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Information-processing Capabilities as a Transactive Memory System

A Comparative Study of Two Distributed R&D Teams

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Informaationkäsittely transaktiivisenä muistijärjestelmänä: Kahden hajautetun tuotekehitystiimin vertailututkimus.

Tiivistelmä

Tämä väitöskirja pyrkii luomaan uutta tietoa hajautetuista tuotekehitys- ja tutkimustiimeistä transaktiivisen muistin teoriasta käsin. Sen mukaan ihmiset saattavat, sen sijaan että itse pyrkivät muistamaan asioita, pitää muistissaan sen kuka on minkäkin alueen ekspertti ja ottamaan heihin yhteyttä tarvittaessa. Tutkimus perustuu hypoteesiin jonka mukaan yksinkertaisissa tehtävissä hyvin suoriutuvalla tiimillä voi olla yksinkertainen transaktiivinen muistijärjestelmä, kun taas monimutkaisissa tehtävissä tehokkaiden tiimien transaktiiviset muistijärjestelmät ovat pidemmälle kehittyneitä.

Työssä tarkastellaan kolmea tutkimuskysymystä: (1) millaisia ovat piirteiltään hajautettujen tuotekehitysryhmien transaktiiviset muistijärjestelmät, (2) kuinka muistijärjestelmät tällaisissa yhteyksissä kytkeytyvät tiimien kommunikaatioon (taajuuteen ryhmän jäsenten välillä) ja (3) onko kehittynyt transaktiivinen muistijärjestelmä välttämätön ehto myös yksinkertaisissa tuotekehitystehtävissä?

Työssä tarkasteltiin kahta hajautettua ohjelmistokehitystiimiä. Molemmissa tapauksissa transaktiiviset muistijärjestelmät olivat vain paikallisia; kaukaisten tiimien osien tietämyksestä jäsenillä oli harvoin mitään tietoa. Ensimmäisellä casetiimeistä oli vain yksinkertaisia tehtäviä, joista se suoriutui hyvin. Pitkälle kehittynyt transaktiivinen muisti ei siis ole yksinkertaisissa tehtävissä välttämättömyys. Tämän löydöksen tulisi teoreettisesti olla yleistettävissä samantyyppisiin menestyksekkäihin tiimeihin.

Käytännön työn kannalta transaktiivisen muistin kehittymiseen ilmeisesti kannattaa panostaa vain monimutkaisissa tehtävissä. Työn teoreettinen kontribuutio on kontingenssihypoteesin tuominen transaktiivisen muistin teoriaan ja tapausevidenssin lisäämistä teoriaan hajautettujen tiimien tapauksissa.

Asiasanat
hajautetut tiimit; informaation käsittely; transaktiivinen muisti; tuotekehitystiimien suorituskyky; case-tutkimus; kontingenssiteoria

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Information-processing capabilities as a transactive memory system: A comparative study of two distributed R&D teams

Abstract

The dissertation deepens knowledge on distributed R&D teams through the lens of transactive memory theory. A transactive memory system consists of individuals' expertise, knowledge on "who knows what", and communication between team members. It is proposed that an R&D team will perform successfully, if simple tasks are matched with less developed transactive memory system whereas complex tasks are matched with more developed transactive memory system.

Qualitative research design is followed. Three research questions are asked: (1) How does a transactive memory system in a distributed R&D team look like?, (2) How is a transactive memory system in a distributed R&D team connected to its communication pattern (frequency of communication between team members)?, and (3) Is a developed transactive memory system a necessary attribute of a successfully performing R&D team with a simple task?

Two distributed software development teams were studied. In both cases transactive memory systems were geographically localized: team members knew better peers from the same geographical location than those in distant offices. Communication was also geographically localized; communication patterns and expertise recognition were correlated. The answer to the third question was positive. The findings are generalizable to the similar type of distributed R&D teams.

Practical implications include that special attention to transactive memory system development should be paid only when team tasks are complex. From a theoretical point of view, the study extends the theory of transactive memory by introducing a contingency factor and bringing qualitative evidence on transactive memory systems in distributed organizational settings.

Keywords

distributed teams; information-processing; transactive memory; R&D performance; case study; contingency theory

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Vaasa, September 2008

Natalia Kitaygorodskaya

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Abbreviations

R&D	Research and Development
TEP	Task-Expertise-Person
TRG	Technical Reference Group
RQ	Research Question

1. INTRODUCTION

1.1. “What is all about?”

Transactive memory system is a relatively new concept in organizational studies. Many people, both at conferences and in “civil” life, have asked me: “What it means?” with perplexity in their voices. So I would like to start this manuscript with a simple explanation of what the concept of transactive memory system is, and of how I, a mathematician according to my master’s degree, ended up doing a doctoral research on a topic which is very far from math.

The fact is that I have always been interested in management. It has aroused my curiosity how people work together and how to manage them in a way that their skills and knowledge add up into something more than a mere sum of their individual work outcomes. I have been thinking that it would be useful to understand the mechanisms of group work in order to be better prepared when it comes to manage people. Once, reading a book on communication networks, I came across a notion of a transactive memory system. Not understanding it quite well at that time, I felt: “There is something”. And so my research started.

A transactive memory system describes, simply speaking, a group memory. People who hear this for the first time ask usually: “Is there anything like a “group memory”? Can groups think? Can groups remember?” I believe they do. Imagine your spouse and yourself discussing household matters. One knows on which shelves spices are, the other can say where exactly to find a spanner number four. Of course, you both may know this. But what is the point in remembering that, if there is always the other who knows better, whom you trust and whom you can ask when necessary? This very system of remembering of “who knows what” which develops and functions on a basis of communication, is called a *transactive* (i.e. based on communication) *memory* (people remember “who knows what”) *system* (pertains to a group, not a single individual). It is necessary to mention that a transactive memory system does not describe how groups remember “lessons of history”. Nor it pertains to changes of one’s reputation over time. These issues are studied by sociologists. The primary application of the concept is explanation of group performance.

The process of doing a PhD research is not only about advancing the science but also about personal growth. I have discovered for myself the world of social sciences which has turned out to be (“surprise”) completely different compared to that of exact sciences, e.g. math. Being trained on the basis of theorems and axioms, I was used to building my reasoning by relying on clear definitions. And I was exhausted having realized that in social sciences numerous definitions of the same concept may exist; some of them may be even conflicting. Thus I had to learn how to deal with this ambiguity and proceed with the research without losing myself in fruitless attempts to find the only one right definition.

The aim of this manuscript is to present in a clear and concise manner the logic behind the study, the research procedure, and the findings. The remainder of this introductory chapter describes the relevance of the research, research questions, and the overall structure of the manuscript.

1.2. Relevance of the research

Research and development (R&D) activities are critical for modern companies. As early as in 1991, Roussel, Saad, & Little (1991) noted that technically based competition increased and, consequently, R&D should be treated as "a strategic competitive weapon". A decade later, Tidd, Bessant, & Pavitt (2001) affirmed their statement by saying that the future winners will be those companies that are able to change their products and processes.

Reflecting a general trend towards organizations becoming more virtual (DeSanctis & Monge 1999), a number of teams whose members are situated in geographically distant places (buildings, cities, countries) are growing nowadays (Lipnack & Stamps 1999). Such teams are called distributed, dispersed, virtual or global, depending on which characteristic different authors stress. R&D activities also become more internationalized (Granstrand 1999; Gassmann & von Zedtwitz 1999; Gerybadze & Reger 1999; von Zedtwitz & Gassmann 2002; Le Bas & Sierra 2002; Howells 2006). Project members increasingly work across time, space, and organizational boundaries (Gassmann & von Zedtwitz 2003; McDonough III, Kahn, & Barczak 2001). Traditional project management training could be inadequate in such context (Gassmann & von Zedtwitz 2003). Distributed teams may suffer from rising project costs and weak internal coordination.

Despite increasing academic interest, distributed teams remain relatively unstudied (Potter, Balthazard, & Cooke 2000; Bell & Kozlowski 2002; Barczak & McDonough III 2003). As Saunders & Ahuja (2006) say, the field is still "'maturing' rather than 'matured'". Snow, Lipnack, & Stamps (1999) note that most of literature on virtual type of organizing is more conceptual rather than empirical. Teams as an organizational form do not receive necessary attention in knowledge management literature either (Becker 2003). Furthermore, knowledge utilization, i.e. application of the knowledge that already exists in teams, is the least studied stream in knowledge management research (Alavi & Tiwana 2002).

This work seeks to deepen knowledge on distributed teams. Following the suggestion of Fulk, Monge, & Hollingshead (2005a), a theory of transactive memory is used to study how knowledge is utilized in distributed R&D teams. A contingency framework is proposed which suggests that R&D team's information processing requirements (operationalized as team' task complexity) should be matched with its information processing capabilities (operationalized as team' transactive memory system). Ambiguities in understanding distributed work as well as untested applicability of transactive memory measurement approaches to distributed settings called for the case study research design. Comparison between two software development teams is presented which tentatively supports the proposed contingency framework.

From a practical point of view, this research brings better understanding on knowledge utilization in distributed R&D teams and comes up with recommendations to managers on which tasks are better for distributed settings and how a transactive memory system could be build when team members are located far from each other. From a theoretical point of view, the study extends the theory of transactive memory by introducing a contingency factor and bringing empirical evidence on transactive memory systems in organizational settings, which is by far rather limited (Fulk, Monge, & Yuan 2005b).

1.3. Introduction to research questions

A theory of transactive memory is built on the observation that people may, instead of memorizing information themselves, remember who experts in certain areas are and contact them when necessary (Wegner 1987). On a team level, individuals' own expertise, knowledge on "who knows what" and communication between team members comprise team memory, i.e. a transactive memory system. It is agreed that a transactive memory system is developed when team members specialize in different knowledge areas, know about specialization of each other, and communicate freely to combine their expertise when necessary. Laboratory experiments have shown that a developed transactive memory system has a positive impact on group performance. Studies in actual work settings are limited.

Two main issues should be considered when applying transactive memory theory to organizational teams. First, actual work teams could be different compared to experimental ones in terms of physical proximity of team members, communication media used, communication patterns, group size, etc. These factors could affect development and functioning of a transactive memory system. The nature of this influence is not clear. Second, laboratory experiments have not controlled for information processing requirements faced by experimental teams, e.g. for task complexity. At the same time and according to contingency theory, for a team to perform successfully, its information processing requirements should be matched with its information processing capabilities. A transactive memory system could be thought of as a team information processing capability. Hence it is questionable if a developed transactive memory system has a positive impact on team's performance in all possible cases, disregard to team information processing requirements.

This work studies transactive memory systems in actual organizational teams and addresses the following questions. The first question is how a transactive memory system in a distributed R&D team looks like. An answer to this question would bring better understanding of both transactive memory systems and distributed work in general.

The second question asks how a transactive memory system in a distributed R&D team is connected to its communication pattern (understood as frequent communication between team members). This question is built on the results of research on communication in R&D settings reviewed in detail the third chapter of this manuscript.

The third question is whether a developed transactive memory system is a necessary attribute of a successfully performing R&D team with a simple task. The answer to this question may falsify the main argument of the transactive memory theory that a developed transactive memory system is beneficial for any team. It could also shed some light on a contingency aspect of a transactive memory system in terms of information processing requirements actual work teams may face.

1.4. Structure of the manuscript

Chapter 1 is the manuscript introduction. It describes research in a plain language and gives a general description of the work.

Chapter 2 is dedicated to main assumptions, definitions, and theories. It provides in-depth description of the theory of transactive memory and related concepts.

Chapter 3 explains the logics behind the research questions. It reviews contingency theory and previous studies on communication in R&D teams. These works are used to build research questions.

Chapter 4 is fully devoted to the empirical part of this work. Research design, cases description, and data analysis lead through the process of answering research questions.

Chapter 5 overviews and discusses the findings. Implications for theory and practice, weaknesses of the research, as well as directions for future studies are also presented there.

2. BASIC ASSUMPTIONS, DEFINITIONS, THEORIES

2.1. Basic assumptions and definitions

Team. Teams are prevalent in contemporary organizations (Devine, Clayton, Philips, Dunford, & Melner 1999). In this paper, a team is defined as a work group whose members (1) have a common goal, (2) are assigned specific roles, (3) communicate with each other to accomplish common goals, and (4) a group has information-processing structure based on its internal communication pattern (Modrick 1986). It should be noted that research literature is marked with definitional disagreement on what a team is and in which way it differs from a group. For example, Salas, Dickson, Converse, & Tannenbaum (1992) stress that a team has a limited life span whereas Saunders & Ahuja (2006) talk about both temporary and ongoing teams. Some researchers emphasize that a team is more than a group by pointing at common commitment of its members (Katzenbach & Smith 1993; Harris & Sherblom 1999) while others argue that, though there are degrees of difference, a team and a group are not fundamentally different (Guzzo & Dickson 1996). In this work the abovementioned definition by Modrick (1986) is kept in mind. As a matter of convenience and following Guzzo & Dickson (1996), the words "group" and "team" are used interchangeably.

Distributed team. For this study, a distributed work setting is chosen. This means some or all team members are situated in geographically distant places (buildings, cities, or countries). Such teams have got different labels in the literature. They are called distributed (Hinds & Kiesler 2002; Saunders & Ahuja 2006), dispersed (Cramton 1997; Fulk et al. 2005a), or, if cultural diversity of team members is stressed, global (McDonough III et al. 2001; Zakaria, Amelinckx, & Wilemon 2004). Geographical separation is also an indispensable part of numerous definitions of virtual teams (Bell & Kozlowski 2002; Townsend, DeMarie, & Hendrickson 1998; Griffith & Neale 2001; Griffith, Sawyer, & Neale 2003; Alavi & Tiwana 2002; McDonough III et al. 2001; Kratzer, Leenders, & van Engelen 2005). In this work the term "distributed" is used to emphasize geographical distance between team members. Other features of "virtualness", such as characteristics of mediating technologies or cultural differences of team members, are not stressed in the research.

Team as a unit of analysis. There are two reasons for choosing a team as a unit of analysis. First, it is a team, not an organizational group, because team members have a common goal (see the team definition above). A common goal is necessary for transactive memory system development because, to fulfill it, team members must coordinate their activities (Wegner, Erber, & Raymond 1991; Brandon & Hollingshead 2004; Hollingshead 2001; Cooke, Salas, Cannon-Bowers, & Stout 2000). If people are assigned to organizational groups which may not necessarily have common tasks, they do not need to interact; hence transactive memory systems in such groups may not develop at all.

Second, the unit of analysis is not an entire organization because the theory of transactive memory describes memory phenomenon on a group level and its extension to organizations is problematic (Nevo & Wand 2005). However, following the principle of inclusion (according to which units that a lower in hierarchy can be defined in terms or properties of a higher unit (Rousseau 1985)), a relative concept of "organizational memory" is reviewed in this work later. It should be noted, though, that generally "[t]he interplay between individual, group, and organizational levels has been poorly described in the literature" (Hedberg 1981).

Functional perspective on teams. To organize current research, a functional perspective on teams is adopted (Wittenbaum, Hollingshead, Paulus, Hirokawa, Ancona, Peterson, Jehn, & Yoon 2004). This means that teams are assumed to be (1) goal-oriented; (2) different in their measurable performance; and (3) influenced by internal and external factors. Specifically, factors that are important for research on distributed teams can be categorized into (1) internal (effective team processes and traits), (2) external (team boundaries and gatekeeping), (3) technological (effective technologies for distributed work), and (4) societal (implications for workplace and society) (Piccoli 2000). This research is focused on internal factors.

Team as a cohesive entity. In this work, teams are conceived of as cohesive entities rather than as a cumulative sum of their members. This is the main premise of a broader stream of studies on social cognition. The initial idea is usually traced back to Durkheim (1965) who argued that group knowledge may go beyond cognitive abilities of individuals. Specifically, regarding collective memory, Durkheim's student Halbwachs (1950) first talked about memory as a collective quality.

The term "social cognition" requires additional discussion. It originated in the field of social psychology and is, confusingly, used to label two research streams which are based on different research paradigms (Ickes & Gonzalez 1996). The first one is focused on cognitions of individuals who are assumed to be independent members of collectives. On the contrary, the second stream emphasizes interdependence of individuals and their involvement with each other and, unlike the first one, is concerned with patterns of individuals' interdependence.

Specifically in organizational studies, research on social cognition is conducted at four levels of analysis: individual, group, organizational, and interorganizatoinal (industry-level) (Schneider & Angelmar 1993; Walsh 1995). The first "social cognition" paradigm is typical for individual level of analysis; the second one is often implicit in studies of groups and whole organizations. Research on transactive memory is based on the second paradigm and stresses interdependent character of group cognition (Wegner, Giuliano, & Hertel 1985; Moreland, Argote, & Krishnan 1996).

It should be noted that not all researchers who study collectives share an intersubjective view on social cognition. Some say that only individuals are capable of cognizing, for example, only individuals can learn (March & Olsen 1976; Simon 1991) or possess knowledge (Grant 1996). At the same time, many others point out that, though organizations do not have brains, they do have cognitive systems and memories (Hedberg 1981). In the same vain, some researchers notice that organizations persist despite employee turnover. For example, standard operating procedures (Cyert & March 1963), customs and symbols (Cohen 1974) are remembered in organizations for a long time. Therefore, it can be said that organizations function as distinct entities (Hall 1987). Weick (1979) views an organization as "a body of thought sustained by a set of thinkers and thinking practices" and stresses that collective rather than individual knowledge should be the object of study. Similarly, Sandelands & Stablein (1987) say that "organizations are mental entities capable of thought".

On reification and anthropomorphism. Studies on group memory are generally criticized for reification (treating an abstract concept as a real thing) and anthropomorphism (attributing human characteristics to nonhuman units) (Schneider & Angelmar 1993). This is a fair critique as long as a researcher forgets about "building blocks" (i.e. individuals and interactions between them) of collective concepts and starts treating these concepts as independent entities that can themselves make individuals perform certain actions (Mouzelis 1991). In this research group memory is studied from interdependent viewpoint on social cognition. This weakens the ground for critique in reification and anthropomorphism.

