phenomenon.

The remainder of this final chapter summarizes the theoretical core, discusses implications for theory and practice, and gives an outlook on future research.

6.1 Summary

Management science and organization theory carefully scrutinize organizations as rational, natural, and open systems. Issues of organizational learning give way to organizational knowledge and as of late organizational memory. For instance, transactive memory systems and group learning theories (e. g., Lewis, Lange, & Gillis, 2005; Reagans, Argote, & Brooks, 2005) stand in the tradition of knowledge creation and conversion (e. g., Nonaka, 1991, 1994) which, in turn, root in concepts of individual and organizational learning (e. g., Argyris & Schön, 1978; Duncan & Weiss, 1979). The various theories of organizational knowledge, organizational learning, and organizational memory evolve, of course, but the basic assumptions are rarely challenged.

The rational systems perspective on organizations combines a pragmatic attitude with normative ambitions. The common concern of bureaucracy theory, scientific management, administration theory, and administrative behavior is with individuals in general and managers in particular. The respective management principles promise maximum organizational performance, then. The natural systems perspective shifts the focus from individuals in organizations to organizations of individuals. Human relations, cooperatives systems, theories X, Y, and Z, and organizational learning acknowledge the importance of social interaction for organizational performance. Still, there is a lack of commitment to a more rigorous definition of organizations. Lastly, cybernetics and the interrelated theoretical ideas of loose coupling, interpretation, and sensemaking describe knowledge, learning, and memory from the open systems perspective to fit both individuals and organizations, thus emphasizing system dynamics at large. Also within this perspective, contingency theory and knowledge management bring together insights from previous theories for the benefit of practice, mostly. Much of the critique on the rational, natural, and open systems perspectives on organizations concerns the insufficient distinction between individuals and organizations, the lack of rigorous definitions of knowledge, learning, and memory, and the disparate terminology in use thereof.

As the paradigm shifts from organizations as rational, natural, or open systems to organizations as social systems, this work's theoretical core offers a clear-cut distinction between (1) individuals and organizations, and between (2) individual and organizational knowledge, learning, and memory based on social systems theory, thereby complementing autopoietic organization theory. The starting premise of social systems theory is that there are self-referential and self-producing systems. These, in other words, autopoietic systems constitute themselves and their environment as composite units in space and time, that is, their operations separate them from the environment, whereas their observations overcome the ensuing endogenous system boundary. In effect, autopoietic systems are operationally closed yet structurally coupled to each other.

Individuals (psychic systems) produce and reproduce consciousness from the conception of system/environment distinctions and expectations. In contrast, organizations (social systems) produce and reproduce communication from the synthesized information, utterance, and (mis)understanding of, likewise, system/environment distinctions and expectations. Both individuals and organizations operate in self-referential closure. However, they incorporate observations of each other in consciousness and communication at the boundary of two alternating roles, namely, alter and ego. More precisely, social systems observe psychic systems in the role of alter, while psychic systems in the role of ego observe social systems. At this, individuals and organizations evolve highly complex networks of consciousness and communication.

The fundamental concepts of social systems theory are premises to autopoietic organization theory which, in turn, defines knowledge as the cognitive structure of psychic and social systems, learning as the partial change, and memory as the connectivity thereof. Hence, knowledge, learning, and memory are no longer "three concepts in search of a theory" (Spender, 1996, p. 63), they are inextricably defined in terms of one another. In the end, the conceptual metaphors of organizational knowledge, organizational learning, and organizational memory find rigorous application all from their source domain of individuals to their target domain of organizations. Autopoietic organization theory then answers the opening questions ("What is organizational knowledge?", "What is organizational learning?", and "How is organizational memory different from individual memory?"; cf. Section 1.2) in unambiguous manner.

Theory presents the distinction between individuals and organizations, and between individual and organizational knowledge, learning, and memory in easy enough terms. The autopoiesis of psychic and social systems, however, largely denies further theoretical as well as empirical study. The computational simulation of organizational structures and dynamics nonetheless responds to more complex, consequential, and opaque issues of knowledge, learning, and memory (e. g., "Of what consequence is it for organizations that they are able to preserve knowledge of past events and bring it to bear on present decisions?"; again, cf. Section 1.2). More specific findings suggest a number of implications for theory and practice, in fact.

6.2 Implications for Theory and Practice

An increasing amount of literature acknowledges that organizations consist primarily of communication. March and Simon (1958, p. 161 ff.) emphasize the importance of organizational communication as early as in 1958. 25 years later Weick (1983) sets an ambitious research agenda for organizational communication and takes a little more than another decade to write, "The communication activity is the organization" (Weick, 1995, p. 75). Unfortunately, Weick does not go through with his initial proposal and retracts to his concept of individual sensemaking. Others call for a unified view on organizational communication (e. g., Church, 1994; Robichaud, Giroux, & Taylor, 2004; Taylor, 1999; Taylor & Van Every, 2000; Yates & Orlikowski, 1992), too, and advocate "the notion of the organization as a densely connected network of communication" (Tsoukas, 2000, p. 110). These few examples imply a strong research community close to autopoietic organization theory and therefore in challenge of the rational, natural, and open systems perspective on organizations. However, little of the literature on organizational communication distinguishes as rigorously between individuals and organizations as this work does.