Research and development (R&D). The term "Research and Development" covers a range of activities that a company pursue to produce new knowledge. Scientists have come up with several R&D typologies.

Pappas & Remer (1985) describe five types of R&D: (1) basic research, (2) exploratory research, (3) applied research, (4) product development, and (5) product improvements. Roussel et al. (1991) talk about (1) incremental (small advances in technology; application of existing knowledge; "small 'r' and big

'D')), (2) radical (discovery of new knowledge with a clear business purpose; "large 'R' and often large 'D'"), (3) fundamental (enquiry into unknown; "large 'R' and no 'D'") types of R&D. Tidd et al. (2001) say that innovations can be put on a two-dimensional space. One dimension describes a perceived extent of change: incremental, radical, or transformational. The other dimension pertains to what is changed: a product, a service, or a process.

Whatever a typology is, R&D activities could be situated on a continuum on the one end of which is "research", aimed at development of new knowledge, while on the other end is "development", focused on application or expansion of already existing knowledge. Empirical part of this research is based on new product development teams ("development" end of the continuum). However, throughout the manuscript, the term "R&D" is used to stress that the label "R&D" may pertain to quite different activities and that apparently no universal approach to management of R&D teams could exist.

Distributed R&D teams. There are several typologies of distributed R&D teams. For example, McDonough III et al. (2001) differentiate between (1) collocated (people work in the same physical location and are culturally similar), (2) virtual (people are relatively physically proximate (located in the same building or country and are culturally similar), and (3) global (physically far from each other and culturally different) new product development teams. In a sample of 103 US companies, they found that a number of collocated teams remained nearly constant during last five years, preceding the moment of the study. However companies were going to use slightly less number of collocated teams in the future. A number of virtual teams had been declining and was going to decline further. At the same time, a number of global teams were increasing. Companies in the sample were also going to abandon an exclusive use of a certain type and rely, instead, on teams of all three types.

Another typology is suggested by Gassmann & von Zedtwitz (2003). They define a virtual team as "a group of people and subteams who interact through interdependent tasks guided by common purpose and work across space, time, and organizational boundaries with links strengthened by information, communication, and transport technologies." Participation in virtual teams may be temporary, so team boundaries could vary. Building on this definition and 204 interviews in 37 multinational companies, Gassmann & von Zedtwitz (2003) identified four types of virtual teams depending on the degree of centralized control. The first type is "decentralized self-coordination". Members of such teams seldom meet face-to-face. They have neither a central project manager nor a rigid time schedule. The second type is "system integration coordinator". Such teams have a system integrator that harmonizes interfaces between people and modules. A system integrator does not have a formal authority. The third type is a "core team as system architect". In such virtual teams, key decision-makers meet regularly and maintain coherence of the project. A core team has a power to enforce its instructions. The forth type is a "centralized venture team". In such teams people from different locations are concentrated in one place. Despite temporal and spatial collocation, venture teams are still virtual in a sense that they are transnational and cross organizational boundaries. Venture teams are very costly and used only for the projects of utmost importance.

It is obvious that existing typologies of distributed R&D teams are quite different which reflects the emerging character of the research field. Thus in this research, in order to avoid confusion, studied teams are not classified according to any typology.

2.2. Information processing perspective on teams

In this research information processing perspective on teams is taken. The term "information processing" originated, as cited by Ungson, Braunstein, & Hall (1981), in communications theory (Shannon & Weaver 1949) and was later popularized by Simon and colleagues (Simon 1969; Newell & Simon 1972) who developed computer simulations of individual thinking processes. In the seventies information processing was extended to organizations (Driver & Streufert 1969; Galbraith 1973; Tushman & Nadler 1978). In psychology, the work of Hinsz, Tindale, & Vollrath (1997) is referred to as being central to conceptualizations of groups as information processors.

The main concept of this perspective is *information*. "Information refers to data which are relevant, accurate, timely, and concise" (Tushman & Nadler 1978). Information leads to changes in knowledge. In their discussion of individual information processing, Ungson et al. (1981) define information as "stimuli (or cues) capable of altering an individual's expectations and evaluation in problem solving and decision making". On a more general level, Driver & Streufert (1969) say that information is "anything that alters subjective (or objective) probabilities or utilities". In organizational context, information could be plans, budgets, feedback on performance, sales reports, market trends, aspects of workmates, the pattern of interaction, etc. (Tushman & Nadler 1978; Hinsz et al. 1997).

The second concept is a *system*. A system is defined as a "complex of elements in mutual interaction" (Driver & Streufert 1969). In early works it was supposed that, despite individuals, groups and organizations are different, they, nevertheless, bear similar basic features in organization and structure. Later works rather talk about functional equivalence of these systems. For example, Lord (1985) discusses five steps of individual information processing which are (1) selective attention/comprehension, (2) encoding, (3) storage and retention, (4) information retrieval, and (5) judgment. In the similar manner, Wegner et al. (1985) include in the theory of transactive memory such processes as transactive acquisition, storage, and retrieval. While doing so, they explicitly underscore functional equivalence of individual and group memory.

The third important concept is *input*. Input is information initially external to the system that is, after being processes by the system, "capable of altering the utility and probability patterns in an individual or group" (Driver & Streufert 1969). The last concept is *complexity* of the information that is "the number of utility or probability changes that an input can potentially evoke…" (Driver & Streufert 1969).

From the information processing perspective, organizations are open systems dealing with environmental and internal uncertainty (Tushman & Nadler 1978). They are transparent to information coming from the external pre-given world and are capable of creating representations of this world (von Krogh & Roos 1995). Information processing is the main activity of organizations and is defined as "gathering, interpreting, and synthesis of information in the context of organizational decision making" (Tushman & Nadler 1978).

Walsh (1995) notes that there are two modes of information processing: "theory-driven" and "data-driven". "Data driven" mode is a "bottom up" process of data analysis. On the contrary, "theory driven" mode is a "top down" process. "Data driven" mode is a primary source of insights; however, it is employed less often than "theory driven" mode. At the heart of "theory driven" information processing lies a concept of mental template (Walsh 1995) or mental model (Klimoski & Mohammed 1994; Mohammed & Dumville 2001). Depending on a level of analysis, researchers study individual or collective mental models. It is assumed that shared team mental models improve group theory-driven information processing. Among their drawbacks is predictable (within the frame of a mental model) information processing that may limit understanding of a situation (Sparrow 1999; Walsh 1995).

Lord & Maher (1990) describe four alternative types of individual information processing models used in management and psychology. According to the *rational model*, people thoroughly process all available information in search for the best solution or maximum output. This model has a strong prescriptive value, but its descriptive accuracy is weak: people rarely behave in a way predicted by this model. *Limited capacity model* weakens conditions of the rational model and assumes that people simplify information processing in search for adequate (not necessarily optimal) solutions. *Expert information processing model* puts emphasis on the use of already developed deep knowledge of experts that complements simplified information processing. Experts have much bigger knowledge base, acquired through experience, than novices; hence they have more resources to tap into during information processing. Rational, limited capacity, and expert models are static ones. According to the last type of information processing models, *cybernetic model*, information processing can be altered by feedback. As for groups, Lord & Maher (1990) mention that expert and cybernetic models may be useful for understanding effective group functioning; whereas rational and limited capacity models could explain the difficulties.

Hinsz et al. (1997) go further in the conceptualization of groups as information-processors. They note that group processing depends on individuals whereas individual processing depends on groups. Group information processing is "the degree to which information, ideas, or cognitive processes are shared, and are being shared, among the group members and how this sharing of information affects both individual and group-level outcomes" (Hinsz et al. 1997). In a step-by-step description of a generic model of information processing (Figure 1), Hinsz and colleagues review studies related to individual and group information processing and outline differences between them.

Group processing *objectives* could arise from instructions, tasks characteristics, group members' perspectives, group interaction, and other sources. Groups may lead members to become more *attentive* to the self (e.g. "Do I behave appropriately?") or, alternatively, make members focus more on task aspects. If information is distributed unevenly in a group (e.g. some people know certain facts whereas others do not), group members discuss more shared information than unshared. Research shows that a group would pay attention to some information if at least two group members know it. Time pressures could force group members to focus more on task completion; however, if there is enough time, members would pay more attention to task completion quality. Evidence on *encoding* (i.e. creating representations of information by structuring, evaluation, interpretation, and transformation) shows that groups may create both simpler and more complex representations compared to individuals depending on a task and situational factors.

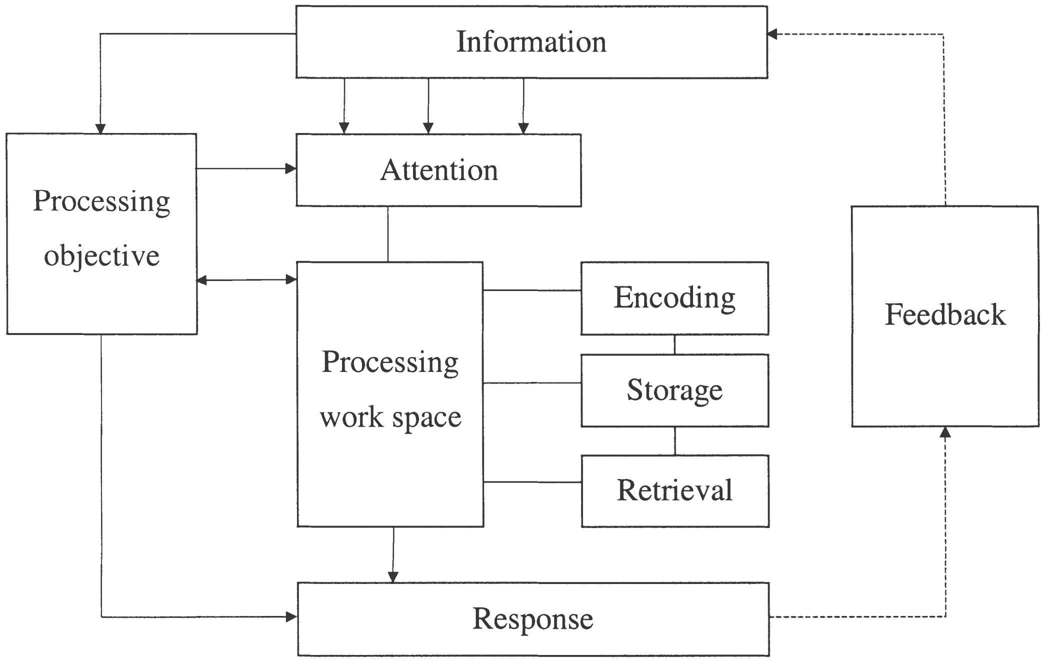

Figure 1. Generic model of information processing (Hinsz et al. 1997).

Storage (i.e. memory) is central to information processing. Research findings demonstrate that groups are more effective than individuals in remembering information; at the same time, they could be less efficient. Hinsz et al. (1997) particularly mention the theory of transactive memory as one that could explain group memory. Regarding *retrieval*, it has been discovered that groups are more accurate than individuals. However interaction during retrieval phase may stimulate or interfere with the retrieval processes of individuals. During *processing* phase, groups combine, integrate, and process information. The evidence shows that groups tend to escalate commitment to the existing course of action. Groups also tend to intensify individuals' information processing biases. At the same time, groups are more consistent on their use of information processing rules and strategies. In this sense, groups are more reliable than individuals. A group *response* could be a decision, inference, evaluative judgment, or solution to a problem. Clearly, a type of response depends on the type of a group task and information processing that precedes it. *Feedback* received by groups may include evaluation of group and/or individual performance. Group members also receive internal feedback during group interactions. Feedback may change the situation and add new information to be processed. It may also influence group processes and outcomes. *Learning*, though not included in the model, spans basically all the phases of information processing.

Altogether, after a through review of studies related to individual and group information processing, Hinsz et al. (1997) conclude that, despite there are similarities between individual and group processing of information, there are distinct differences. Some of these differences are already known to researchers; some may still be waiting to be identified in the future.

Coming back to the studies of organizations, Tushman and Nadler (1978) say that, because organizations consist of interdependent subunits, a subunit should be a central unit of analysis from an information processing viewpoint. R&D teams are organizational subunits and, thus, suit well for the study of organizations from information processing perspective. This view is shared by other researchers. For example, Song, van der Bij, & Weggeman (2005) studied antecedents of knowledge application from both knowledge-based and information processing perspectives. Veldhuizen, Hultnik, & Griffin (2006) explored market information processing during the stages of new product development process. Leenders, van Engelen, & Kratzer (2003) note that "innovation is mainly an information processing activity". Kekäle (1999) conceives of an R&D team as a black box that gets task as incoming information (including customer needs, product strategy, and manufacturing constraints), processes it and produces a required output (e.g. product design) (Figure 2). Managerial efforts are normally aimed at fulfillment of the task by guiding effective and efficient information processing.

Task → R&D team → Result

Figure 2. R&D team from information processing viewpoint.

This research focuses on the memory constituent of group information processing. Following Hinsz et al. (1997), a theory of transactive memory is used to explain group memory.

2.3. The theory of transactive memory

Definition. "A transactive memory system is a set of individual memory systems in combination with the communication that takes place between individuals" (Wegner 1987). This concept evolved from the observation that people in groups may not memorize all information themselves. Instead, they may memorize who are, among their group-mates, experts in certain areas, or in other words "who knows what", and contact these experts when necessary. In this way, people in groups may have access to detailed information without actually possessing it in their own memory (Wegner et al. 1985; Wegner & Wegner 1995).

Individual memory systems as components of a group transactive memory system are comprised of three types of information (Wegner et al. 1985; Wegner 1987; Wegner & Wegner 1995). The first type is low-order information (Wegner & Wegner 1995) or memory items (Wegner 1987). This information "what is remembered"; it consists of specific details on a subject. The second type is high-order information (Wegner & Wegner 1995) or memory item labels (Wegner 1987). This information indicates a broader category to which the memory item belongs. The third type is location information (Wegner 1987; Wegner & Wegner 1995). It describes where the memory item is stored. In a group with a transactive memory system, a group member may not remember specific details on a subject (i.e. may not store a memory item internally). Instead, he or she may remember that another group member already knows necessary details. In this case location information in the individual memory points out to that person.

Individual memory systems, comprised of individual areas of expertise as well as knowledge on "who knows what", constitute a structural ("knowledge") component of a transactive memory system. Communication processes among group members constitute a process component (Wegner et al. 1985; Wegner & Wegner 1995). A transactive memory system is a property of a group (Wegner 1987) and not reducible to individual memories (Wegner et al. 1985, 1991). The word "transactive" points out to the importance of communication for group memory development and functioning.

Development of a transactive memory system. A transactive memory system is likely to change over time. This change involves updates of information group members have of each other knowledge.

At the early stages of group existence, expertise judgments on "who knows what" are often based on stereotypes. Hollingshead & Fraidin (2003) demonstrated that, when other information is not available, assumptions about group members' expertise are based on gender stereotypes. These assumptions can also be based on age, race, occupation, and other characteristics. Such "default entries" (Wegner 1995) are often erroneous and memory systems built on them are poor (Wegner 1987). When people stay together longer, they learn each other better and expertise judgments become more accurate.

The process of getting to know each other is often implicit. For example, people may be recognized as experts on the basis of demonstrated skills ("expertise entries") or as a result of accessing information first in the group ("access entries") (Wegner 1987, 1995). Formal groups may explicitly assign responsibility for certain knowledge domains to specific individuals. In this case "negotiated entries" on "who knows what" are created (Wegner et al. 1991; Wegner 1995). Hollingshead (2000) discovered that, in new groups with no social interaction, explicitly given knowledge on “who knows what” affects what individuals would learn. At the same time, Wegner et al. (1991) demonstrated that performance of groups with already existing transactive memory systems (close couples in the experiment) deteriorated when group members got explicit assignments on “who knows what”. Newly created groups in the same experiment benefited from getting explicit memory assignments; however the improvement was not significant. Wegner et al. (1991) suggested that groups may need some time to make explicit expertise assignments work.

Though a transactive memory system could develop of the basis of stereotypes (Hollingshead & Fraidin 2003) or provided descriptions of “who knows what” (Hollingshead 2000; Moreland & Myaskovsky 2000), group members usually communicate, and communication plays important role in development of a transactive memory system (Hollingshead & Brandon 2003; Fulk et al. 2005b). For example, communication during encoding phase enhances group performance if their members explicitly negotiate and assign responsibility according to actual members’ expertise (Hollingshead 1998a). Rulke & Rau (2000) found that groups spend more time on finding out “who knows what” at the early stages of group interaction; a number of such conversations decrease over time.

Cognitive interdependence of group members is seen as a prerequisite condition for the development of a transactive memory system (Wegner et al. 1991; Brandon & Hollingshead 2004; Hollingshead 2001). Cognitive interdependence describes a situation when individuals rely on each another for being experts in certain knowledge domains and individual outcomes depend partially on what others in the group know. Hollingshead (2001) demonstrated that neither group membership nor communication per se lead to development of a transactive memory system but rather group members’ cognitive interdependence and convergent (accurate and shared) expectations on “who knows what”.

Moreland and colleagues (Moreland 1999; Liang, Moreland, & Argote 1995; Moreland et al. 1996; Moreland, Argote, & Krishnan 1998; Moreland & Myaskovsky 2000) demonstrated that group, rather than individual, training positively affects development of a transactive memory system and improves group performance. At the same time, Moreland & Myaskovsky (2000) note that group training is not a necessary condition for the development of a transactive memory system: when groups of people trained individually received information on “who knows what” from experimenters, they performed as well as groups of people trained together.

Processes of transactive memory system. There are several processes that underlie transactive memory system' development and functioning. The first one is transactive encoding (Wegner et al. 1985; Wegner & Wegner 1995) or information allocation (Wegner 1995). During this process, information item encountered by a group is channeled to a person responsible for the corresponding knowledge domain. Often a group member passes information to the person "in charge" without remembering information item details. In this manner, group members learn information which pertains to their own areas of expertise only and expect that others in the group would do the same (Hollingshead 2000). This process leads to progressive differentiation of group members' knowledge and division of cognitive labor (Wegner 1995; Hollingshead 2000). Rulke & Rau (2000) say that transactive encoding occurs in small cycles "that begin with either questions about the task or statements indicating no expertise, continue with declarations of expertise and evaluations of members' competence and expertise, and end with efforts at coordination who does what in the group".

The second process is transactive storage (Wegner et al. 1985; Wegner & Wegner 1995). During this process group members discuss past events. The third process is transactive retrieval (Wegner et al. 1985; Wegner & Wegner 1995) or retrieval coordination (Wegner 1995). It occurs when individuals, confronted with a task for which they do not possess all the necessary skills, coordinate retrieval of information from other group members. Hollingshead (1998b) proposed an elaborate nine-proposition model of transactive retrieval for the situations when a group has to find a correct or the best answer by reaching a unanimous consensus. The fourth process is called (by analogy with computers) directory updating (Wegner 1995). It refers to modification of knowledge on "who knows what" in the group.

Role of transactions. Transactions between group members during encoding, storage, and retrieval stages may cause losses or distortion of information (Wegner et al. 1985; Wegner 1987, 1995; Wegner & Wegner 1995). A process of encoding may be accompanied by a group discussion which could lead to a new understanding of information. As a result, a label attached to the information item may be incorrect. Discussion of past events may modify originally stored information. Similarly, during retrieval stage the initial label may be translated into another one that a person who looks for the information internally finds to be more appropriate. As a result, a group may forget what it initially was looking for or find something useful but what it didn't set out to find.

Transactions may also produce positive effects by facilitating knowledge creation. For example, when different group members respond to a particular label they may retrieve different information items which, after further discussions, may add up to absolutely new idea. Such integrative processes are seen as the most important in groups. However, it is necessary to note that no studies to date have been done to support or reject this theorizing on transactive memory system impact on new knowledge creation.

Structure of transactive memory systems. Two polar structures of transactive memory systems are theoretically hypothesized: differentiated and integrated (Wegner et al. 1985; Wegner 1987). A system is differentiated when different individuals remember different types of information and all of them know general labels of this information and who holds it. A transactive memory system is integrated when different individuals remember the same information and are aware of it.

Depending on the task at hand, either differentiated or integrated transactive memory system will facilitate its fulfillment. If a task requires that all group members carry out the same functions (e.g. sales persons), integrated transactive memory system is preferable. However, if a task requires generation of new knowledge, differentiated transactive memory system would be more appropriate.

Hollingshead (1998b) proposes a subtler typology of transactive memory systems' structure. She says that knowledge in a group can be distributed in four ways: (1) knowledge known to all group members; (2) knowledge known to some group members (i.e. partially shared); (3) unique (held by only one person) knowledge; and (4) unavailable (not known by anyone) knowledge.

Differentiated structure as a developed transactive memory system. Research on transactive memory systems is focused mainly on differentiated structures. Most of papers implicitly assume that a transactive memory system is developed when it is differentiated.

In laboratory studies this assumption is expressed in the design of experiments. For example, Wegner et al. (1991) assigned expertise for the studied couples in the manner that "one partner was given responsibility for remembering items from some of the categories and the other partner was given responsibility for remembering items from the remaining categories". Then group recall of the couples with assigned expertise and those without was compared. The abovementioned assumption is also expressed in transactive memory system measures. For example, one of indirect behavioral characteristics Moreland and colleagues (Moreland 1999; Liang et al. 1995; Moreland et al. 1996, 1998; Moreland & Myaskovsky 2000) used to detect a developed transactive memory system was memory differentiation, i.e. a tendency of group members to specialize in remembering different aspects of a group task. An exception of this trend is a paper by Hollingshead (2001) who studied development of both differentiated and integrated transactive memory systems.

Studies conducted in organizational settings are built on the results of the laboratory ones. Thus the assumption that a developed transactive memory system has a differentiated structure is prevalent among them too. The emphasis is given to distribution of knowledge among team members and the division of cognitive labor. For example, Lewis (2003) says: "The TMS [transactive memory system] construct specifically focuses on utilizing and integrating distributed expertise…". In order to maintain consistency with the previous research, in this study the mainstream viewpoint is taken.

Interestingly, research papers lack a clear definition of a developed transactive memory system. Discussion initiated by Wegner (1987, 1995) of possible changes in awareness of "who knows what" suggests that a transactive memory system undergoes transformations throughout the group existence. This view is explicit in Lewis' (2004) study which compared transactive memory systems during planning and implementation project stages. Research results indicated that transactive memory system indeed changes over time. However a discussion when it can be called developed for a particular group at a certain period of group existence is missing. Adjectives like "mature" (Lewis 2004), "well-developed" (Austin 2003), "developed" (Hollingshead 1998a), "strong" (Austin 2003), and "effective" (Akgün, Byrne, Keskin, Lynn, & Imamoglu 2005) are left in research papers without specific explanation.

In this work and building on the previous studies, the following definition is suggested. *A transactive memory system is said to be developed* when group members possess different knowledge, are accurate in recognition of "who knows what" and freely communicate to combine their knowledge when necessary. This definition does not resolve the abovementioned problem. It is still "soft"; however, it is less ambiguous than existing (or lacking) ones.

Impact of a developed transactive memory system on group performance. A developed transactive memory system is reported to be beneficial for group performance (Wegner 1987, Moreland et al. 1996, 1998; Moreland 1999; Moreland & Myaskovsky 2000). It reduces information burden on an individual by providing an opportunity to divide cognitive labor among group members. Furthermore, because people in a group are experts in different areas, they may give answers to questions that are far beyond their own individual expertise. Moreover, if group members are well aware of "who knows what" in the group they could assign tasks to each other more sensibly and anticipate, rather than react to, each other's behavior. Laboratory studies have demonstrated a positive impact of a developed transactive memory system on group performance: groups with developed transactive memory systems outperformed those without (Wegner et al. 1991; Liang et al 1995; Moreland et al. 1996, 1998; Moreland 1999; Moreland & Myaskovsky 2000; Hollingshead 1998a, 1998b, 1998c).

There are also detrimental effects of a developed transactive memory system. Turnover, inevitable at work places, could have a negative effect on group performance if a group has a developed transactive memory system (Moreland et al. 1996, 1998). Both departure of old members and arrival of new ones may disrupt functioning of a transactive memory system. Collective training, as in the studies of Moreland et al. (1996, 1998) could incur a risk of free-riding, i.e. when people do not want to learn their own tasks thoroughly, but rely, instead, on their teammates. On the individual level, people may become too specialized and overconfident in the group members; so that when the group ceases to exist they could be frustrated and find used-to-be-easy tasks problematic (Wegner et al. 1985; Wegner 1987; Wegner & Wegner 1995). Hollingshead (2001) notes that too much differentiation may impede group performance when both unique and overlapping knowledge is required or when an expert is not motivated to contribute unique knowledge. It may also be speculated that overall costs (financial and human) necessary to develop and support a transactive memory system may be high, but the effect on group performance may be not significant.

Extensions of the original theory. Since its inception in the eighties, the theory of transactive memory has undergone further development. The extensions include Fulk et al.' (2005a) conceptualization of a transactive memory system as a distributed knowledge common; Brandon & Hollingshead' (2004) inclusion of tasks as indispensable components of a transactive memory system; Yuan, Monge, & Fulk' (2005) multilevel perspective taking into account both individual and group level network properties; Peltokorpi's (2004) investigation into antecedents and consequences of directory formation of a transactive memory system; as well as incorporation of non-human agents, i.e. information systems, into the theory of transactive memory (Hollingshead, Fulk, & Monge 2002; Yuan, Fulk, & Monge 2007).

Fulk et al. (2005a) conceptualize a transactive memory system as a distributed knowledge common, i.e. a common property of a team, created by collective actions of team members. Participation of individuals in such knowledge commons could be motivated by (1) providing external incentives, (2) building members' identification with a team, (3) encouraging distribution, rather than division, of labor, (4) mobilizing communal knowledge stores (e.g. project websites, expert databases), (5) providing supportive communication systems, (6) utilizing prior member ties, and (7) making instants of individual cooperation visible.

Moreover, transactive memory systems could be thought of as elements of populations that evolve (emerge, transform, and expire) over time (Fulk et al. 2005a). This view could explain how knowledge elements in a transactive memory system undergo variation, selection, and retention. Being potentially interesting, this perspective is the least developed in the studies on transactive memory systems.

Brandon & Hollingshead (2004) offer another extension of the theory of transactive memory. First, they introduce a notion of a task-expertise-person unit (TEP unit). TEP units describe connections between people ("who"), knowledge domains ("who knows what"), and tasks ("who does what"). TEP units are not static but develop through iterative process of construction on a basis of available information, evaluation, and utilization. Connection to tasks moves a general reference system ("who knows what") to a more meaningful and useful description of a group memory. Second, Brandon & Hollingshead (2004) view development of a transactive memory system as an outcome of iterative, reciprocally influential cyclical processes: (1) development of cognitive interdependence; (2) development of TEPs; and (3) adjusting perceptions of group work among group members. Interestingly, Lewis, Gillis, & Lange (2003) challenged the assumption that a transactive memory system is task-specific and demonstrated in laboratory experiments that a team's transactive memory system could be transferred across tasks.

Yuan et al. (2005) stress the multilevel nature of the transactive memory concept. In essence, a transactive memory system describes group (macro-level) cognition that emerges from individual (micro-level) interactions. In this way and building on social capital theories, Yuan et al. (2005) explore how individual and collective social capital (conceptualized in terms of communication network properties) influence development of both individual transactive memories and emergent group-level transactive memory systems. Among other findings they discovered that individual social capital has a significant impact on development of individual knowledge on "who knows what". Collective social capital and task interdependence do not influence transactive memory system development. The effect of task interdependence on collective access to information is significant.

Peltokorpi (2004) extends the theory of transactive memory by studying antecedents and consequences of directory formation (i.e. learning "who knows what"). He found that value congruence, organizational commitment, and electronic communication have a big positive impact on formation of directories. Interpersonal communication mediates the impact of value congruence and psychological safety on learning “who knows what”. Furthermore, knowledge on “who knows what” has a positive relationship with the service capital, i.e. an ability to properly respond to customers’ requests.

Hollingshead et al. (2002) turn their attention to intranets. By incorporating intranets into a transactive memory system, they propose an integration of transactive memory and public goods (Dougherty 2003) theories. A transactive memory system is shown to be a public good: it is non-excludable (every group member can benefit from it) and non-rival (individual use does not reduce it). Intranets could help to develop and sustain a public good of transactive memory system by offering a capability to identify and link people. A recursive relationship between a transactive memory system and use of intranets is proposed. Namely, individuals in groups with a developed transactive memory system possess unique knowledge and, thus, believe that their contribution to intranets will be valuable. The more individuals publish knowledge on intranets, the more it becomes obvious that they all have different expertise. This leads to further development of the transactive memory system.

Yuan et al. (2007) develop ideas of Hollingshead et al. (2002) further. They introduce a distinction between connective and communal knowledge repositories. The former are humans; access to information in these repositories involves direct human interaction. The latter are non-human information systems repositories such as databases, archives, intranets, wikis, etc. Yuan et al. (2007) studied how the use of these repositories influences individual access to information. They found that knowledge on “who knows what” indeed leads to more direct information exchanges between team members. However and contrary to expectations, these exchanges do not improve individual access to information whereas the use of communal repositories does. Furthermore, individual perception that others use communal repositories extensively leads to more actual individual usage. Finally, individuals should be technology competent in order to use communal repositories.

2.4. Studies on a transactive memory system in organizational settings

The theory of transactive memory was developed on the basis of intimate couples’ behavior observations (Wegner 1987; Wegner et al. 1985, 1991). Subsequent research has shown that a transactive memory system has nothing to do with intimacy itself. Experiments conducted by Hollingshead (1998a, 1998b, 1998c) demonstrated that even strangers could have a transactive memory system. Transactive memory systems characterize also work groups (Hollingshead 2000).

In a review of the studies on transactive memory theory, Fulk et al. (2005b) note that most of research is done in controlled laboratory settings. Indeed, a number of filed studies are limited. Research conducted and reported, to the best of our knowledge, in public sources on the date of writing this manuscript is discussed below. The studies are described in a chronological order. A list of the works and their corresponding settings is presented in Table 1. It should be noted that Yuan et al. (2007) also conducted a study in organizational settings (project teams from a variety of industries). However they focused only on individual-level components of a transactive memory system. Therefore, the work of Yuan et al. (2007) is not included in the following review.

Table 1. A list of studies on transactive memory system conducted in organizational settings.

Authors	**Type of a team**
Yoo and Kanawattanachai (2001)	Virtual teams in a business game
Lewis (2003)	Consulting teams; project, cross-functional, and functional teams in high-technology companies
Austin (2003)	Continuing product line groups in a large apparel and sporting goods company
Peltokorpi (2004)	Small Nordic sales subsidiaries in Japan
Lewis (2004)	MBA consulting teams
Palazzolo (2005)	Academic, consulting, governmental, management, and manufacturing teams
Rau (2005a)	Bank top management teams
Rau (2005b)	Bank top management teams
Akgün et al. (2005)	New product development teams
Akgün, Byrne, Keskin, & Lynn (2006)	New product development teams
Zhang, Hempel, Han, & Tjosvold (2007)	Marketing and sales teams, R&D teams, production and quality control teams, and some other functional teams in high-technology companies in China (information technology, telecommunications, electronic engineering, biological engineering, and related fields)
Jackson & Klobas (2008)	Distributed organization
Oshri, van Fenema, & Kotlarsky (forthcoming)	Distributed software development projects

Yoo and Kanawattanachai (2001) studied development and impact of a transactive memory system and a collective mind in virtual teams. A collective mind is a concept which explains how individuals heedfully interrelate their actions. It is not fully developed at the early stage of team existence and is preceded by a transactive memory system. The authors demonstrated that communication volume has early positive influence on team performance. However its importance diminishes as the team develops a transactive memory system and, later on, a collective mind. Yoo and Kanawattanachai (2001) argued that a transactive memory system cannot alone explain team performance: its influence is mediated by a collective mind.

It should be noted that the setting of Yoo and Kanawattanachai' (2001) research was experimental: they recruited students to work in virtual teams during the study. However this study is different compared to that of, for example, Hollingshead (2000) who studied work groups in laboratory settings. Yoo and Kanawattanachai (2001) did not include control groups and measured transactive memory system indirectly instead of using group recall (approach typical for laboratory experiments). In this sense the work of Yoo and Kanawattanachai (2001) is more close to studies in actual organizational settings and, hence, included in this review.

Lewis (2003) conducted extensive work aimed at development and validation of a scale for transactive memory system measurement. In order to reassess the scale items and check for internal validity, Lewis (2003) measured transactive memory systems in several organizational settings. Among those were consulting teams as well as project, cross-functional, and functional teams in high-technology companies. Results demonstrated that the proposed scale was valid.

Austin (2003) studied the effects of a transactive memory system on group performance. The study was conducted in continuing product line groups in a large apparel and sporting goods company. Austin (2003) demonstrated that a transactive memory system is positively related to group goals' accomplishment and its external and internal evaluations. Accuracy of a transactive memory system, i.e. accurate knowledge on "who knows what", is shown to have the biggest impact on team performance.

Peltokorpi (2004) examined antecedents and consequences of directory formation (learning "who knows what"). The research was conducted in small Nordic sales subsidiaries in Japan. Its findings are discussed above in the extensions of transactive memory theory.

Lewis (2004) investigated into development and impact of a transactive memory system. Regarding memory development, the emphasis was given to the influence of initial conditions and communication processes during different stages of a project life. Among initial conditions, distribution of team members' expertise (homo- or -heterogeneous) and team members' familiarity were selected. Regarding the impact of a developed transactive memory system, the emphasis was given to its influence on team performance and viability (i.e. ability to perform well in the future). The study was conducted in MBA consulting teams and their clients. Lewis (2004) discovered that distributed expertise positively influences development of a transactive memory system when measured at the end of a planning period of a project. This influence is even stronger when team members are familiar with each other prior to the team formation. At the same time, overlapping expertise combined with prior familiarity results in a poorly developed transactive memory system. Furthermore, early communication patterns set the stage for transactive memory system development throughout the project. Frequent face-to-face communication is a major determinant of transactive memory system emergence and functioning in terms of transactive retrieval. A developed transactive memory system is positively related to team's performance and viability.

Palazzolo (2005) researched information retrieval in work groups. The study was conducted in different contexts: in academic, consulting, governmental, management, and manufacturing teams. By employing the latest developments in social network analysis, Palazzolo (2005) analyzed communication ties between team members. Results demonstrated that a concept of transactive memory is, generally, relevant to organizational settings. However, it was also found that laboratory findings based on small groups cannot be fully generalized to larger ones.

In particular, Palazzolo (2005) showed that some group members would be more central than others with regard to information retrieval. Moreover, people would retrieve information from those whom they perceive as experts. Interestingly, such perceptions are not connected to self-reported expertise. Individuals could also look for information by going from one person to another to a third. Furthermore, people do not retrieve information from just one person. Instead, they seek for it from several persons at the same time. This finding contradicts a theory of transactive memory which implies that a person would contact the most knowledgeable person in a specific area. Such multiple requests could be explained by efficiency of time (an answer for a question asked from several persons may come sooner than if asked from just one person) or by willingness to obtain multiple perspectives on the same topic.

Rau (2005a, 2005b) conducted studies in bank top management teams. One study (Rau 2005a) was focused on how conflict and trust influence the extent of transactive memory system use in effective decision making. Results demonstrated that location dimension (knowledge on "who knows what") positively influences team performance with low levels of relationship conflict. At the same time, in teams with high levels of relationship conflict, location dimension has no significant effect. Furthermore, the level of trust was found to have no influence on relation between location dimension and team performance.

The other study (Rau 2005b) examined relationships between a transactive memory system, information gathering, and perceptual accuracy about environmental volatility. Data was collected twice with two years interval. Results showed that a transactive memory system does not influence the extent of information gathering between time one and two. Furthermore, information gathering between time one and two increases perceptual accuracy at time two only for firms that have little variation in prior performance.