The distinction between individuals and organizations and the subsequent application of the conceptual metaphors of organizational learning, knowledge, and memory present an advancement to the research agenda for organizational communication and, in a more general respect, to all of management science and organization theory. On a minor note, this work grants access to the fundamental concepts of social systems theory and autopoietic organization theory for the international readership, as the larger part of these theories is still untranslated from German to English.

Among the most interesting simulation findings with implications for theory is the further specification of organizational memory. Luhmann (1996) claims that forgetting is the primary function of memory, whereas remembering is more or less an exception. This is well the case for organizations in flux. However, as organizational structures become inert over time, remembering takes over as the primary function of memory, thereby endangering organizations of being trapped in their own past.

Theoretical perspectives are partial guides to the empirical world and thus knowledge, learning, and memory are essential theoretical constructs in understanding organizations (Grandori & Kogut, 2002). This works' simulation findings implicate advise for managerial practice, indeed. For example, if all organizational decisions are remembered rather than forgotten, a communicational lock-in occurs whereby no genuinely new decisions come about. Remedy takes the form of irritations such as personnel turnover and layoff. Depending on the structure of the network of communication, moderate turnover as well as layoff in small numbers may benefit organizational knowledge, learning, and memory. While personnel turnover is to a large extent voluntary, layoff lies exclusively within managerial discretion. Laying off employees is certainly not a pleasant management task. Notwithstanding, a practical difficulty is to estimate the trade-off between the frequency and the variety of irritations that accompanies personnel layoff. On a cautionary note, neither turnover nor layoff is a simple matter of how many employees come and go but also who exactly comes and goes. Unfortunately, personal relations, friendship ties, and the like are too complex issues to address in computational simulation, at least for the time being.

In the light of the present simulation findings, the trade-off between, in other words, network size and network density furthermore points to considerate managerial practice with respect to organizational structures. Keeping track of social networks is of utmost importance to management nowadays (Cross, Martin, & Weiss, 2006), and simple group structures are not necessarily the best means to achieve organizational ends. The boundary spanning communication that communities of practice provide forgoes little frequency of irritations in favor of a widened variety of irritations. This work supports the literature's major theme that communities of practice are generally beneficial to organizations in terms of knowledge, learning, and memory. Any organization with a community develops a significantly higher final level of organizational knowledge, for instance. Moreover, the findings show significant differences between organizations with an expert community and organizations with either a random or a gatekeeper community. The expert community model outperforms any other organizational scenario, in the end.

6.3 Future Research

The purpose and objective of this work present the distinction between individuals and organizations, and between their knowledge, learning, and memory in scientific rigor. The subsequent computational simulation of organizational structures and dynamics inquires into just these complex issues that hardly lend themselves to further theoretical inquiry or empirical research. While this work complements autopoietic organization theory in terms of knowledge, learning, and memory, the simulation offers several more opportunities for future research.

Empirical data are of great benefit to any computational simulation. Simple observation is one way to approximate the reliability, coherence, and age of consciousness, communication, and expectation, just as observation formalizes business opportunities, task performances, and the like. Judging from socialization during early childhood, educational development, and work-related experiences, one may roughly deduce an individual's experience, for example. While this cumbersome procedure needs to stay within theoretical boundaries and simultaneously produce practical results, it is often applied in the course of hiring, promoting, or discharging employees

(e. g., in the analysis of resumes, in assessment centers, or feedback interviews). The identification of organizational issues, topics, and themes is a similar way to go about communication. These data reflect a snapshot of an organization and thus easily serve as the starting point for computational simulation. In the instance that management demands to restructure the organization, simulation is a non-invasive means to find a structure better suited for organizational needs. Empirical data in combination with computational simulation is much like a weather forecast for organizations.

In addition to empirical data, other theoretical perspectives such as social network theory (Scott, 1991; Wasserman & Faust, 1999) promise an interesting perspective onto the simulation of organizational structures and dynamics. The latter theory already pinpoints a number of quantitative measures to describe networks of communication (e. g., betweenness, centrality, closeness, cohesion, density, radiality, reach). These measures may well drive further theoretical and practical considerations, particularly in combination with empirical data and computational simulation.

On a more particular note, reconsider the above simulation of communities of practice (cf. Subsection 5.3.5). Management is assumed to be able to successfully identify the expert in each work group and have him join the respective expert community. In practice, this may be done based on hard evidence (e. g., education, tenure, age), soft facts (e. g., personnel evaluations, peer reviews, subjective recommendations), or both. Nonetheless, it is considerably harder to choose ten experts (one from each group) than it is to pick just one individual and have him invite peers based on social similarity, as the gatekeeper community suggests, or identify and support an emergent (here, random) community of practice. However, a community commanded by management may not foster knowledge, learning, and memory at all. Employee motivation is certainly an important aspect which is not incorporated in the simulation, so far. Motivational factors may be simulated in such a way that they influence the time and the intensity that an individual devotes to communication within his group and community of practice (cf. Carley & Krackhardt, 1996).