Akgün and colleagues conducted two studies in new product development teams (Akgün et al. 2005, 2006). In the fist study they examined antecedents and consequences of transactive memory systems (Akgün et al. 2005). It was discovered that team stability, team member familiarity, and interpersonal trust have a positive impact on a transactive memory system. The same factors have a positive impact on team learning, speed-to-market, and new product success. A transactive memory system was shown to have a higher impact on team learning, speed-to-market, and new product success when team tasks are more complex.

In the second study Akgün et al. (2006) examined the effects of a transactive memory system on new product development outcomes including mediating (collective mind) and moderating (environmental turbulence) factors. It was demonstrated that a transactive memory system has a positive impact on team learning and speed-to-market. Collective mind mediates relationships between transactive memory system, team learning, and speed-to-market. Team learning and speed-to-market mediates relations between a transactive memory system and new product success. At the same time, a transactive memory system has a negative impact on speed-to-market when environmental turbulence is high.

Zhang et al. (2007) examined relationships between team characteristics, a transactive memory system, and team performance. Three team characteristics were chosen for the study: task interdependence, cooperative goal interdependence, and support for innovation. Task interdependence is the extent to which team members believe they need help from others in order to carry out their tasks. Goal interdependence refers to team members' perception that their goals are related to other members' goals, i.e. that achieving personal goals could help others in achieving their goals. Support for innovation describes a group climate in organizations which emphasize innovation and encourage sharing resources in the application of new ideas. Zhang et al. (2007) found that task interdependence, cooperative goal interdependence, and support for innovation have positive connection to the team transactive memory system. Moreover, a transactive memory system mediates the relationship between team characteristics and team performance and is positively related to team performance.

Jackson & Klobas (2008) conducted a case study in a distributed organization with a centralized head office in Northern Europe and a large number of distributed staff based in different remote locations. The analysis of semi-structured interviews revealed that organizations (not only dyads and groups) can have transactive memory systems. Specifically, Jackson & Klobas (2008) observed directories (i.e. knowledge on "who knows what") in both humans' descriptions and codified directory systems. Transactive memory processes, such as maintenance, allocation, and retrieval, were also in place. At the same time, collected data showed the evidence that physical separation of organizational members degrades transactive memory processes. For example, it reduces opportunities to build and maintain knowledge on "who knows what". It also hinders information allocation and retrieval from people in distant places. It is suggested that information systems purposefully designed to support transactive memory processes could compensate for the effects of physical distribution.

Oshri et al. (forthcoming) studied knowledge transfer in globally distributed software development projects through the lens of transactive memory theory. They found that transactive memory system processes, i.e. encoding, storage, and retrieval, enable knowledge transfer in distributed settings. Specifically, encoding helps to define the procedure through which knowledge is to be transferred. Storage creates a pointer for knowledge location which helps to find and transfer knowledge later on. Retrieval brings together different experts and makes knowledge transfer possible. These processes rely on either codified (e.g. databases) or personalized (e.g. project members' memories) directories of "who knows what" or both. Standardization of project work and use of document templates were discovered to contribute to development of codified directories. Training, rotation between different project sites, regular communication, and division of work on the basis of expertise enable personalized directories development. Codified and personalized directories are seen as complementary in facilitating knowledge transfer in distributed settings.

Among the reviewed studies two were qualitative (Jackson & Klobas 2008; Oshri et al. forthcoming), one was based on social network analysis (Palazzolo 2005); the rest were quantitative. Comparison of the findings presented in this chapter is difficult due to different conceptualizations of a transactive memory system and varying approaches to its measurement. These differences are discussed in more detail in the next chapter.

2.5. Measurement of a transactive memory system

2.5.1. General considerations

A transactive memory system, as it follows from its original conceptualization by Wegner (1987) and in agreement with recent extensions (e.g. Yuan et al. 2005), is a group-level construct. This makes its measurement a non-trivial task. A research community is confused over how to measure group-level cognitive phenomena (Cooke et al. 2000; Mohammed & Dumville 2001; Mohammed, Klimoski, & Rentsch 2000). As Klimoski and Mohammed (1994) note, measurement at the group level is “complex and problematic”. There are two basic approaches to measurement of group phenomena: collective and holistic (Cooke et al. 2000; Mohammed et al. 2000).

According to collective approach, individual measures are collected first and then aggregated into a group-level one. Individual measures can be collected during observations, interviews, or surveys (Cooke et al. 2000). This approach is easy and most of the research to date uses aggregation. However collective approach underestimates the importance of team members’ interactions (Cooke et al. 2000) and simplifies relationships within a team by assuming that every member’s contribution to team phenomenon is of equal importance (Mohammed et al. 2000).

Holistic approach appreciates importance of team process behaviors and treats a group as a whole, allowing collectivity to “speak for itself” (Mohammed et al. 2000). Observations of group performance or interviewing key informants are possible group-level techniques (Mohammed et al. 2000).

Furthermore, approaches to measurement of group-level cognitive phenomena can be divided into direct and indirect (Lewis 2003). A measurement approach is called direct if a cognitive content of a study can be provided by researchers; for example, if it can be said in advance what knowledge is required for a team to fulfill a certain task (Mohammed et al. 2000). While this approach is appropriate for well structured tasks, its application may be difficult for tasks of high complexity (e.g. R&D projects aimed at development of new knowledge). To overcome this problem, team members may be asked to provide cognitive content by themselves. However, in this case a difficulty lies in interpreting peculiar responses (Mohammed et al. 2000). Another limitation of using a task specific content is that it precludes comparison between different cases and quantitative research in field settings (Lewis 2003).

To overcome these problems, indirect approach can be used. It is aimed at measurement of group-level phenomenon manifestations. Manifestations are indirect behavioral characteristics that allow detecting existence of a studied construct (Moreland 1999). This approach is generally recommended for the measurement of conceptual abstractions (Spector 1992).

2.5.2. Review of approaches to transactive memory system measurement in organizational settings

Studies conducted to date on transactive memory systems in organizational settings differ in terms of both measurement approaches and content (i.e. interpretation of a transactive memory system). Though all the studies refer to the works of Wegner as a founder of transactive memory theory, a transactive memory system is defined in these studies in different ways (Table 2).

Table 2. Definitions of a transactive memory system in the field studies.

Authors	**Definition of transactive memory system**
Yoo & Kanawattanachai (2001)	"…transactive memory system is the team members' meta-knowledge about who knows what in the team."
Lewis (2003)	"Transactive memory … consists of metaknowledge about what another person knows, combined with the body of knowledge resulting from that understanding. … A transactive memory system describes the active use of transactive memory by two or more people to cooperatively store, retrieve, and communicate information."
Austin (2003)	"Wegner's definition of transactive memory includes two parts: (a) a combination of individual knowledge and (b) interpersonal awareness of others' knowledge."
Peltokorpi (2004)	"Transactive memory is a combination of the knowledge possessed by actors and a collective awareness of 'who knows what'."

(continued on the next page)

(Table 2 continued)

Authors	Definition of transactive memory system
Lewis (2004)	"A TMS [transactive memory system] is the cooperative division of labor for learning, remembering, and communicating team knowledge… it is a form of knowledge that is embedded in team members and in a team's structure and processes." "TMS itself consists of the set of members' individual knowledge repositories and a shared understanding about which members possess what knowledge."
Palazzolo (2005)	"The two basic components that create a TM [transactive memory] system are two or more individuals' memories and the communication between these individuals."
Rau (2005a)	"Transactive memory is the set of knowledge possessed by members of the team, combined with an awareness of who knows what within the team."
Rau (2005b)	"Transactive memory is the set of knowledge possessed by the members of a team, combined with an awareness of who knows what within the team."
Akgün et al. (2005)	"..a TMS [transactive memory system] consists of the memory stores of particular individuals and any social interactions in which they participate."
Akgün et al. (2006)	"… a TMS [transactive memory system] depicts the "awareness of who knows what in a group."
Zhang et al. (2007)	"TMS [transactive memory system] is defined as the way that groups process and structure information and as the shared division of cognitive labor regarding group members' encoding, storing, and retrieving of information."
Jackson & Klobas (2008)	"Transactive memory is a system for encoding, storing, and retrieving information in groups: it is a set of individual memory systems in combination with communication that take place between individuals."
Oshri et al. (forthcoming)	"A TMS [transactive memory system] has been defined as the combination of individual memory systems and communications … between individuals."

Some definitions include only knowledge on "who knows what" (Yoo & Kanawattanachai 2001; Akgün et al. 2006). Others incorporate both knowledge on "who knows what" and individual expertise (Lewis 2003, 2004; Austin 2003; Peltokorpi 2004; Rau 2005a, 2005b). Some researchers take also into account communication (Palazzolo 2005; Akgün et al. 2005; Jackson & Klobas 2008). It is important to be aware of these differences because they demonstrate that, when talking about a transactive memory system, different authors may talk of and consequently try to measure close but still different phenomena.

Approaches to transactive memory system measurement used in the abovementioned studies are presented in Table 3. They are described on the basis of the content (i.e. "what was measured") and characteristics of group-level measures outlined in the previous section.

The content of the studies varied depending on the research question at hand and a method employed. Some works, while acknowledging existence of several components of a transactive memory system, were explicitly focused on only one. For example, Peltokorpi (2005) studied only antecedents and consequences of directories (knowledge on "who knows what"); Palazzolo (2005), having said that a transactive memory system usefulness can be assessed only by its usage, collected data specifically on information retrieval. Still, a common thread can be identified: many works tried to assess awareness of "who knows what". Moreover, some studies treated a transactive memory system as composed solely of "who knows what" component (Yoo & Kanawattanachai 2001; Akgün et al. 2006) (cf. definitions in Table 2).

Most studies that assessed expertise recognition did it by measuring team members' agreement on "who knows what". However, there are two other aspects of expertise recognition which have been identified in laboratory studies (Moreland 1999): complexity (how detailed knowledge about "who knows what" is) and accuracy. Accuracy was measured in only one study (Austin 2003); complexity in the reviewed studies was not addressed at all.

Yuan et al. (2007) proposed another approach to assessment of individual knowledge on "who knows what". They measured it along two dimensions: accuracy and extensiveness. Accuracy refers to deviation of individual perceptions from the team-level perception. Extensiveness reflects how many team members an individual could describe. Individual directories of "who knows what" are then called well developed if they are accurate and extensive. Yuan et al. (2007) did not discuss how these individual measures translate into group-level measures. However, it could be suggested that aggregation could also be used for this purpose.

Table 3. Characteristics of approaches to transactive memory system measurement in organizational settings.

Authors	Direct/ indirect	Data collection	Aggregated/ holistic	Number of dimensions	What was measured	Measurement of awareness
Yoo & Kanawattanachai (2001)	Indirect	Questionnaires	Aggregation	1	Awareness of "who knows what"	Agreement
Lewis (2003)	Indirect	Questionnaires	Aggregated	3	(1) Specialization (2) Credibility (3) Coordination	
Austin (2003)	Combination	Questionnaires	Aggregated	4	(1) Knowledge stock (combination of individual knowledge) (2) Consensus about knowledge sources (agreement) (3) Specialization of expertise (4) Accuracy of knowledge identification	Agreement, accuracy
Peltokorpi (2004)	Indirect	Questionnaires	Aggregation	1	Awareness of "who knows what"	
Lewis (2004)	Indirect	Questionnaires	Aggregated	3	The same as in Lewis (2003)	
Palazzolo (2005)	Indirect	Questionnaires	Social network analysis	1	Information retrieval process	

(continued on the next page)

(Table 3 continued)

Authors	Direct/ indirect	Data collection	Aggregated/ holistic	Number of dimensions	What was measured	Measurement of awareness
Rau (2005a)	Combination	Questionnaires	Aggregated	2	(1) Composition of expertise (diversity and depth) (2) Awareness of “who knows what”	Agreement
Rau (2005b)	Direct	Questionnaires	Aggregated	2	(1) Knowledge possessed by team members; (2) Awareness of “who knows what”	Agreement
Akgün et al. (2005)	Indirect	Questionnaires	Key informants (holistic)	3	Adapted from Lewis (2003) (10 items out of 15)	
Akgün et al. (2006)	Indirect	Questionnaires	Key informants (holistic)	1	The same as in Yoo & Kanawattanachai (2001)	
Zhang et al. (2007)	Indirect	Questionnaires	Aggregation	3	The same as in Lewis (2003)	
Jackson & Klobas (2008)	Indirect	Interviews	Holistic	2	(1) Awareness of “who knows what” (2) Processes: directory maintenance; information allocation and storage; information retrieval	
Oshri et al. (forthcoming)	Indirect	Interviews	Holistic	2	(1) Awareness of “who knows what” (2) Processes: encoding, storage, and retrieval	

Most of the studies employed indirect measures or a combination of direct and indirect ones. With regard to indirect measures, a 15-item scale developed by Lewis (2003) should be specifically mentioned (appendix 1). It is based on three manifestations of a transactive memory system identified by Moreland and colleagues (Liang et al. 1995; Moreland et al. 1996; Moreland 1999). These manifestations are (1) specialization (how different task-related knowledge possessed by teammates is), (2) credibility (how deeply team members trust each other), and (3) effective coordination. This tool allows comparisons between different cases and because of that has been employed in a number of studies (Lewis 2004; Akgün et al. 2005; Zhang et al. 2007).

It is necessary to say that Lewis's scale is not the only one indirect measure used by researchers (cf. Yoo & Kanawattanachai 2001) but the only one that has undergone thorough validation (Lewis 2003). At the same time, Fulk et al. (2005b) note that the construct validity of the scale is still under debate. For example, Xu, Fulk, Hollingshead, & Levitt (2004) (unpublished manuscript; reported by Fulk et al. 2005b) argue that credibility is an antecedent, not a consequence, of a transactive memory system. Furthermore, regarding the scale, it is not clear whether these dimensions are equally important or some are less important than others. In this sense, interpretation of the results obtained in a field setting could be problematic if scale dimensions are scored differently.

Nearly all the studies used questionnaires for data collection. Most of them used aggregation for obtaining a group-level measure out of individual answers. Though, there are several exceptions. Akgün et al. (2005, 2006) used key informants (product or project managers) to fill in questionnaires. Palazzolo (2005) applied social network analysis to investigate structural characteristics of information retrieval. Two works (Jackson & Klobas 2008; Oshri et al. forthcoming) relied on semi-structured interviews. In these studies, interviewees' remarks were analyzed to find the evidence of transactive memory system directories and processes.

The reviewed works demonstrate a lack of parsimony in definitions and approaches used for measurement of a transactive memory system in organizations. This could preclude further development of empirical research in work settings. At the same time, it should be noted that measurement approaches used in laboratory experiments are not applicable to field studies because control groups are not available for comparisons in real life (Fulk et al. 2005b; Lewis 2003).

2.6. On transactive memory theory within a framework of studies on cognition in organizations

2.6.1. *Other studies on group memory*

Studies on group memory could be divided into two main groups: those originated in psychology, and those originated in the field of organizational studies (Table 4). Studies from the first group are usually of experimental character; empirical research in organizational settings is rare. Studies from the second group are mostly focused on development of particular software applications which are called group memory systems. The link between theoretical studies on group memory and group memory systems is weak.

Most of the studies on group memory conducted in psychology filed are focused on the process of collaborative remembering, i.e. “the negotiation and agreement of a joint account of some past mutual experience with others” (Clark & Stephenson 1989; Hartwick, Sheppard, & Davis 1982; Steiner 1972; Tindale & Sheffey 2002). Empirical research is mainly concentrated on tests of group versus individual recall productivity. In these tests individuals are presented with stimuli (e.g. word lists); then quantity of accurate recall is counted both for individuals and groups. The general finding is that groups can recall more items than individuals. However, compared to summated recall of randomly chosen individuals, groups have been found to perform worse. This result points out that group recall is not equal to simple pooling of individuals’ remembrances. There are group processes that influence individual recall; hence generalizing from an individual to group level would be erroneous (Tindale & Sheffey 2002). Despite a long history of experimental studies, a general theory of remembering, that would explain relationships between individual and group remembering as well as take into account their social nature, is missing (Clark & Stephenson 1989). No studies on group recall have been conducted in organizational settings.

One exception among the theories originated in psychology in terms of applicability to organizational settings is a theory of transactive memory discussed in detail above. It is the only theory of group remembering which is, to the best of our knowledge, used to study organizations and infer managerial implications.

Models of group memory that originated in organizational studies bear a clear functional perspective, i.e. they explain how memory would improve different aspects of group performance. Quite often discussion revolves around group memory systems, i.e. computerized information repositories with shared access,

Table 4. Areas of research on group memory[1].

Area of research	Field of origin	Papers illustrating research area	Empirical research in organizational settings	Findings
Group recall (models of group productivity: "truth wins", truth-supported wins", majority model)	Psychology	Clark & Stephenson (1989); Hartwick et al. (1982); Tindale & Sheffey (2002)	No tests in real organizational settings; laboratory experiments only	Groups outperform individuals in terms of quantity of recalled items
Theory of transactive memory (Wegner 1987, 1995; Wegner et al. 1985, 1991)	Psychology	Moreland (1999); Moreland & Myaskowsky (2000); Hollingshead (1998a, 1998b, 1998c)	Rau (2005a, 2005b); Austin (2003); Lewis (2003); Yoo & Kanawattanachai (2001); Akgün et al. (2005, 2006); Zhang et al. (2007); Jackson & Klobas (2008); Oshri et al. (forthcoming)	Developed transactive memory system improves group performance
Group memory systems	Organizational studies; information technologies	Haseman et al. (2005); Satzinger et al. (1999); Berlin et al. (1993), Weiser & Morrison (1998); Ackerman & Mandel (1999), Zimmermann & Selvin (1997)		Effects of group memory systems on idea generation, decision-making etc.

[1] A list of works is not inclusive but illustrative.

in the context of group support systems. For example, Haseman, Nazareth, & Paul (2005) discovered that a group memory system can speed up decision-making process (at the expense, however, of considering fewer information sources that could, potentially, contain valuable information). Satzinger, Garfield, & Nagasundaram (1999) studied effects of group memory on idea generation and found that individuals conformed to group memory content presented to them during brainstorming sessions. Berlin, Jeffries, O'Day, Paepcke, & Wharton (1993) discovered that development of a shared structured information repository valuable for a group is not easy because developers may be confronted with many cognitive and social problems, including different individual strategies for putting information into a repository and structuring of information. Some memory systems were developed for particular tasks or projects (Ackerman & Mandel 1999; Weiser & Morrison 1998). To make comparisons of such systems easier, Zimmermann & Selvin (1997) developed a framework to assess which group memory system is better in a particular context.

Development of group memory systems is driven mostly by advances in information technology; connection to theoretical research on group memory is minimal. Paying attention to the proliferation of information systems, recent works on transactive memory began to incorporate them into research agenda (Hollingshead et al. 2002; Yuan et al. 2007). Jackson & Klobas (2008) see information systems as a natural solution to support a transactive memory system on an organizational level. They propose that such systems should have (1) an easily accessible directory of "who knows what", (2) a method for keeping this directory up to date, (3) a functionality to retrieve information from the directory, and (4) methods for assigning expertise and information allocation. Anand, Manz, & Glick (1998), Lehner & Maier (2000), and Nevo & Wand (2005) also theorize on how a theory of transactive memory may contribute to organizational memory systems. However, practical implementation of their ideas is still at the early stage.

Taken together, these studies demonstrate that psychological and organizational streams of research on group memory exist rather independently. Research on group recall is conducted on the basis of experiments. Group memory systems are developed with the purpose to improve group performance but their connection to group memory theories is weak. Cross-fertilization is, thus, minimal. A promising direction for future work would be incorporation of transactive memory theory into information systems development.

A number of studies on collective memory are also conducted by sociologists. These works are focused mainly on memory processes in social institutions and changes the concept of collective memory has undergone during centuries (Olick & Robbins 1998). Some of the memory processes studied by sociologists are malleability of collective memory and reputational dynamics of those remembered. Generally, research on collective memory in sociology is characterized by "insufficient conceptual clarity" (Zelizer 1995). It exists rather independently from research in psychology and organizational studies and, hence, it is not reviewed in this manuscript.

2.6.2. Relationships between individual, group and organizational memories

Relationships between individual, group and organizational memories are discussed seldom. It is sometimes said explicitly that group memory is a particular case of organizational memory: "'project memory' is a subset of organizational memory" (Weiser & Morrison 1998). Though, in the majority of papers this question is not discussed at all. The latter is understandable, given that relationships between the levels in organizational research are not well explained (Hedberg 1981; Rousseau 1985).

Generally speaking, the same construct can be applied without any changes to different levels of analysis if functional relationships between variables at these levels are the same (Rousseau 1985). With regard to memory, it is agreed that individuals retain the most knowledge possessed by an organization. However, as it is shown by studies of group recall, group performance does not equal the sum of group members' remembrances (Tindale & Sheffey 2002). Moreover, organizational memory is not limited to individual memories either but lies also in procedures, documents, etc. of organization (Walsh & Ungson 1991). Thus relationships between variables at different levels are not similar; hence, a memory construct developed at one level cannot be applied in full at other levels.

Nevertheless, there are some cases when a construct developed for one level can be applied at another one. The principle of inclusion says that the elements at a higher level of hierarchy are comprised of lower ones and lower level units can be defined in terms or properties of a higher unit and not vice versa (Rousseau 1985). It follows that constructs developed at higher levels can be in some cases applied at lower ones. However, "lower level" constructs need further development if they are applied at levels that are higher in hierarchy.

According to the principle of inclusion, an organization is comprised of groups where the latter bear properties of the whole organization whereas the opposite is not true[2]. Consequently, coming from the top down, constructs of organizational memory may be applied at a group level. At the same time, group memory theories need further development if they are to be used at the organizational level. Research on organizational memory will be discussed in the next chapter. Papers that extend group memory constructs to organizations are few. They include works of Lehner & Maier (2000), Nevo & Wand (2005), Anand et al. (1998), and Jackson & Klobas (2008). They are also discussed in the next chapter.

Individual memory is a constituent, but not the only one, of group and organizational memories. Thus the concept of individual memory is not fully applicable at group and organizational levels. This clarification helps to diminish critique in anthropomorphism (attributing human characteristics to nonhuman units) and reification (treating an abstract concept as a real thing) typical for memory studies at a collective level (Schneider & Angelmar 1993).

2.6.3. Transactive memory system and organizational memory

Studies on organizational memory

Research on organizational memory can be divided into two main streams. The first stream consists of conceptual works that discuss content and structure of organizational memory, its processes and measurement. The second stream is focused on the use of information technologies in purposeful design of organizational memory which is supposed to improve organizational effectiveness and efficiency. It should be noted that no clear border exists between these streams because papers in the first stream often discuss consequences of organizational memory as well as papers in the second stream sometimes develop their own understandings of organizational memory content and structure. In this paper theoretical issues of organizational memory will be discussed first; then the “design stream” will be reviewed.

An overview of the important conceptual works is presented in Table 5. These works take different perspectives and, as a result, the concept of organizational memory is quite nebulous. The earliest and the most oft-cited paper is that by

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[2] It is necessary to note that organizations are often characterized by partial inclusion because some individuals may be, at the same time, members of several groups (Rousseau 1985). This point is not developed here further, though; the definitional issue of hierarchy in general and inclusion in particular are underdeveloped areas of organizational research.

Table 5. An overview of the important conceptual works on organizational memory.

(continued on the next page)

Authors	Definition	Content
Walsh & Ungson (1991)	"[O]rganizational memory refers to stored information from an organization's history that can be brought to bear on present decisions.	Interpretations about organizational decisions and their subsequent consequences (who, what, when, where, why, how).
Stein & Zwass (1995)	Organizational memory is "the means by which knowledge from the past is brought to bear on present activities, thus resulting in higher or lower levels of organizational effectiveness".	(1) Semantic (general) information (organizational practices contained in handbooks, manuals, standard operating procedures, etc.); (2) episodic (context-specific) information (engineering work-arounds, contextually situated decisions and their outcomes).
Stein (1995)	Organizational memory is "the means by which knowledge from the past is brought to bear on present activities, thus resulting in higher or lower levels of organizational effectiveness".	Knowledge from the past where "[k]nowledge is an awareness of the efficiency and effectiveness of different courses of action in producing particular outcomes based on experience".
Moorman & Miner (1997)	Organizational memory is "collective beliefs, behavioral routines, or physical artifacts that vary in their content, level, dispersion, and accessibility".	(1) Procedural memory (memory for underlying skills for performing tasks); (2) declarative memory (memory of concepts, facts, events).
Wijnhoven (1998)	The means by which knowledge and information from the past is brought to bear on present activities.	Four types of knowledge and information aspects of organization's (core) competencies: (1) "know-how": knowledge and information that can be applied in operational activities; (2) "know-why": knowledge and information that gives the theoretical understanding of know-how. "Know-how" and "know-why" constitute operational memory (3) Meta-memory: memory about the value of operational memory (4) Memory information: knowledge and information that are important for retrieving and use of operational and meta-memories.

(Table 5 continued)

Structure	**Processes**
5 storage bins inside organization (individuals, culture, transformations, organizational structures, workplace ecology), 1 storage bin outside organization (external archives).	Acquisition, retention, retrieval.
5 internal bins of Walsh & Ungson (1991) plus organizational memory information system.	Acquisition, retention, maintenance, search, retrieval.
	Acquisition, retention, maintenance, loss, retrieval.
Organizational memory can be found in (1) organizational beliefs, frames of reference, values, norms, organizational myths, legends, stories; (2) formal and informal behavioral routines, procedures, scripts; (3) physical artifacts.	
6 bins of Walsh & Ungson (1991) plus computer-based information systems.	Acquisition, retention, and maintenance (update), retrieval and dissemination.

Walsh & Ungson (1991). According to them, interpretations about organizational decisions and their subsequent consequences are stored in five internal storage bins (individuals, culture, transformations, organizational structures, and workplace ecology) and one external bin (external archives). Including virtually everything in organization, this framework is sometimes criticized for being too complex (e.g. Bannon & Kuutti 1996).

Other researchers have developed the work of Walsh & Ungson (1991) further. For example, Stein & Zwass (1995) and Wijnhoven (1998), by stressing the role of information technologies, added computerized information systems to five internal storage bins. On the contrary, Moorman & Miner (1997) simplified the original storage bin system and said that organizational memory can, instead, be found in (1) organizational beliefs, (2) formal and informal behavioral routines, procedures, scripts, and (3) physical artifacts.

With regard to the content of organizational memory, there is less agreement among the researchers. For Walsh & Ungson (1991), organizational memory consists of interpretations about organizational decisions (regarding who, what, when, where, why, and how). Stein & Zwass (1995) talk about semantic (general) information and episodic (context-specific) information. Moorman & Miner (1997) use concepts of procedural and declarative memory. The former is a memory of skills necessary to perform tasks; the latter is a memory of concepts, facts, and events. For Stein (1995), memory content is knowledge about past actions' effectiveness and efficiency. Wijnhoven (1998) elaborates on it further by saying that organizational memory consists of four types of knowledge and information: (1) "know-how", (2) "know-why", (3) meta-memory: memory about the value of "know-how" and "know-why", as well as (4) knowledge and information that are important for retrieval and use of the first three components.

Concerning processes of organizational memory, Walsh & Ungson (1991) recognize, similar to traditional approach in psychology (cf. Crowder (1976) as cited by Hartwick et al. 1982), three types of processes: acquisition (putting information into memory storage), retention, and retrieval (extracting information from the storage). Other researchers, given their attention to organizational memory information systems, recognize also maintenance (Stein & Zwass 1995; Stein 1995; Wijnhoven 1998), search (Stein & Zwass 1995), loss (Stein 1995), and dissemination (Wijnhoven 1998).

Despite the lack of definitional clarity demonstrated above, the term "organizational memory" is often used to label various information systems developed within the "design stream". The main premise of this stream is that organizational memory does not lead to organizational effectiveness by itself; in order to improve it, organizational memory should be purposefully designed (Stein & Zwass 1995; Stein 1995; Wijnhoven 1998).

For example, Wijnhoven (1998) argues that the content of organizational memory influences organizational effectiveness while organizational memory means (processes and media) affect organizational efficiency. To improve effectiveness, the content of organizational memory should satisfy organizational needs; to improve efficiency, the means of organizational memory should be chosen in a way that provides low-cost, easy, and high-speed use of organizational memory.

Stein & Zwass (1995) say that organizational memory information system is "a system that functions to provide means by which knowledge from the past is brought to bear on present activities, thus resulting in increased levels of effectiveness for the organization." To support organizational effectiveness, such systems should consist of (1) integrative subsystem (that has to provide sharing organizational knowledge across time and space), (2) adaptive subsystem (that has to allow collecting and storing information about environment), (3) goal attainment subsystem (that has to help organizational actors to identify goals and attain them), and (4) pattern maintenance subsystem (that has to support organizational protocols and preserve and develop human resources). These are "layer 1" subsystems. These subsystems are supported by "layer 2" mnemonic functions that are knowledge acquisition, retention, maintenance, search, and retrieval.

There are numerous implementations of organizational memory information systems (for reviews see Bannon & Kuutti 1996; Guerrero & Pino 2001). Most of them concentrate on design of "additional", sixth internal bin; however some also take into account other bins, e.g. individuals (Ackerman & McDonald 2000; Ackerman 1994a, 1994b; Olivera 2000). There are also group-level applications within "design stream" that are based on variations of Walsh & Ungson's (1991) concept of organizational memory (e.g. Berlin et al. 1993).

Connection of organizational memory studies to a group level is weak. This could be due to the lack of agreement on what organizational memory per se is. Different definitions, with some of them hardly comparable, make the concept of organizational memory difficult to apply.

Extensions of transactive memory theory to organizations

There are several attempts to extend the theory of transactive memory to organizations. Theoretical works include research by Anand et al. (1998), Lehner & Maier (2000), and Nevo & Wand (2004). Jackson & Klobas (2008) tried to detect existence of organizational transactive memory system by conducting a case study.

Anand et al. (1998) started with articulating differences between organizations and groups. Namely (1) organizations consists of multiple (overlapping) groups; (2) information technologies may locate information without using individuals' knowledge on "who knows what"; (3) communication media in organizations vary in terms of effectiveness (e.g. face-to-face vs. electron communication); and (4) soft knowledge (knowledge that is not easily communicable) is difficult to retrieve from distant parts of organization. Thus the theory of transactive memory needs adaptation to organizations. Anand et al. (1998) used a term systemic memory to refer to organization memory.

Systemic memory consists of several group memories where groups may not follow organizational boundaries and partly overlap. Moreover, information held by an outsider who is well-know to an organizational member is also a part of systemic memory. Unlike in original group transactive memory system, employees can allocate an item in a systemic memory by using not only their own knowledge on "who knows what" but also (a) search engines and (b) email broadcasts. In this way, systemic memory consists of internal (knowledge known by employees) and external (knowledge known by outsiders but available to employees) components. Furthermore, unlike in traditional groups, face-to-face communication in organizations may not be simply impractical but even lead to miscommunication if transmitted information is simple and unequivocal. Thus groups and individuals need to be media sensitive, i.e. choose information communication media depending on the nature of transmitted information. Soft (not communicable) knowledge plays an important part in organizational decision making. Thus additional processes were introduced to the original set of transactive memory processes depicting search, evaluation, use of, and shifting decision making to external experts.

Lehner & Maier (2000) also noted that organizations consist of groups (that do not necessarily follow organizational structure). Individuals are often members of more than one group and, hence, are parts of several transactive memory systems. Thus organizational memory consists of multiple transactive memory systems that overlap through individuals who belong to multiple groups. Such overlap could also occur on a basis of common resources (e.g. databases). Exchange of information in such system may proceed in three ways: (1) between groups; (2) between a group and another group' "component" (a person or computer agent); and (3) between "components" of two different groups. These exchanges could be uni- or bi-directional, formal or informal, electronic or face-to-face, etc. Lehner & Maier (2000) mentioned that a huge number of possible combinations preclude devising a structure of organizational transactive memory system.

Nevo & Wand (2004) identified two barriers that hinder direct extension of group transactive memory to a whole organization. These are (1) an organization could be too big for one person to remember "who knows what"; and (2) uncertainty about who should remember certain types of knowledge that formally do not belong to any department in an organization could cause information allocation problems. Nevo & Wand (2004) suggested that information technology could help to overcome these barriers. They proposed to extend directories of "who knows what" so that they would include (1) "what" (knowledge subjects, i.e. organizational ontology); (2) "who" (retainers of knowledge), and (3) cognitive, descriptive, and persuasive meta-knowledge that is intended to capture tacit dimension of group knowledge. In these extended directories, retainers are characterized by descriptive (information about retainers) and cognitive (perceived self-expertise) meta-knowledge. Retainers possess knowledge subjects in the form of truth statements (predicates). Knowledge predicates are characterized by descriptive (e.g. intended audience) and persuasive (retainers' credibility) meta-knowledge. Knowledge subjects are characterized by descriptive and conceptual (signifying type of relationships between predicates) meta-knowledge. Nevo & Wand (2004) proposed a formal model of such transactive memory system and pointed out that information technology could support knowledge allocation process. They also noted that the main challenge of this approach is to keep meta-memory directories updated.

Jackson & Klobas (2008) acknowledged the abovementioned works but noticed that research on transactive memory theory extensions to organizations had been conceptual rather than empirical. Therefore, one of the research questions they asked was if an organizational transactive memory system exists. Results of their case study demonstrated that directories of "who knows what" and transactive processes were, indeed, in place in the studied organization. However, it was in some respects different compared to groups and dyads. For example, "gatekeepers", i.e. those who know well "who knows what", may coordinate transactive processes in an organization. This work is the first one on a transactive memory system at organizational level; it demonstrates the potential of this research direction.

2.6.4. *Transactive memory system and team mental models*

Team mental models

The term team mental model “refers to an organized understanding of relevant knowledge that is shared by team members” (Mohammed & Dumville 2001). Klimoski & Mohammed (1994) stress that it is a construct, not a metaphor, because it allows capturing real life phenomenon. Discussion of team mental models often revolves around their content, form, and function.

A content of team mental models can be grouped into knowledge related to situations (what goes on with a team including mental representations of equipment, knowledge of others, environment, etc.) and knowledge related to actions (what to do about those situations; e.g. behavioral routines) (Klimoski & Mohammed 1994). Cooke et al. (2000) say that a team mental model is comprised of task- (e.g. expertise in a certain area) and team-related knowledge (e.g. understanding of task procedures and knowledge of what teammates know). Alternatively, four content domains can be identified (Cannon-Bowers, Salas, & Converse 1993; Rouse, Cannon-Bowers, & Salas 1992; Mohammed et al. 2000): (a) equipment mental model (equipment-related knowledge); (b) task mental model (task-related knowledge); (c) team member mental model (team members-related knowledge, including “who knows what”); and (d) teamwork schema (process-related knowledge).

As for the form, a team mental model is not any but organized knowledge (Cannon-Bowers et al. 1993; Mohammed et al. 2000). Meaningful patterns of organized knowledge can be, for example, cause-effect relationships or categorical membership (Klimoski & Mohammed 1994).

In connection with the function, it is said that shared mental models improve team performance. There is no clarity, though, on the meaning of the word “shared”. It can mean (a) identical (held in common) knowledge; (b) “divided” or “distributed among team members” (individuals possess different knowledge; no overlap); or (c) overlapping knowledge (some of the knowledge is different, some is held in common) (Cannon-Bowers et al. 1993; Klimoski & Mohammed 1994; Cooke et al. 2000). Though researchers do not usually specify what the term “shared” means (Klimoski & Mohammed 1994), most of the studies are focused on measuring homogeneity of mental models held by team members. The general premise of team mental model research is that knowledge held in common improves team performance.

Relationship between transactive memory system and team mental models

Both knowledge heterogeneity and knowledge homogeneity are important for team performance. On the one hand, knowledge heterogeneity is important because teams are created specifically to fulfill tasks that a single individual cannot accomplish (Cooke et al. 2000). On the other hand, teammates require some shared knowledge as well in order to be able to understand each other: "overlapping teamwork knowledge is necessary to provide adequate coordination" (Mohammed & Dumville 2001). However, totally overlapping knowledge makes teams dysfunctional: it leads to single-minded view on tasks, so called "groupthink" (Cannon-Bowers et al. 1993; Janis 1972). Thus, it can be suggested that for successful team performance both heterogeneous task-related and homogeneous team-related knowledge are required.