The computational simulation may also be extended to incorporate information systems (cf. Carley & Lin, 1997, and the brief discussion above), organizational culture (cf. Carroll & Harrison, 1998; Harrison & Carroll, 1991), or power relations (cf. Fox, 2000). These are but a few ideas that may guide future research with this computational simulation of organizational structures and dynamics based on autopoietic organization theory. After all, complex issues such as knowledge, learning, and memory are at best subject to simulation, as Luhmann (1984, p. 275) maintains.

A Appendix

Table A.1: Descriptive Statistics and Two-tailed t-Tests for Different Organizational Structures

						$n = 50, g = 2$		$n = 50, g = 5$		$n = 50, g = 10$	
		min.	max.	mean	s.d.	p	t	p	t	p	t
OrgKnw	$n = 50$	0.446	0.577	0.530	0.025	< 0.001	8.645	0.019	2.371	< 0.001	31.549
	$n = 50, g = 2$	0.473	0.623	0.564	0.032			< 0.001	10.328	< 0.001	36.181
	$n = 50, g = 5$	0.449	0.593	0.521	0.028					< 0.001	26.447
	$n = 50, g = 10$	0.391	0.474	0.432	0.019						
OrgLrn	$n = 50$	0.006	0.022	0.012	0.004	< 0.001	9.613	< 0.001	25.772	< 0.001	29.066
	$n = 50, g = 2$	0.002	0.014	0.008	0.002			< 0.001	22.771	< 0.001	28.209
	$n = 50, g = 5$	0.001	0.005	0.002	0.001					< 0.001	16.368
	$n = 50, g = 10$	0.000	0.002	0.001	0.000						
OrgFgt	$n = 50$	0.392	0.436	0.411	0.009	< 0.001	74.233	< 0.001	166.774	< 0.001	197.124
	$n = 50, g = 2$	0.283	0.332	0.309	0.011			< 0.001	71.137	< 0.001	99.425
	$n = 50, g = 5$	0.185	0.232	0.214	0.008					< 0.001	33.998
	$n = 50, g = 10$	0.157	0.195	0.174	0.008						
IndKnw	$n = 50$	0.760	0.976	0.897	0.041	< 0.001	11.395	< 0.001	37.176	< 0.001	72.242
	$n = 50, g = 2$	0.692	0.910	0.827	0.046			< 0.001	22.680	< 0.001	51.867
	$n = 50, g = 5$	0.586	0.791	0.692	0.037					< 0.001	30.529
	$n = 50, g = 10$	0.504	0.605	0.557	0.024						
IndLrn	$n = 50$	0.001	0.016	0.007	0.004	< 0.001	4.711	< 0.001	16.281	< 0.001	18.152
	$n = 50, g = 2$	0.000	0.011	0.005	0.002			< 0.001	17.381	< 0.001	20.645
	$n = 50, g = 5$	0.000	0.003	0.001	0.001					< 0.001	10.710
	$n = 50, g = 10$	0.000	0.001	0.000	0.000						
IndFgt	$n = 50$	0.017	0.048	0.029	0.007	0.920	0.101	0.001	3.394	< 0.001	7.226
	$n = 50, g = 2$	0.018	0.040	0.029	0.005			< 0.001	4.769	< 0.001	9.125
	$n = 50, g = 5$	0.018	0.032	0.026	0.003					< 0.001	16.280
	$n = 50, g = 10$	0.024	0.045	0.035	0.004						

Table A.2: Descriptive Statistics and Two-tailed *t*-Tests for Organizational Structures ($n = 50$) at Personnel Turnover

						low turnover		medium turnover		high turnover	
		min.	max.	mean	s.d.	*p*	*t*	*p*	*t*	*p*	*t*
OrgKnw	no turnover	0.446	0.577	0.530	0.025	< 0.001	63.845	< 0.001	95.718	< 0.001	109.538
	low turnover	0.292	0.383	0.331	0.019			< 0.001	27.163	< 0.001	41.034
	medium turnover	0.249	0.302	0.274	0.010					< 0.001	19.888
	high turnover	0.239	0.266	0.252	0.005						
OrgLrn	no turnover	0.006	0.022	0.012	0.004	< 0.001	103.310	< 0.001	186.801	< 0.001	198.363
	low turnover	0.062	0.086	0.077	0.005			< 0.001	32.499	< 0.001	35.295
	medium turnover	0.089	0.099	0.093	0.002					< 0.001	3.755
	high turnover	0.091	0.098	0.094	0.001						
OrgFgt	no turnover	0.392	0.436	0.411	0.009	< 0.001	73.774	< 0.001	91.418	< 0.001	92.758
	low turnover	0.469	0.494	0.483	0.004			< 0.001	19.027	< 0.001	20.325
	medium turnover	0.487	0.497	0.492	0.002					0.294	1.051
	high turnover	0.489	0.496	0.493	0.001						
IndKnw	no turnover	0.760	0.976	0.897	0.041	< 0.001	68.455	< 0.001	104.931	< 0.001	122.216
	low turnover	0.466	0.626	0.539	0.033			< 0.001	27.711	< 0.001	44.139
	medium turnover	0.392	0.482	0.435	0.017					< 0.001	25.201
	high turnover	0.361	0.414	0.386	0.010						
IndLrn	no turnover	0.001	0.016	0.007	0.004	< 0.001	63.546	< 0.001	132.879	< 0.001	146.244
	low turnover	0.036	0.058	0.048	0.005			< 0.001	30.396	< 0.001	30.764
	medium turnover	0.060	0.072	0.066	0.003					0.009	2.648
	high turnover	0.061	0.069	0.065	0.002						
IndFgt	no turnover	0.017	0.048	0.029	0.007	< 0.001	126.138	< 0.001	238.041	< 0.001	297.190
	low turnover	0.164	0.225	0.199	0.012			< 0.001	35.859	< 0.001	85.306
	medium turnover	0.232	0.262	0.245	0.006					< 0.001	76.661
	high turnover	0.296	0.328	0.312	0.006						

Table A.3: Descriptive Statistics and Two-tailed t-Tests for Organizational Structures ($n = 50, g = 2$) at Personnel Turnover

						low turnover		medium turnover		high turnover	
		min.	max.	mean	s.d.	p	t	p	t	p	t
OrgKnw	no turnover	0.473	0.623	0.564	0.032	< 0.001	51.530	< 0.001	75.294	< 0.001	96.725
	low turnover	0.331	0.417	0.375	0.019			< 0.001	29.081	< 0.001	61.069
	medium turnover	0.277	0.333	0.309	0.012					< 0.001	40.080
	high turnover	0.240	0.271	0.254	0.006						
OrgLrn	no turnover	0.002	0.014	0.008	0.002	< 0.001	119.179	< 0.001	217.243	< 0.001	294.294
	low turnover	0.054	0.077	0.066	0.004			< 0.001	32.044	< 0.001	47.499
	medium turnover	0.077	0.088	0.082	0.002					< 0.001	20.401
	high turnover	0.085	0.090	0.087	0.001						
OrgFgt	no turnover	0.283	0.332	0.309	0.011	< 0.001	100.436	< 0.001	138.677	< 0.001	159.863
	low turnover	0.420	0.461	0.442	0.008			< 0.001	29.381	< 0.001	50.882
	medium turnover	0.457	0.479	0.468	0.004					< 0.001	33.487
	high turnover	0.479	0.487	0.483	0.002						
IndKnw	no turnover	0.692	0.910	0.827	0.046	< 0.001	47.991	< 0.001	70.633	< 0.001	94.976
	low turnover	0.503	0.631	0.567	0.028			< 0.001	27.638	< 0.001	63.519
	medium turnover	0.418	0.510	0.472	0.019					< 0.001	43.695
	high turnover	0.348	0.406	0.377	0.010						
IndLrn	no turnover	0.000	0.011	0.005	0.002	< 0.001	83.046	< 0.001	148.675	< 0.001	229.352
	low turnover	0.033	0.053	0.043	0.004			< 0.001	29.024	< 0.001	48.530
	medium turnover	0.049	0.065	0.057	0.003					< 0.001	21.197
	high turnover	0.059	0.066	0.063	0.001						
IndFgt	no turnover	0.018	0.040	0.029	0.005	< 0.001	135.147	< 0.001	223.479	< 0.001	374.140
	low turnover	0.155	0.216	0.192	0.011			< 0.001	32.689	< 0.001	100.149
	medium turnover	0.215	0.255	0.237	0.008					< 0.001	81.643
	high turnover	0.302	0.334	0.319	0.006						

Table A.4: Descriptive Statistics and Two-tailed t-Tests for Organizational Structures ($n = 50, g = 5$) at Personnel Turnover

						low turnover		medium turnover		high turnover	
		min.	max.	mean	s.d.	p	t	p	t	p	t
OrgKnw	no turnover	0.449	0.593	0.521	0.028	< 0.001	33.591	< 0.001	57.795	< 0.001	94.452
	low turnover	0.363	0.462	0.406	0.020			< 0.001	28.063	< 0.001	75.315
	medium turnover	0.294	0.375	0.335	0.016					< 0.001	49.707
	high turnover	0.231	0.276	0.248	0.007						
OrgLrn	no turnover	0.001	0.005	0.002	0.001	< 0.001	134.987	< 0.001	225.958	< 0.001	508.329
	low turnover	0.044	0.064	0.055	0.004			< 0.001	26.105	< 0.001	50.510
	medium turnover	0.059	0.073	0.067	0.003					< 0.001	26.120
	high turnover	0.072	0.080	0.075	0.001						
OrgFgt	no turnover	0.185	0.232	0.214	0.008	< 0.001	120.749	< 0.001	193.603	< 0.001	290.343
	low turnover	0.348	0.404	0.378	0.011			< 0.001	33.065	< 0.001	74.799
	medium turnover	0.400	0.435	0.421	0.007					< 0.001	55.140
	high turnover	0.456	0.468	0.462	0.003						
IndKnw	no turnover	0.586	0.791	0.692	0.037	< 0.001	31.449	< 0.001	51.895	< 0.001	91.002
	low turnover	0.494	0.619	0.553	0.024			< 0.001	26.306	< 0.001	81.498
	medium turnover	0.412	0.517	0.467	0.022					< 0.001	53.060
	high turnover	0.304	0.383	0.336	0.012						
IndLrn	no turnover	0.000	0.003	0.001	0.001	< 0.001	106.382	< 0.001	182.093	< 0.001	430.357
	low turnover	0.028	0.045	0.037	0.003			< 0.001	26.563	< 0.001	64.218
	medium turnover	0.042	0.055	0.048	0.003					< 0.001	41.729
	high turnover	0.057	0.065	0.060	0.001						
IndFgt	no turnover	0.018	0.032	0.026	0.003	< 0.001	125.837	< 0.001	181.938	< 0.001	404.739
	low turnover	0.156	0.218	0.190	0.013			< 0.001	30.276	< 0.001	108.171
	medium turnover	0.218	0.266	0.241	0.011					< 0.001	78.380
	high turnover	0.329	0.366	0.348	0.007						