Heterogeneity and homogeneity are present in the structural component of a transactive memory system. Differentiation of individual expertise describes heterogeneity of task-related knowledge while awareness of "who knows what" puts stress on homogeneity of team-related knowledge (cf. Cannon-Bowers et al. 1993). Team mental models emphasize homogeneity of any part of the whole spectrum of knowledge (not only task-related). Thus, team mental models and a transactive memory system are close but different concepts.

Both research streams could benefit from cross-fertilization (Mohammed & Dumville 2001). Research on team mental models may assist in measuring structural component of a transactive memory system, especially its homogeneous constituent (Lewis 2003; Austin 2003). Similarly, team mental models research can benefit from the studies on transactive memory systems by adopting techniques for measuring heterogeneity (Mohammed & Dumville 2001).

2.6.5. Transactive memory system and organizational learning

Research on organizational learning is usually traced back to time when behavioral theories of organization emerged (Cyert & March 1963). Since then many works on the topic have appeared. A consensus, however, has not been reached on either the meaning of the term or the basic nature of organizational learning (Crossan, Lane, White, & Djurfeldt 1995; Crossan, Lane, & White 1999). Bell, Whitwell, & Lukas (2002) identified four related, but focused on distinctively different topics, schools of organizational learning research: (1) an economic view, (2) a developmental view, (3) a managerial view, and (4) a process view.

An economic view focuses on learning-by-doing and seeks to explain decrease in costs that accompanies increase in experience. From this point of view, learning is a by-product of production. The developmental school stresses that learning proceeds in linear stages and is a phase or objective in the organization's evolution. For example, as an organization becomes more mature, it achieves higher levels of learning. According to the developmental school, learning is highly path dependant (i.e. shaped by previous experiences). The managerial school says that high-order learning does not occur by itself and, in order to achieve it, a set of prescriptive guidelines, aimed at development of an organization-wide culture, should be followed. Literature that belongs to this stream often offers clear prescriptions for organizational learning. The process school focuses on the fundamental processes of organizational learning. These are information acquisition, dissemination, utilization, as well as memory processes. This school argues that these processes are characteristics of not only individuals but also occur at a macro level. It also stresses social nature of organizational learning.

Crossan et al. (1995) distinguish between levels at which learning occurs in organizations: (1) individual, (2) group, and (3) organizational. It is generally agreed that it is individuals who learn (Kim 1993; Hedberg 1981). However, as ideas are shared and relationships get more structured, individual learning becomes institutionalized (Crossan et al. 1999). Group level of analysis in organizational learning literature has much less been developed compared to, for example, individual one (Crossan et al. 1995). As Kim (1993) notes, memory could play a critical role in linking the levels. A few papers seek to explain group learning with the help of the theory of transactive memory.

Lewis et al. (2003), Lewis, Lange, & Gillis (2005) explore how transactive memory systems affect group learning. They conceive of a transactive memory system as a learning system that enables reciprocal learning between individual and group levels. At first, a transactive memory system develops on a basis of group members' interactions (learning cycle 1). When in place, it influences future interactions and learning (subsequent learning cycles). As the team continues doing the same task, it learns by doing and elaborates team members' knowledge on "who knows what" and team's communication patterns (learning cycle 2). The second task initiates learning cycle 3. During this cycle, a transactive memory system facilitates development of abstract knowledge and underlying principles of both tasks.

In the series of experiments Lewis et al. (2003, 2005) have discovered the following. Learning during cycle 1 (i.e. development of a transactive memory system) is evidenced by higher team performance on the same task. This finding supports results of experiments conducted by other researchers (e.g. Moreland et al. 1996). Furthermore, transactive memory systems transfer across tasks, i.e. teams with a transactive memory system in place develop it further on subsequent tasks. However such transfer is successful only when team members maintain the same division of cognitive labor across tasks. Interestingly, this is true even if team membership changes. Lewis and colleagues suggest that those individuals who developed strong expertise in their prior teams tend to declare it in the new ones. In this case, other members have to adjust. Furthermore, medium levels of expertise recognition tend to reduce subsequent performance. In this situation, team members do not find their own expertise and prior division of labor relevant to subsequent tasks. Lewis and colleagues have also demonstrated that a transactive memory system helps team members to develop procedural knowledge on task domain. Such learning transfer does not occur, however, after a single task. Instead, procedural knowledge becomes deeper as teams gain more experience with subsequent tasks.

London, Polzer, & Omoregie (2005) developed a multilevel model of group learning in which development of a transactive memory system and interpersonal congruence take central places. London and colleagues started with the process of self-verification, group diversity, and task demands. Self-verification means seeking feedback on one's self-concept. Its aim is to satisfy individuals' feelings of predictability and control. Group diversity stands for diversity of skills, knowledge, and ideas of group members. Task demands define how input of team members is combined, i.e. the pattern of members' interdependence. Self-verification, group diversity, and task demands determine how the processes of identity negotiation will occur. Identity negotiation consists of the processes of self-disclosure and feedback. The latter seeks to test self-disclosed information by other group members throughout time. Identity negotiation results in individual self-verification and development of a transactive memory system and interpersonal congruence at a group level. These processes can be influenced by feedback interventions (e.g. the group leader's encouragement to engage in self-disclosure process) or changes in group membership, goals, or task progress. Group outcomes may also increase future identity negotiations.

The works by Lewis et al. (2003, 2005) and London et al. (2005) contribute to the process school of organizational learning (Bell et al. 2002) and, apparently, have a big potential for future research because they acknowledge (thanks to the theory of transactive memory) the link between individuals and groups, diminishing in this way the risk of group anthropomorphization.

3. BUILDING RESEARCH QUESTIONS

The main proposition made by the theory of transactive memory is that a developed transactive memory system enhances team performance (Wegner et al. 1991; Liang et al 1995; Moreland et al. 1996, 1998; Moreland 1999; Moreland & Myaskovsky 2000; Hollingshead 1998a, 1998b, 1998c). This proposition is universalistic because it describes unconditional relationship between variables, i.e. a transactive memory system and team performance (Drazin & Van de Ven 1985). More complex, conditional relationships between two or more independent variables and a dependent one could exist. In this research, a contingency approach to study R&D teams is adopted, which brings a contingency component into transactive memory research.

This chapter describes development of research questions. The basic logic behind this process is as follows. Among two main structural contingency theories, organic and bureaucracy ones, organic theory is shown to be more suitable for R&D teams' studies. Specifically, the work of Perrow (1967) with its emphasis on task characteristics is chosen for research questions development because it stresses a cognitive aspect of a contingency variable. Building on a combination of contingency theory and information processing view, a concept of fit is introduced that is, for a team to perform successfully, its information processing requirements should be matched with information processing capabilities. Information processing requirements are conceptualized in this work as task complexity. Information processing capabilities are conceptualized as a team transactive memory system. Thus, a general contingency framework proposed for team studies is as follows: for a team to perform successfully, tasks of different complexity should be matched with different transactive memory systems.

This framework is then applied to R&D teams. Namely, a place of transactive memory system in R&D research and the applicability of the proposed framework to R&D teams' studies are demonstrated. Research by Tushman and colleagues (Tushman 1978a, 1978b, 1979a, 1979b; Katz & Tushman 1979; Allen, Lee, & Tushman 1980) is used to develop the framework further. Building on their findings, it is proposed that, for an R&D team to perform successfully, simple R&D tasks should be matched with less developed transactive memory system; complex R&D tasks should be matched with more developed transactive memory. Specifics of distributed settings, i.e. their effects on a transactive memory system, are then presented. Not well understood nature of transactive memory phenomenon in distributed teams calls for a qualitative research design which determines the final formulation of research questions.

The abovementioned logic is followed in the structure of this chapter. In the first half of the chapter a general contingency framework for the team studies is developed. Organic contingency theory is given in more detail than bureaucracy one. Subchapters on task conceptualizations in other research streams and on the concept of fit are given to broaden perspective on the discussed topic. The second half of the chapter applies the framework to distributed R&D teams. The chapter finishes with research questions formulation.

3.1. Contingency framework for studies of teams

3.1.1. Overview of contingency research

At its simplest, the contingency approach posits that a relationship between two variables is conditional on some third variable. While there are debates on if there is the contingency theory or a collection of different contingency theories (Donaldson 2001), the main idea is that organizational effectiveness depends on a fit between organizational characteristics and contingencies. In this way, “a contingency is any variable that moderates the effect of an organizational characteristic on organizational performance” (Donaldson 2001).

Theories that put emphasis on organizational structure as an organizational characteristic are referred to as structural contingency theories. Following a conceptual and theoretical integration presented by Donaldson (2001), it could be argued that the main structural contingency theories are organic and bureaucracy ones. Contingencies they take into account are task uncertainty, task interdependence, and size. Task uncertainty is influenced by environmental and technological change. Task interdependence refers to the way activities in an organization are connected to each other. Size stands for how many people work in the organization. Organic and bureaucracy theories distinguish between main and minor contingencies (Table 6). The theories and corresponding contingencies are discussed in more detail below.

Table 6. Main and minor contingencies of organic and bureaucracy theories.

Contingencies	**Theories**	
	Organic	Bureaucracy
Task uncertainty	main contingency	
Task interdependence	minor contingency	minor contingency
Size		main contingency

According to organic theory (Burns & Stalker 1961; Hage 1965; Lawrence & Lorsch 1967; Perrow 1967; Thompson 1967; Woodward 1965), organizational structure is situated on a continuum that spans from mechanistic to organic structure (Table 7). Mechanistic structure is characterized by centralized decision making, high specialization (expressed in detailed, narrow domain job assignments), and high formalization (expressed in written rules for employees to follow). In contrast, organic structure is characterized by decentralized decision making (initiative and expertise of employees are taken into account) and is low on both functional specialization and formalization. Decision making style, specialization, and formalization go together and are the parts of the same dimension.

The main contingency of the organic theory is task uncertainty. If task uncertainty is low, top managers are able to possess and process information necessary for making decisions leading to organizational effectiveness. So the mechanistic structure fits tasks of low uncertainty. In contrast, if task uncertainty is high, top managers cannot possess all required information and have to rely on expertise and participation of lower level employees; hence, the organic structure fits tasks of high uncertainty.

Table 7. Main characteristics of organic theory.

Structure	Characteristics	Contingency fit
Mechanistic	Centralized decision making; high on functional specialization; high on formalization	Low task uncertainty
Organic	Decentralized decision making; low on functional specialization; low on formalization	High task uncertainty

According to bureaucracy theory (Blau 1970, 1972; Child 1973; Weber 1968), organizational structure is situated on a continuum that spans from simple to bureaucratic structure (Table 8). Simple structure is characterized by centralized decision making but, unlike in the organic theory, is low on functional specialization and formalization. In simple structure, top management controls the organization directly. In contrast, bureaucratic structure is characterized by decentralized decision making and is high on functional specialization and formalization. In bureaucratic structure, top management controls the organization indirectly through job definitions and rules.

The main contingency of bureaucracy theory is organization's size. If the size is small, top management is able to control the organization directly. So, simple structure fits the contingency. On the contrary, if the size is big, high complexity and a tall hierarchy require delegation of decision making. At the same time, a big size encourages division of labor (high specialization) whereas recurrent nature of many decisions allow for high formalization. Thus bureaucratic structure suits big size companies.

Table 8. Main characteristics of bureaucracy theory.

Structure	Characteristics	Contingency fit
Simple	Centralized decision making; low on functional specialization; low on formalization	Small size
Bureaucratic	Decentralized decision making; high on functional specialization; high on formalization	Big size

It should be noted that organic and bureaucracy theories understand decentralization slightly differently. In bureaucracy theory, decentralization is achieved through delegation of authority to middle managers mostly; whereas in organic theory, decentralization involves participation in decision making of lower level managers and even shop-floor workers. In this way, organic structure of the organic theory is more decentralized than bureaucratic structure of the bureaucracy theory.

R&D activities, as it has already been mentioned (chapter 2.1), range from "research", aimed at development of new knowledge, to "development", focused on application or expansion of already existing knowledge. "Research" and "development" are, in essence, task descriptions that involve different degrees of uncertainty: high uncertainty in research tasks, much lower uncertainty in development tasks. Moreover, the unit of analysis of this work is a team. Size, though important, seems to play much less role in differentiation of R&D teams. The latter is supported by the study of Comstock & Scott (1977) who demonstrated that size is a less powerful predictor of work unit structure than a task. Therefore, the organic theory of structural contingency has been chosen as a theoretical lens for this research. Basic features of the main contributions into organic theory are discussed in the next chapter.

It should also be mentioned that empirical testing of contingency theories has produced contradictory findings (Fry 1982): some studies confirmed contingency propositions, some did not. The major source of confusion lies in different conceptualizations and operationalizations of both task and structure. This research is not aimed at development of an integral contingency theory (cf. Miller, Glick, Wang, & Huber 1991); neither considers it the concept of fit from the system approach which would require making a thorough analysis of different contingencies, structures, and performance measures (Drazin & Van de Ven 1985). Instead, this study questions the universalistic claim of the transactive memory theory that a developed transactive memory system improves performance of any team. In this light, only those empirical studies in contingency theory pertaining to this research objective will be considered. Those interested in a deeper review of the state of the art in contingency theory and problems in empirical research are advised to refer to Donaldson (2001) and Fry (1982).

3.1.2. Organic theory

The main contributors to organic theory are, as presented by Donaldson (2001), Burns & Stalker (1961), Hage (1965), Lawrence & Lorsch (1967), Perrow (1967), Thompson (1967), and Woodward (1965). Their works are reviewed below. The review is structured according to three parameters: structure, contingency variable, and fit.

Burns & Stalker (1961) distinguished between mechanistic and organic structures. Mechanistic structure is characterized by centralized decision making and high formalization. Subordinates in mechanistic structure are psychologically dependent on their supervisors. Unlike in mechanistic structure, work relationships in organic structure are characterized by employee discretion, i.e. their empowerment and participation in decision making. Organic structure is best described as a network of collaborating experts. Mechanistic and organic structures present two poles of a continuum. A real organization may lie at any point in between. A contingency variable proposed by Burns & Stalker (1961) is a rate of technological and market change. If the rate is low, a mechanistic structure would be appropriate. If the rate is high, an organization would be effective if it has an organic structure.

Hage (Hage 1965; Hage & Aiken 1969; Hage & Dewar 1973) used another approach to describe contingency variable and structure. He distinguished between two structures, one of which maximizes efficiency, the other – innovation. Structure that is centralized in decision making, formalized, and low on complexity maximizes efficiency. Structure that is decentralized, low on formalization, and high on complexity maximizes innovation. The former corresponds to mechanistic structure, the latter – to organic structure of Burns & Stalker (1961). It should be noted that the usage of the term “complexity” is rather idiosyncratic to Hage. By “complexity” he understands amount of knowledge available in an organization. This amount is defined, to the great extent, by employees’ educational level. If an organization employs highly educated people, its complexity is high; otherwise, it is low. Though Hage does not say it explicitly, reviewers (Donaldson 2001) see environment as a contingency variable in his reasoning. That is if environment competes on costs and requires efficiency, a centralized and formalized structure is needed. If environment favors innovation, decentralized and lowly formalized structure would be more appropriate.

Lawrence and Lorsch (Lawrence & Lorsch 1967; Lorsch & Allen 1973; Lorsch & Lawrence 1972) describe organizational structure along two dimensions: differentiation and integration. Differentiation is the differences between the departments in terms of goal orientations, time orientations, formality of structures, and interpersonal orientations. Integration between departments is achieved by using integrating mechanisms that are, in the order of increasing sophistication: hierarchy, rules, integrating individuals, and integrating departments. A contingency model they propose is more complicated than those discussed above.

A contingency variable for Lawrence and Lorsch is a market rate of product innovation and/or change that influences intended innovation. Innovation is understood here as a degree of novelty and number of new products per unit of time. Intended innovation influences task interdependence and task uncertainty. Greater intended innovation increases functional interdependence between departments because they need to transfer information back and forth between each other. Greater intended innovation also causes greater task uncertainty in some departments but not others, thus leading to differentiation. The greater the interdependence, the greater degree of integration is required. Moreover, greater differentiation between departments calls for the more sophisticated integrating mechanisms. Thus, high performance is achieved when there is a fit between requisite and actual integration provided by integrating mechanisms between differentiated functional departments.

Works of Burns and Stalker, Hage, and Lawrence and Lorsch can be put into one group that sees task uncertainty as the main contingency. For the other group, which includes works by Thompson, Woodward, and Perrow the main contingency is technology.

Thompson (1967) distinguishes between three types of technologies: mediating, long-linked, and intensive. Each type corresponds to specific types of interdependence between organizational subunits: pooled, sequential, and reciprocal. Mediating technology can be described as linking customers. It involves pooled interdependence: two organizational subunits do not have direct connections. In essence, interdependence between subunits in this case is minimal; hence, an organization can be structured by rules and procedures. Long-linked technology involves sequential interdependence: an output of one subunit is an input to the other. This interdependence is medium and can be structured by planning. The last type of technology, intensive technology, is based on a feedback which allows choosing appropriate techniques. It involves reciprocal interdependence: an output of each subunit is an input for other subunits. Intensive technology is structured by mutual adjustment: each subunit seeks to attain own objectives, which can be reformulated on a basis of other units' feedback.

Altogether, three types of structure identified by Thompson (1967) are rules and procedures, planning, and mutual adjustment. When compared to other works (Donaldson 2001), it can be said that rules and procedures is a mechanistic type of structure. Planning is more flexible but still mechanistic. Mutual adjustment corresponds to organic structure.

Woodward (1965) puts emphasis on internal technology and describes it in terms of produced product types and their quantity. Following product types are distinguished. Products can be discrete and hence easily counted or they may be in a form that has to be measured by volume or weight. Building on these characteristics, Woodward describes three stages of advance in technology: (1) unit and small batch production; (2) large batch and mass production; and (3) process production. By examining structures of real companies, Woodward (1965) found that mechanistic structure is typical for large batch and mass production. Both process production and unit and small batch production are managed through organic structure.