Table A.5: Descriptive Statistics and Two-tailed t-Tests for Organizational Structures ($n = 50, g = 10$) at Personnel Turnover

						low turnover		medium turnover		high turnover	
		min.	max.	mean	s.d.	p	t	p	t	p	t
OrgKnw	no turnover	0.391	0.474	0.432	0.019	< 0.001	9.684	< 0.001	37.994	< 0.001	98.792
	low turnover	0.343	0.465	0.404	0.022			< 0.001	24.592	< 0.001	72.314
	medium turnover	0.300	0.381	0.335	0.018					< 0.001	51.480
	high turnover	0.225	0.250	0.239	0.006						
OrgLrn	no turnover	0.000	0.002	0.001	0.000	< 0.001	99.060	< 0.001	162.448	< 0.001	387.621
	low turnover	0.031	0.049	0.040	0.004			< 0.001	26.051	< 0.001	55.041
	medium turnover	0.046	0.060	0.053	0.003					< 0.001	28.295
	high turnover	0.060	0.068	0.063	0.002						
OrgFgt	no turnover	0.157	0.195	0.174	0.008	< 0.001	80.759	< 0.001	142.241	< 0.001	277.474
	low turnover	0.274	0.376	0.320	0.016			< 0.001	28.472	< 0.001	73.221
	medium turnover	0.347	0.398	0.375	0.011					< 0.001	53.370
	high turnover	0.429	0.453	0.442	0.005						
IndKnw	no turnover	0.504	0.605	0.557	0.024	< 0.001	16.511	< 0.001	41.664	< 0.001	103.695
	low turnover	0.445	0.574	0.498	0.026			< 0.001	22.721	< 0.001	75.872
	medium turnover	0.371	0.475	0.421	0.022					< 0.001	55.430
	high turnover	0.269	0.309	0.290	0.009						
IndLrn	no turnover	0.000	0.001	0.000	0.000	< 0.001	83.888	< 0.001	137.991	< 0.001	353.762
	low turnover	0.019	0.039	0.029	0.003			< 0.001	26.292	< 0.001	72.146
	medium turnover	0.035	0.047	0.042	0.003					< 0.001	45.955
	high turnover	0.053	0.061	0.057	0.002						
IndFgt	no turnover	0.024	0.045	0.035	0.004	< 0.001	95.234	< 0.001	147.824	< 0.001	354.195
	low turnover	0.155	0.253	0.200	0.017			< 0.001	27.849	< 0.001	95.250
	medium turnover	0.224	0.291	0.262	0.015					< 0.001	68.817
	high turnover	0.358	0.399	0.380	0.009						

Table A.6: Two-tailed t-Tests of Organizational Knowledge, Learning, and Forgetting for Different Organizational Structures at Low, Medium, and High Turnover

			low turnover		medium turnover		high turnover	
			p	t	p	t	p	t
OrgKnw	low turnover	$n = 50$	< 0.001	16.318	< 0.001	27.349	< 0.001	25.236
		$n = 50, g = 2$			< 0.001	11.313	< 0.001	10.135
		$n = 50, g = 5$					0.601	0.524
	medium turnover	$n = 50$	< 0.001	21.990	< 0.001	32.278	< 0.001	30.266
		$n = 50, g = 2$			< 0.001	12.658	< 0.001	12.109
		$n = 50, g = 5$					0.842	0.199
	high turnover	$n = 50$	0.004	2.929	< 0.001	4.264	< 0.001	15.578
		$n = 50, g = 2$			< 0.001	6.647	< 0.001	17.702
		$n = 50, g = 5$					< 0.001	9.513
OrgLrn	low turnover	$n = 50$	< 0.001	16.122	< 0.001	35.701	< 0.001	59.088
		$n = 50, g = 2$			< 0.001	20.378	< 0.001	45.671
		$n = 50, g = 5$					< 0.001	26.824
	medium turnover	$n = 50$	< 0.001	39.145	< 0.001	79.022	< 0.001	109.322
		$n = 50, g = 2$			< 0.001	40.425	< 0.001	72.207
		$n = 50, g = 5$					< 0.001	32.706
	high turnover	$n = 50$	< 0.001	44.673	< 0.001	109.344	< 0.001	155.192
		$n = 50, g = 2$			< 0.001	72.364	< 0.001	124.469
		$n = 50, g = 5$					< 0.001	58.048
OrgFgt	low turnover	$n = 50$	< 0.001	45.766	< 0.001	89.354	< 0.001	98.646
		$n = 50, g = 2$			< 0.001	47.953	< 0.001	68.936
		$n = 50, g = 5$					< 0.001	30.066
	medium turnover	$n = 50$	< 0.001	54.585	< 0.001	99.111	< 0.001	100.802
		$n = 50, g = 2$			< 0.001	58.540	< 0.001	76.136
		$n = 50, g = 5$					< 0.001	33.666
	high turnover	$n = 50$	< 0.001	42.413	< 0.001	99.348	< 0.001	101.813
		$n = 50, g = 2$			< 0.001	62.661	< 0.001	79.785
		$n = 50, g = 5$					< 0.001	36.623

Table A.7: Two-tailed t-Tests of Individual Knowledge, Learning, and Forgetting for Different Organizational Structures at Low, Medium, and High Turnover

			low turnover		medium turnover		high turnover	
			p	t	p	t	p	t
IndKnw	low turnover	$n = 50$	< 0.001	6.523	0.001	3.445	< 0.001	9.567
		$n = 50, g = 2$			< 0.001	3.869	< 0.001	17.928
		$n = 50, g = 5$					< 0.001	15.413
	medium turnover	$n = 50$	< 0.001	14.329	< 0.001	11.538	< 0.001	5.068
		$n = 50, g = 2$			0.090	1.703	< 0.001	17.432
		$n = 50, g = 5$					< 0.001	14.861
	high turnover	$n = 50$	< 0.001	6.226	< 0.001	32.312	< 0.001	69.673
		$n = 50, g = 2$			< 0.001	26.592	< 0.001	63.282
		$n = 50, g = 5$					< 0.001	30.593
IndLrn	low turnover	$n = 50$	< 0.001	7.707	< 0.001	17.337	< 0.001	28.879
		$n = 50, g = 2$			< 0.001	11.129	< 0.001	25.098
		$n = 50, g = 5$					< 0.001	15.529
	medium turnover	$n = 50$	< 0.001	24.656	< 0.001	49.314	< 0.001	61.889
		$n = 50, g = 2$			< 0.001	23.350	< 0.001	37.857
		$n = 50, g = 5$					< 0.001	16.842
	high turnover	$n = 50$	< 0.001	10.058	< 0.001	25.105	< 0.001	34.922
		$n = 50, g = 2$			< 0.001	17.874	< 0.001	29.582
		$n = 50, g = 5$					< 0.001	13.952
IndFgt	low turnover	$n = 50$	< 0.001	4.338	< 0.001	5.459	0.715	0.365
		$n = 50, g = 2$			0.155	1.426	< 0.001	3.822
		$n = 50, g = 5$					< 0.001	4.801
	medium turnover	$n = 50$	< 0.001	8.596	0.002	3.075	< 0.001	10.521
		$n = 50, g = 2$			0.001	3.251	< 0.001	14.997
		$n = 50, g = 5$					< 0.001	11.041
	high turnover	$n = 50$	< 0.001	8.331	< 0.001	37.250	< 0.001	62.895
		$n = 50, g = 2$			< 0.001	30.308	< 0.001	57.007
		$n = 50, g = 5$					< 0.001	27.705

Table A.8: Descriptive Statistics and Two-tailed t-Tests for Organizational Structures ($n = 50$) at Personnel Layoff

						low layoff		high layoff	
		min.	max.	mean	s.d.	p	t	p	t
OrgKnw	no layoff	0.446	0.577	0.530	0.025	< 0.001	5.416	< 0.001	14.312
	low layoff	0.484	0.598	0.548	0.024			< 0.001	9.385
	high layoff	0.509	0.634	0.582	0.027				
OrgLrn	no layoff	0.006	0.022	0.012	0.004	0.084	1.735	< 0.001	6.719
	low layoff	0.005	0.023	0.011	0.004			< 0.001	4.842
	high layoff	0.003	0.018	0.009	0.004				
OrgFgt	no layoff	0.392	0.436	0.411	0.009	< 0.001	14.952	< 0.001	41.931
	low layoff	0.376	0.417	0.393	0.009			< 0.001	27.131
	high layoff	0.328	0.381	0.356	0.010				
IndKnw	no layoff	0.760	0.976	0.897	0.041	0.884	0.147	0.892	0.136
	low layoff	0.792	0.976	0.898	0.038			0.995	0.007
	high layoff	0.791	0.980	0.898	0.040				
IndLrn	no layoff	0.001	0.016	0.007	0.004	0.413	0.821	< 0.001	4.248
	low layoff	0.001	0.017	0.006	0.004			0.001	3.269
	high layoff	0.000	0.012	0.005	0.003				
IndFgt	no layoff	0.017	0.048	0.029	0.007	0.985	0.018	0.845	0.195
	low layoff	0.014	0.049	0.029	0.007			0.829	0.217
	high layoff	0.016	0.044	0.029	0.007				