The last work to be described in organic theory is that of Perrow (1967). It is chosen as a basis for research questions development and is discussed in detail in the next chapter.

3.1.3. Tasks as Perrow's (1967) technology

In this research, among different theories under organic umbrella, a stream of research based on the work of Perrow (1967) is chosen because it stresses a cognitive aspect of contingency variable which suits best studies of knowledge work units. Moreover, Perrow's theory seems to be hold strongest at the work unit level where diverse activities do not confuse relationships between technology and structure (Withey, Daft, & Cooper 1983).

Perrow defines *technology* as "actions that an individual performs upon an object, with or without the aid of tools or mechanical devices, in order to make some change in that object" (Perrow 1967). Thus an object or a "raw material" could be a hard object as well as a human being or information. *Structure* is the form of individual's interactions taking place in the course of changing objects.

Perrow identifies two aspects of technology: (1) *number of exceptions* encountered in the course of work and (2) *analyzability* of encountered problems. Number of exceptions is related to the degree of perceived familiarity with the stimuli. Analyzability is understood as a nature of the search process undertaken when an exception occurs. If the search is done on a logical basis, the technology is analyzable. On the contrary, if the problem is vague and poorly conceptualized, the technology is unanalyzable.

Two dimensions of technology result in four different technology types: (1) routine technology, (2) engineering technology, (3) craft technology, and (4) nonroutine technology (Figure 3). Routine technology is characterized by few exceptions and analyzable problems. Engineering technology has many exceptions and analyzable problems. Nonroutine technology is characterized by many exceptions and unanalyzable problems. Craft industries have few exceptions and unanalyzable problems.

Unanalyzable problems	Craft industries	Nonroutine
Analyzable problems	Routine	Engineering
	Few exceptions	*Many exceptions*

Figure 3. Technology types according to Perrow (1967).

To describe structure, Perrow originally used terms control and coordination. Coordination is achieved by either planning or feedback. Control is described by (a) degree of discretion (relating to choices among means) and (b) power (relating to choices on goals and strategies). By combining these parameters to describe two organizational areas – technical control and supervision of production, Perrow came up with four structure types (Figure 4). They are (1) formal, centralized structure, (2) flexible, centralized structure, (3) decentralized structure, and (4) flexible, polycentralized structure.

Later works abandoned original dimensions of control and coordination and adopted terms “centralization” and “flexibility” to describe structural dimensions (Figure 5). Perrow himself notes that flexible, polycentralized structure is closest to Burns and Stalker’ (1967) organic structure; whereas formal, centralized structure corresponds to Burns and Stalker’ (1967) mechanistic structure.

	Discretion	*Power*	*Coordination*	*Discretion*	*Power*	*Coordination*
Technical control	Low	Low	Planning	High	High	Feedback
Supervision of production	High	High	Feedback	High	High	Feedback
	Decentralized			**Flexible, polycentralized**		
Technical control	Low	High	Planning	High	High	Feedback
Supervision of production	Low	Low	Planning	Low	Low	Planning
	Formal, centralized			**Flexible, centralized**		

Figure 4. Structure types and their characteristics according to Perrow (1967).

	Flexibility low	*Flexibility high*
Centralization low	Decentralized	Flexible, polycentralized
Centralization high	Formal, centralized	Flexible, centralized

Figure 5. Structure types in “centralization” and “flexibility” dimensions.

The general principles of fit proposed by Perrow (1967) are: (1) analyzable technologies require centralized structure; (2) unanalyzable technologies require decentralized structures; (3) the greater the number of exceptions, the more flexibility is needed. In this manner, routine technology requires formal, centralized structure; engineering technology needs flexible centralized structure; craft technology is better suited by decentralized structure; nonroutine technology requires flexible, polycentralized structure.

The original work of Perrow (1967) has been used in the number of studies. These studies are, however, characterized by what Comstock & Scott (1977) call “misplaced creativity of researchers who seem reluctant to replicate definitions or measures”. The latter can be illustrated by the study of Van de Ven & Delbeq (1974). Building on Perrow’s work, Van de Ven & Delbeq conceptualize tasks along dimensions of *task difficulty* and *task variability*. Task difficulty repeats to the great extent Perrow’s task analyzability and underscores if there is a known procedure that specifies the sequence of the steps necessary to perform the task. Task variability corresponds to Perrow’s “number of exceptions” and is “the number of exceptional cases encountered in the work requiring different methods or procedures” (Van de Ven & Delbeq 1974). Van de Ven & Delbeq demonstrate empirically that task difficulty and task variability result into three basic structural modes: systematized (low task variability; low to medium task difficulty), service (intermediate task variability; low to high task difficulty), and group (high task variability; medium to high task difficulty).

Furthermore, regarding task dimensions, Perrow (1967) says that analyzability and number of exceptions are connected. Some researchers follow his reasoning and collapse task analyzability and number of exceptions into routine-nonroutine continuum. Others, in contrast, stress that these are two independent dimensions (e.g. Van de Ven & Delbeq 1974; Withey et al. 1983). Adding more to the terminological turmoil, words “nonroutine” and “complex”, “uncertain” and “complex” are often used as synonymous (e.g. Tushman 1978b; Tushman & Nadler 1978).

3.1.4. Task conceptualizations in other research streams

It is interesting to look at how tasks and task complexity are conceptualized in other research streams, e.g. organizational studies, information studies, and small group research (Table 9). Most of works are done on the individual level (Campbell 1988; Wood 1986; Byström & Hansen 2005). Only McGrath (1984) presents a task typology on a group level.

Table 9. Task conceptualizations in other research streams.

Research area	Authors	Level of analysis
Organizational studies	Campbell (1988)	Individual tasks
Organizational studies	Wood (1986)	Individual tasks
Information studies	Byström & Hansen (2005)	Individual work tasks
Small group research	McGrath (1984)	Group tasks

Campbell (1988) distinguishes between four basic attributes of task complexity: (1) presence of multiple paths to a desired end-state, (2) presence of multiple desired end-states, (3) presence of conflicting interdependence among paths to desired outcomes, and (4) presence of uncertain or probabilistic linkages among paths and outcomes. Task complexity is then determined by a degree to which a task incorporates each of these attributes and by the total number of attributes characterizing the task.

Building on task complexity, Campbell (1988) distinguished the following types of tasks: (1) simple tasks (contain none of the complexity attributes); (2) decision tasks (emphasize choosing or discovering an optimal outcome); (3) judgment tasks (characterized by conflicting and probabilistic nature of task-associated information; set out to find a shared solution); (4) problem tasks (characterized by a multiplicity of paths to a well-specified, desired outcome); and (5) fuzzy tasks (characterized by both multiple desired end-states and multiple ways to achieve them).

Another example of task conceptualizations in organizational studies is that of Wood (1986). Three task components are distinguished: (1) products (measurable results of acts), (2) acts (required to create a certain product), and (3) information cues (pieces of information that can be processed to make conscious judgments in the course of task execution). Product is a task output; acts and information cues are inputs.

According to Wood (1986), task complexity describes relationships between task inputs. Three types of complexity are recognized: (1) component, (2) coordinative, and (3) dynamic. The more acts need to be executed as well as the more information cues need to be processed, the higher is the component task complexity. The form and strength of relationships between task inputs and products as well as sequencing of inputs define coordinative task complexity. Changes in the environment that lead to changes in task inputs as well as between task inputs and products cause dynamic task complexity.

In information studies Byström & Hansen (2005) offer the following framework for individual work tasks. Work tasks are defined by an organization and have goals. They consist of three stages: (1) task construction, (2) task performance, and (3) task completion. Each stage involves information seeking and information search. Information seeking is initiated by a recognized need for information. Information search is focused on a separable fraction of the information need. Thus information seeking consists of separable information searchers. Sources of information used in information search could be both non-human (typically emphasized in information studies) and human (addressed less often).

In small group research McGrath (1984) proposed a circumplex (circular arrangement of variables in a two-dimensional space, including different possible blends of the dimensions) for group tasks. The horizontal dimension of the task space is the degree to which the task involves cognitive vs. behavioral performance requirements. The vertical dimension refers to the degree to which the task is cooperative or conflictual. These dimensions produce four task categories that are “generate”, “choose”, “negotiate”, and “execute” whose names reflect four basic processes involved in tasks’ execution. Altogether, McGrath proposes eight types of tasks depending on the degree each dimension is presented in a particular task type.

Among these conceptualizations, Campbell’s (1988) attributes of task complexity lie squarely into Perrow’s (1967) task analyzability and Van de Ven & Delbeq’s

(1974) task difficulty. Other conceptualizations do not have common points with Perrow's (1967) work.

It should also be noted that, though contingency research is carried out at different levels of analysis (Fry & Slocum 1984; Comstock & Scott 1977), the possibility that individual, group, and organizational tasks could be different is not addressed in contingency literature. For example, in case of Perrow's (1967) work the same task analyzability and number of exceptions are used at all levels. Furthermore, diversity in task conceptualizations points out that there is no any adequate theoretical model to date which could describe tasks comprehensively (Wood 1986; Byström & Hansen 2004).

3.1.5. Contingency theory and information-processing

Some researchers combine contingency thinking with information processing view. A general assumption is that the greater the task uncertainty, the greater is the amount of information to be processed in order to achieve a certain level of performance. Thus, unless task requirements and organization's capacity to process information are matched, organization's performance will inevitably suffer (Galbraith 1974). The most comprehensive work in this stream is that of Tushman & Nadler (1978). They propose that information processing view could be an integrating concept in organizational design.

The main objective of organizational design, according to Tushman & Nadler (1978), is to design subunits and relations between them in a way that organization' information-processing capability matches its information-processing requirements. Information-processing requirements are defined by task uncertainty that is influenced by (1) subunit task characteristics, (2) subunit task environment, and (3) interunit task interdependence. Subunit task characteristics include task complexity and task interdependence. Routine tasks with little intra-unit interdependence have lower information-processing requirements than non-routine tasks with high intra-unit interdependence. Subunit task environment, as perceived by subunit members, could be placed along a continuum from static to dynamic: more dynamic environment causes greater uncertainty. Inter-unit task interdependence, which could be pooled, sequential, and reciprocal, as defined by Thompson (1967), also influences task uncertainty: higher levels of task interdependence produce greater uncertainty.

Subunits differ in their capabilities to process information. The differences depend on subunit structure which can be described along the continuum spanning from organic to mechanistic structures. Tightly connected communication networks of organic structures give more opportunities for feedback and synthesis of different points of view; they are less sensitive to information overload than centralized communication networks of mechanistic structures. Thus, subunits with organic structure have greater ability to deal with task uncertainty, i.e. they have greater information-processing capabilities than subunits with mechanistic structure.

To integrate subunits within an organization, different mechanisms for coordination and control can be used. In the order of increased complexity these mechanisms are (1) rules and programs, (2) hierarchy, (3) joint planning, and (4) formal information systems and/or lateral relations. More complex integrating mechanisms are associated with greater information-processing capabilities.

Organic structure and complex integrating mechanisms are costly. Thus an organization should balance its information-processing capabilities against task requirements: too much information-processing capabilities could be redundant, too little may be not enough. Following this line of reasoning, Tushman and Nadler (1978) propose that "[o]rganizations will be more effective when there is a match between information processing requirements facing the organization and information processing capacity of the organization's structure". Mismatch in capacity results in lower performance. The main propositions of the information processing model are schematically presented on Figure 6.

The information-processing view on contingency theory has been applied and further developed by other researchers. Ito & Peterson (1986) studied relationships between inter-unit interdependence, task difficulty (knowledge of cause-effect relationships), amount of boundary spanning activity, level of participation in decision making, and degree of unit members' autonomy. Daft & Macintosh (1981) introduced notions of information equivocality and information amount in order to gain richer understanding of information-processing in organizations. Egelhoff (1982) looked at strategy and structure in multinational corporations from an information-processing perspective. Zeffane & Gul (1993) explored the effects of task characteristics and subunit structure on information processing.

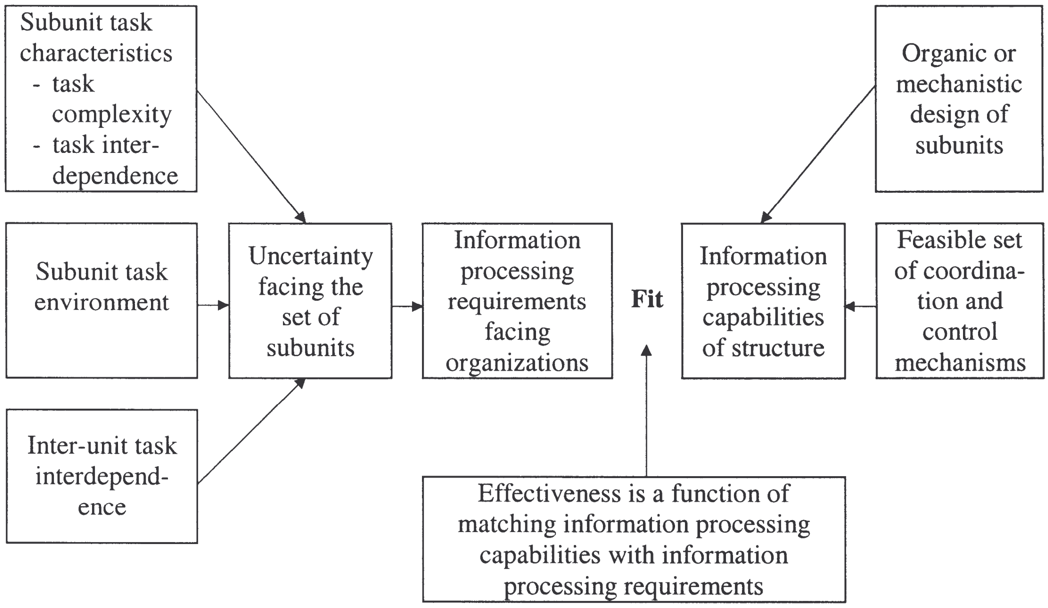

Figure 6. Organization information processing model (Tushman & Nadler 1978).

3.1.6. On the concept of fit

The concept of fit, central to the contingency theory, needs additional clarification. Drazin and Van de Ven (Drazin & Van de Ven 1985; Van de Ven & Drazin 1985) identify three types of fit in contingency research. According to *selection* approach, an organization must adapt to its context to be effective. In this way, fit is a result of natural selection: only those organizations survive that are effective because of having adapted well. In *interaction* approach, the focus is on how organizational performance depends on the interaction between organizational structure and its context. Thus, fit is a conformance to an interaction relationship between structure and context; misfit (nonconformance to the relationship) results in low performance. Selection and interaction approaches are reductionist, i.e. they assume that an organization is decomposable to independent elements that are to be examined separately; after examination, knowledge about each element is aggregated to gain understanding of the whole organization. In contrast, *systems* approach considers many contingencies, structural alternatives, and performance criteria simultaneously. Fit is understood as internal consistency of multiple contingencies and structural alternatives. It is achieved via a feasible set of equally effective, internally consistent alternative designs.

Doty, Glick & Huber (1993) elaborate further on systems approach and develop four models of configurational fit based on the notion of an ideal type. An ideal type is a theoretical construct that describes a holistic configuration of organizational factors. Four models of configurational fit are ideal types fit, contingent ideal types fit, contingent hybrid types fit, and hybrid types fit. In *ideal types* model, a number of ideal types are finite and fit is understood as the lack of deviation from the ideal type. An organization is effective if it closely resembles an ideal type. *Contingent ideal types* fit takes into account possible contingency constraints; a number of ideal types are also finite. In this model an organization is effective if it mimics an ideal type which is the most congruent with contingencies facing the organization. *Contingent hybrid types* fit model allows for hybridization among specified ideal types which form continua. It also allows for continua of contexts. In this model infinite number of types is pared with infinite number of contexts. To be effective, an organization must mimic a hybrid type determined by the contingencies facing the organization. *Hybrid types fit* also allows for multiple hybrid types. However it does not put any contingency constraints on the choice of a specific type. Thus an organization would be effective if it mimics close enough any of hybrid types.

Venkatraman (1989) proposes another framework for the concept of fit. It is based on two dimensions. The first one is a degree of specificity of the theoretical relationships between variables (high-low) and their number (few-many). The second one is anchoring of fit to a particular criterion (e.g. effectiveness): some researchers specify that fit is connected to a criterion variable; others do not. By combining dimensions, Venkatraman (1989) identifies six types of fit: (1) fit as moderation, (2) fit as mediation, (3) fit as matching, (4) fit as gestalts, (5) fit as profile deviation, (6) fit as covariation (figure 7).

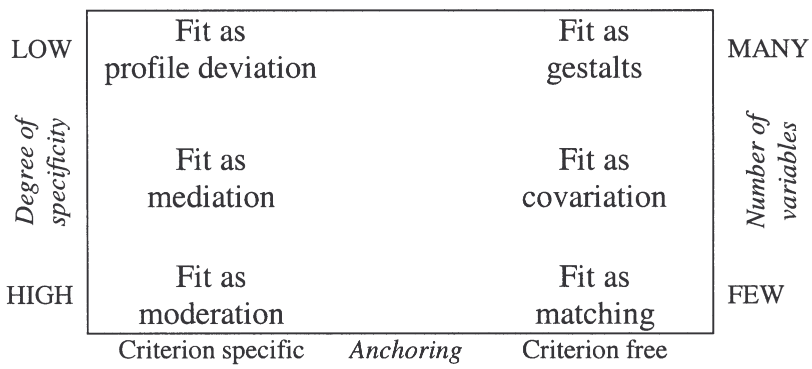

Figure 7. Six perspectives on fit (Venkatraman 1989).

Fit as moderation is high on specificity, has few (usually two) variables and anchored to some criterion. It is, in essence, an interaction perspective: the fit (i.e. interaction) between the predicting variable and the moderator determines the criterion variable. Schematic representation of fit as moderator, proposed by Venkatraman (1989), is presented on Figure 8.