Table A.9: Descriptive Statistics and Two-tailed t-Tests for Organizational Structures ($n = 50, g = 2$) at Personnel Layoff

						low layoff		high layoff	
		min.	max.	mean	s.d.	p	t	p	t
OrgKnw	no layoff	0.473	0.623	0.564	0.032	0.035	2.124	< 0.001	5.659
	low turnover	0.496	0.638	0.574	0.031			< 0.001	3.728
	high turnover	0.506	0.659	0.591	0.035				
OrgLrn	no turnover	0.002	0.014	0.008	0.002	0.001	3.410	< 0.001	12.397
	low turnover	0.002	0.013	0.007	0.002			< 0.001	8.672
	high turnover	0.002	0.008	0.004	0.002				
OrgFgt	no layoff	0.283	0.332	0.309	0.011	< 0.001	7.739	< 0.001	20.859
	low turnover	0.276	0.325	0.298	0.010			< 0.001	13.542
	high turnover	0.251	0.305	0.277	0.011				
IndKnw	no layoff	0.692	0.910	0.827	0.046	0.810	0.241	0.724	0.354
	low turnover	0.717	0.918	0.826	0.043			0.897	0.129
	high turnover	0.703	0.926	0.825	0.048				
IndLrn	no layoff	0.000	0.011	0.005	0.002	0.001	3.320	< 0.001	10.887
	low turnover	0.000	0.010	0.004	0.002			< 0.001	7.332
	high turnover	0.000	0.006	0.002	0.001				
IndFgt	no layoff	0.018	0.040	0.029	0.005	0.474	0.718	0.120	1.561
	low turnover	0.019	0.041	0.029	0.005			0.396	0.850
	high turnover	0.018	0.045	0.030	0.005				

Table A.10: Descriptive Statistics and Two-tailed t-Tests for Organizational Structures ($n = 50, g = 5$) at Personnel Layoff

						low layoff		high layoff	
		min.	max.	mean	s.d.	p	t	p	t
OrgKnw	no layoff	0.449	0.593	0.521	0.028	0.783	0.276	0.101	1.648
	low turnover	0.430	0.597	0.522	0.030			0.064	1.866
	high turnover	0.433	0.587	0.514	0.030				
OrgLrn	no turnover	0.001	0.005	0.002	0.001	< 0.001	3.664	< 0.001	6.865
	low turnover	0.001	0.004	0.002	0.001			< 0.001	3.779
	high turnover	0.001	0.004	0.001	0.001				
OrgFgt	no layoff	0.185	0.232	0.214	0.008	0.009	2.649	< 0.001	8.186
	low turnover	0.188	0.237	0.210	0.009			< 0.001	5.798
	high turnover	0.172	0.234	0.202	0.012				
IndKnw	no layoff	0.586	0.791	0.692	0.037	0.616	0.502	< 0.001	3.919
	low turnover	0.565	0.792	0.689	0.040			0.001	3.319
	high turnover	0.558	0.758	0.671	0.040				
IndLrn	no layoff	0.000	0.003	0.001	0.001	< 0.001	3.747	< 0.001	5.190
	low turnover	0.000	0.002	0.000	0.000			0.050	1.974
	high turnover	0.000	0.003	0.000	0.001				
IndFgt	no layoff	0.018	0.032	0.026	0.003	0.001	3.435	< 0.001	9.577
	low turnover	0.021	0.037	0.028	0.003			< 0.001	6.635
	high turnover	0.020	0.048	0.032	0.005				

Table A.11: Descriptive Statistics and Two-tailed t-Tests for Organizational Structures ($n = 50, g = 10$) at Personnel Layoff

						low layoff		high layoff	
		min.	max.	mean	s.d.	p	t	p	t
OrgKnw	no layoff	0.391	0.474	0.432	0.019	0.009	2.651	< 0.001	26.012
	low turnover	0.377	0.475	0.425	0.021			< 0.001	23.178
	high turnover	0.258	0.415	0.339	0.031				
OrgLrn	no turnover	0.000	0.002	0.001	0.000	0.692	0.397	< 0.001	5.979
	low turnover	0.000	0.002	0.001	0.000			< 0.001	5.368
	high turnover	0.000	0.002	0.001	0.000				
OrgFgt	no layoff	0.157	0.195	0.174	0.008	0.055	1.931	< 0.001	23.117
	low turnover	0.150	0.192	0.172	0.009			< 0.001	20.975
	high turnover	0.101	0.166	0.137	0.014				
IndKnw	no layoff	0.504	0.605	0.557	0.024	0.003	3.048	< 0.001	26.800
	low turnover	0.483	0.609	0.546	0.026			< 0.001	23.822
	high turnover	0.328	0.536	0.431	0.040				
IndLrn	no layoff	0.000	0.001	0.000	0.000	0.473	0.720	0.215	1.244
	low turnover	0.000	0.001	0.000	0.000			0.078	1.773
	high turnover	0.000	0.001	0.000	0.000				
IndFgt	no layoff	0.024	0.045	0.035	0.004	0.001	3.505	0.895	0.132
	low turnover	0.023	0.050	0.037	0.005			0.003	2.982
	high turnover	0.019	0.048	0.035	0.006				

Table A.12: Descriptive Statistics and Two-tailed t-Tests for Communities of Practice ($n = 50, g = 5$)

						expert		gatekeeper		random	
		min.	max.	mean	s.d.	p	t	p	t	p	t
OrgKnw	no cop	0.449	0.593	0.521	0.028	< 0.001	37.548	< 0.001	38.479	< 0.001	37.876
	expert	0.553	0.715	0.668	0.027			0.262	1.126	0.388	0.865
	gatekeeper	0.598	0.710	0.663	0.024					0.803	0.249
	random	0.591	0.715	0.664	0.026						
OrgLrn	no cop	0.001	0.005	0.002	0.001	< 0.001	27.749	< 0.001	32.189	< 0.001	30.142
	expert	0.007	0.028	0.014	0.004			0.177	1.354	0.937	0.079
	gatekeeper	0.008	0.025	0.014	0.004					0.185	1.330
	random	0.006	0.024	0.014	0.004						
OrgFgt	no cop	0.185	0.232	0.214	0.008	< 0.001	47.873	< 0.001	49.787	< 0.001	48.388
	expert	0.246	0.281	0.263	0.007			0.749	0.321	0.995	0.006
	gatekeeper	0.246	0.278	0.263	0.006					0.750	0.320
	random	0.250	0.282	0.263	0.006						
IndKnw	no cop	0.586	0.791	0.692	0.037	< 0.001	35.357	< 0.001	35.866	< 0.001	36.254
	expert	0.727	0.935	0.873	0.035			0.187	1.325	0.376	0.887
	gatekeeper	0.777	0.929	0.867	0.031					0.644	0.463
	random	0.782	0.932	0.869	0.031						
IndLrn	no cop	0.000	0.003	0.001	0.001	< 0.001	26.942	< 0.001	30.420	< 0.001	29.117
	expert	0.004	0.018	0.009	0.003			0.236	1.189	0.802	0.252
	gatekeeper	0.005	0.018	0.010	0.003					0.133	1.508
	random	0.003	0.016	0.009	0.003						
IndFgt	no cop	0.018	0.032	0.026	0.003	< 0.001	40.210	< 0.001	42.859	< 0.001	36.648
	expert	0.036	0.062	0.048	0.005			0.103	1.636	0.678	0.415
	gatekeeper	0.039	0.061	0.049	0.004					0.276	1.093
	random	0.035	0.063	0.048	0.005						

Table A.13: Descriptive Statistics and Two-tailed t-Tests for Communities of Practice ($n = 50, g = 10$)

						expert		gatekeeper		random	
		min.	max.	mean	s.d.	p	t	p	t	p	t
OrgKnw	no cop	0.391	0.474	0.432	0.019	< 0.001	69.738	< 0.001	66.607	< 0.001	58.653
	expert	0.606	0.729	0.664	0.028			0.068	1.837	0.045	2.020
	gatekeeper	0.565	0.706	0.656	0.028					0.735	0.339
	random	0.571	0.715	0.655	0.033						
OrgLrn	no cop	0.000	0.002	0.001	0.000	< 0.001	29.008	< 0.001	32.653	< 0.001	30.013
	expert	0.004	0.026	0.014	0.004			0.023	2.288	0.006	2.772
	gatekeeper	0.005	0.027	0.015	0.004					0.537	0.618
	random	0.005	0.030	0.016	0.005						
OrgFgt	no cop	0.157	0.195	0.174	0.008	< 0.001	84.588	< 0.001	81.607	< 0.001	77.941
	expert	0.255	0.299	0.272	0.008			0.775	0.286	0.297	1.046
	gatekeeper	0.244	0.294	0.272	0.009					0.454	0.750
	random	0.251	0.294	0.273	0.010						
IndKnw	no cop	0.504	0.605	0.557	0.024	< 0.001	72.216	< 0.001	69.454	< 0.001	61.393
	expert	0.787	0.937	0.859	0.034			0.034	2.141	0.024	2.278
	gatekeeper	0.734	0.916	0.849	0.035					0.749	0.321
	random	0.741	0.915	0.847	0.041						
IndLrn	no cop	0.000	0.001	0.000	0.000	< 0.001	25.759	< 0.001	28.705	< 0.001	27.047
	expert	0.002	0.023	0.010	0.004			0.031	2.171	0.005	2.813
	gatekeeper	0.002	0.021	0.012	0.004					0.454	0.750
	random	0.003	0.025	0.012	0.004						
IndFgt	no cop	0.024	0.045	0.035	0.004	< 0.001	38.442	< 0.001	42.538	< 0.001	41.360
	expert	0.050	0.089	0.067	0.007			0.014	2.486	0.001	3.262
	gatekeeper	0.052	0.089	0.069	0.007					0.379	0.882
	random	0.053	0.091	0.070	0.007						

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