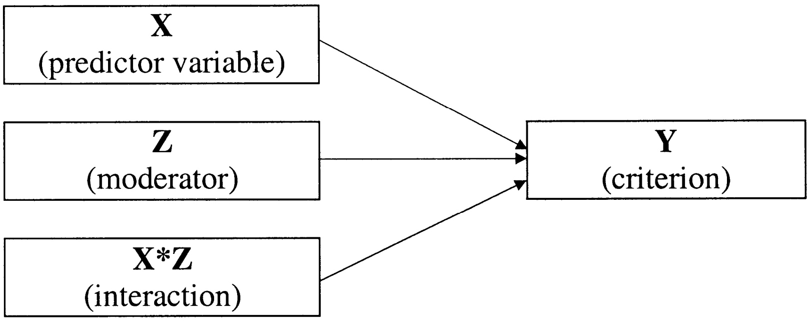

Figure 8. Schematic representation of fit as moderation (Venkatraman 1989).

Fit as mediation is medium on specificity, could have moderate number of variables, and anchored to some criterion. It describes intervention mechanism between predicting variables and the criterion variable. The schematic representation is presented on Figure 9.

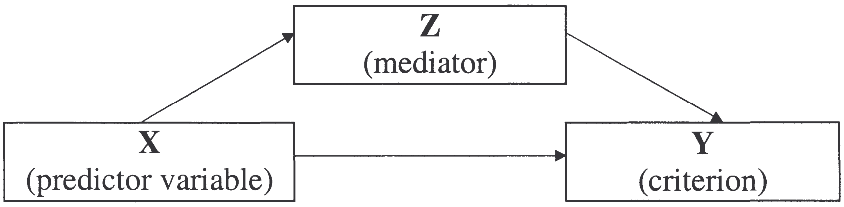

Figure 9. Schematic representation of fit as mediation (Venkatraman 1989).

Fit as matching is high on specificity, has few (usually two) variables, and not anchored to any criterion. From this perspective fit is a match between variables without reference to any anchor (e.g. performance). *Fit as gestalts* is low on specificity, has many variables, and not anchored to any criterion. This perspective on fit refers to the degree of internal coherence among a set of variables. *Fit as profile deviation* is low on specificity, has many variables, and anchored to some criterion. Fit from this perspective is a degree of adherence to an externally specified profile linked to specific criterion. *Fit as covariation* is medium on specificity, has medium number of variables, and not anchored to any criterion. From this perspective fit is understood as internal consistency of variables.

3.1.7. Proposed framework

To summarize, from a point of view of contingency theory and information processing perspective it is argued that, to be effective, an organization should match its information processing capabilities with the information processing requirements. Information processing requirements are defined by subunits' tasks, subunits' task environment, and subunits' task interdependence. Information processing capabilities stem from the structure of subunits (organic or mechanistic) and coordination mechanisms between them.

The unit of analysis of this research is a team, i.e. an organizational subunit. Therefore, subunits' task interdependence as well as subunits' coordination mechanisms are not considered in this research. Moreover, among the factors that influence subunit task uncertainty, subunit task complexity is distinguished because it is a major contingency of organic theory. To clarify, the terminology of Tushman and Nadler (1978) is followed who use terms "complex" and "routine" as synonymous.

Furthermore, among different conceptualizations of subunit structure (Fry & Slocum 1984), structure as communication network between individuals that constitute subunit is chosen (Perrow 1967; Becker and Baloff 1969; Tushman 1978a, 1978b, 1979a, 1979b). This choice is based on the importance of communication for development and functioning of transactive memory.

Then, one step further is made compared to the previous research that is information-processing capabilities are operationalized in this work as subunit's memory. As Hintz et al. (1997) mention, memory is central to information processing. Wegner (1987) says: "transactive memory derives from individuals to form a group information-processing system". Similarly, Rau (2005b) notices that information-processing structure is represented by the unit's transactive memory system.

Building on the previous discussion, it is proposed that due to different information processing requirements, teams should have different memories to correspond effectively to these requirements. Here "different memories" are understood as structurally different. The actual content of memory is not taken into account. In case of a transactive memory system, it could be expressed by better or worse developed transactive memory system and/or by different underlying communication patterns.

Putting the above discussion together, it is suggested that, for a team to perform successfully, its task complexity (information-processing requirement) should be matched with the corresponding transactive memory system (information-processing capability). In other words, tasks of different complexity require different transactive memory systems. Thus, contrary to the main stream of transactive memory studies, a contingency component is brought up to the research agenda.

According to classification of fit presented by Drazin and Van de Ven (Drazin & Van de Ven 1985; Van de Ven & Drazin 1985), the proposed framework uses interaction approach to explain relationships between variables. Though reductionist, it could provide initial understanding of a contingency relationship between a transactive memory system and team performance. This understanding could be incorporated into system approach later.

According to classification of fit presented by Venkatraman (1989), the proposed framework treats fit as moderation. Team performance (criterion) depends on fit between a transactive memory system (predicting variable) and task complexity (moderator). Schematic representation of the proposed framework is presented on Figure 10.

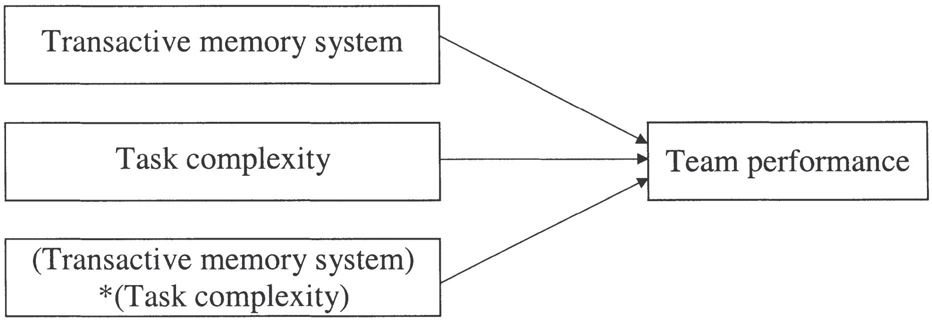

Figure 10. Schematic representation of the proposed framework of fit as moderation.

It should be noted that because memory is a cognitive characteristic of a task-doer the proposed framework could also be put under the rubric of cognitive contingency theory. However, in this research memory structure, not its content, is emphasized. Moreover, the main findings this study is built upon belong to structural contingency theory. Therefore, the proposed framework is considered as belonging to structural contingency theory.

3.2. Contingency framework applied to distributed R&D teams

3.2.1. Transactive memory system in streams of R&D research

To develop the proposed framework further, it is necessary to check if research on transactive memory system is in agreement with the previous studies on R&D teams. Three main streams of R&D research are recognized (Brown & Eisenhardt

1995): (1) “rational plan” (the focus is on a broad range of factors, such as team, senior management, market, and product characteristics, which determine financial performance of a new product); (2) “communication web” (the focus is on the effects of communication on project performance); and (3) “disciplined problem solving” (the focus is on how a team and its management contribute to a more effective process of product development). There is a plethora of factors that influence R&D team performance (Balachandra & Friar 1997). Some of them are external and hence uncontrollable; others are internal, within organizational control. Internal factors include external and internal communication, financial resources, project management, product characteristics, and combination of different expertise (Figure 11).

Researchers from a “communication web” stream have shown the impact of communication on team performance. For example, it was demonstrated that internal communication is the primary means for transfer of new ideas and information in R&D projects (Allen 1970, 1977; Ebadi & Utterback 1984). External communication with colleagues outside the project facilitates acquisition of new information and helps keep abreast with new technological and scientific developments (Ancona & Caldwell, 1992, 2007; Tushman 1977; Tushman & Katz 1980).

Furthermore, combining efforts of people from different functional areas (for example, engineering, manufacturing, and marketing) in one project is vital for new product success (Ancona & Caldwell 2007; Dougherty 1992). Such teams are called cross-functional (Brown & Eisenhardt 1995). Knowing “who knows what” helps to coordinate communication within teams (Faraj & Sproull 2000).

The concept of transactive memory combines such factors affecting R&D teams’ performance as internal communication, knowledge specialization of team members (expertise from different functional areas), and knowledge of “who knows what” (Figure 11). Therefore, it is in agreement with the previous studies on R&D. Moreover, it can be conceived of as a factor on its own right which gives an opportunity to move from the studies of relatively isolated factors to research on their aggregated manifestation.

At the same time, transactive memory system differs from other concepts used for studies of teams in general and R&D teams in particular. First, it stresses heterogeneity of knowledge possessed by team members and explains how cognitive work can be divided among them. This is different from research on knowledge sharing which emphasizes knowledge held in common (Cummings & Teng 2003; Berends, van der Bij, Debackere, & Weggeman 2006). Second, awareness of “who knows what” is studied within transactive memory research together with

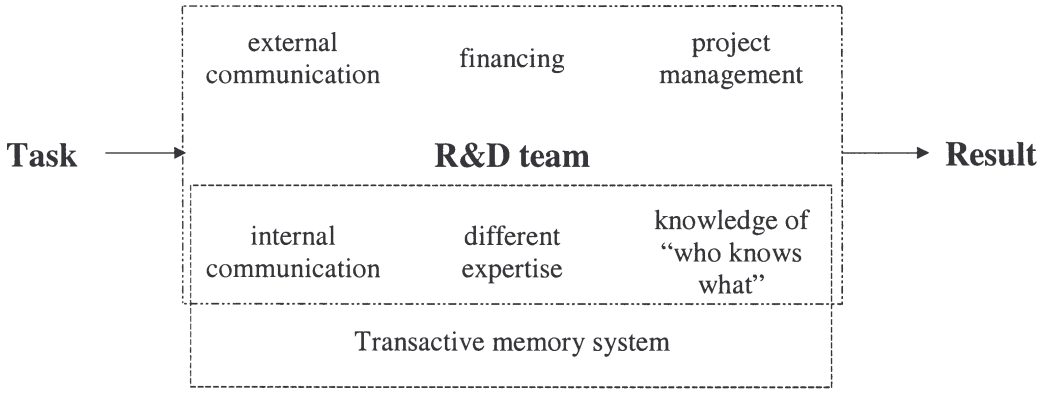

Figure 11. Transactive memory system and factors that influence R&D team performance.

communication. This is different from research on shared mental models: similar understandings of "who knows what" may be necessary but not sufficient for effective work without communication. Third, communication is not studied per se but in connection with the division of cognitive labor. This distinguishes research on transactive memory systems from the "communication web" research stream.

3.2.2. Applicability of the proposed framework to R&D teams

The applicability of a contingency approach to study of R&D teams is advocated by other researchers. First, it is agreed that R&D tasks differ in terms of task complexity: "research" tasks, aimed at development of new knowledge, are more complex than "development" tasks, focused on application or expansion of already existing knowledge (Pappas & Remer 1985; Roussel et al. 1991; Tidd et al. 2001). Second, it is pointed out that task complexity is the main moderator of team design (Bell & Kozlowski 2002) and several researchers have opted for contingency framework for R&D teams (Balachandra & Friar1997; Gassmann & von Zedtwitz 2003).

Regarding transactive memory system, it has been discovered that the impact of a transactive memory system on team performance is less when a team has a simple task (Akgün et al. 2005). Mohammed & Dumville (2001), when discussing a related concept of mental models, suggested that different configurations of team mental models could be superior for different types of teams and tasks. Findings of Moorman & Miner (1997) indicate that knowledge per se is not an unconditionally positive asset; attention should also be paid to memory dispersion and deployment. Below, empirical studies conducted in R&D settings and related to the concept of a transactive memory system are discussed in more detail.

Moorman & Miner (1997) studied how organizational memory influences new product short-term financial performance and creativity. Financial performance refers to the level of new product profitability and sales that occur within the first year of introduction. Creativity refers to the degree of new product novelty. According to Moorman & Miner (1997), organizational memory is manifested in three forms: (1) organizational beliefs, (2) formal and informal behavioral routines, and (3) physical artifacts (see Table 5 in chapter 2.6.3). It is characterized by (1) *level* or amount of stored information about a particular phenomenon; (2) *dispersion* or degree to which organizational members share organizational beliefs; (3) *accessibility* or ease of information retrieval from memory; and (4) *content* which refers to procedural (memory of underlying skills for performing tasks) and declarative (memory of concepts and facts) memory. Broadly speaking, Moorman & Miner (1997) found that (1) memory influences short-term financial performance and creativity in different ways; (2) environmental turbulence moderates memory's impact. Detailed description of the findings is, however, of little use for this work because Moorman and Miner (1997) used memory dimensions quite different compared to those used in transactive memory theory. Nevertheless, this study is important because it indicates moderating character of environmental contingencies on memory effects.

Faraj & Sproull (2000) investigated the importance of expertise coordination in software development teams. To them, there are two coordination mechanisms: (1) administrative coordination and (2) expertise coordination. Administrative coordination refers to formal or prespecified mechanisms to assign tasks, allocate resources, and integrate outputs; it includes budgets, critical path analysis, review meetings, etc. Expertise coordination refers to socially shared cognitive processes that evolve to meet task demands; it includes knowing where expertise is located, recognizing where expertise is needed, and bringing expertise to bear by means of content-rich interpersonal interactions. Faraj & Sproull (2000) found that administrative coordination is related to team efficiency but not to effectiveness. Moreover, the mere presence of expertise in a team was demonstrated to not affect team effectiveness. To bring it to bear, expertise coordination is required.

In essence, Faraj & Sproull (2000) studied effects of "who knows what" in teams and coordination mechanisms of team members. Putting their findings in other words, expertise coordination was discovered to have strong positive influence on team performance. Faraj & Sproull (2000) also tested for moderating effects of task uncertainty but did not discover any significant relationship. Attributing the result to intentional task homogeneity of the studied sample, Faraj & Sproull (2000) propose that task uncertainty and complexity would moderate relationships between expertise coordination and team performance. That is, administrative coordination is more suitable for simple routine tasks whereas expertise coordination is preferable for complex non-routine tasks (the original is followed in the use of terms "simple", "routine", "non-routine", "complex", and "uncertain". The usage reflects terminological inconsistency mentioned earlier.)

Two works of Akgün and colleagues (Akgün et al. 2005, 2006) were focused specifically on transactive memory systems in new product development teams. They discovered that a transactive memory system has a higher impact on team learning (the level of knowledge the team gets in the course of task performance), speed-to-market (how fast the new product is developed), and new product success (market performance of the new product) when team tasks are more complex (Akgün et al. 2005). Task complexity for the authors is determined by the difficulty or uncertainty of the task outcome. This definition is close to Campbell's (1988) task complexity, Perrow's (1967) task analyzability, and Van de Ven & Delbeq's (1974) task difficulty.

Thus the abovementioned studies indicate that the proposed contingency framework is indeed applicable to studies of R&D teams. It should be noted, though, that within transactive memory research stream there is an opposite view on the role of tasks. Brandon & Hollingshead (2004) propose that tasks are not external (contingency variable) of a transactive memory system but its integral part (see chapter 2.3 for the detailed description). In this research, however, a conventional view is taken.

3.2.3. Further development of the proposed contingency framework

The proposed contingency framework says that, for a team to perform successfully, tasks of different complexity (information-processing requirements) should be matched with different transactive memory systems (information processing capabilities), where different memory systems are understood as being structurally different, i.e. better or worse developed. Communication plays a crucial role in transactive memory system development[3] (Wegner & Wegner 1995; Wegner et al. 1985; Hollingshead & Brandon 2003; Fulk et al. 2005b; Hollingshead 1998a). Consequently, communication studies of R&D teams are used to develop the proposed framework further.

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[3] Interestingly, Akgün et al. (2005) did not find support for the effect of communication on the development of a transactive memory system. Because this result could be an artifact of the research design, the mainstream perspective on the role of communication in transactive memory system is taken in this research.

Tushman and colleagues (Tushman 1978a, 1978b, 1979a, 1979b; Katz & Tushman 1979; Allen et al. 1980) explored verbal communication in the corporate R&D laboratory of a large American corporation. This laboratory was physically isolated from the rest of the organization; its members were collocated. The main finding is that successful projects with different tasks have different communication patterns.

To be more specific, three types of projects were distinguished on the basis of performed tasks: (1) *research project*: task is complex, universally defined and aims at creation of new knowledge; (2) *technical service project*: task is locally defined (i.e. closely tied to the needs of the firm), technologies involved are stable and well known; (3) *development project*: task complexity stays in between those of research and technical service projects, it is locally defined, but technologies involved are not well understood. Due to intermediate nature of development tasks, in later works Tushman and colleagues talk about task continuum ranging from research to development to technical service tasks (Katz & Tushman 1979).

The following match between the type of task and team communication pattern was discovered. Successfully performing research projects had tightly connected decentralized communication networks. They relied greatly on peer decision making and problem solving. On the contrary, successful teams with technical service tasks had centralized patterns of communication networks. They relied less on peer decision making and more on supervisory involvement and direction. Communication networks of high-performing development projects were found to be situated somewhere in between research projects' decentralized networks and technical service projects' centralized networks. All in all, high-performing technical service projects exhibited systematically different communication patterns compared to high-performing research projects. Low-performing projects did not exhibit any patterns.

Putting these findings in other words, it can be said that for a team to perform successfully, simple tasks should be matched with centralized communication network; complex tasks should be matched with decentralized communication network. One of the possible explanations of this finding is that complex tasks (typical for research projects) require non-codified knowledge transfers which are more effective when communication is direct. Less complex tasks (technical service projects) depend on transfers of codified knowledge that can be communicated easily from one person to another via indirect links without serious distortions (Hansen 2002).

The abovementioned findings of Tushman and colleagues have critical implications for speculating on team transactive memory system development. Namely, when team communication network is centralized, team members, most likely, have little direct contact with each other and, consequently, have less opportunity to get to know "who knows what" in the team. Thus, a transactive memory system of such team is likely to be not well developed. Conversely, in a team with decentralized communication, i.e. in a team with a high proportion of direct to indirect contacts among peers, team members have more opportunity to get to know each other; hence a transactive memory system of such team is likely be well developed.

Table 10. Implications of Tushman and colleagues' findings for understanding transactive memory development.

Contingency variable	**Fit as a team communication network**	**Speculation on transactive memory system development**
Simple task	Centralized communication network	Less opportunity to get to know each other
Complex task	Decentralized communication network	More opportunity to get to know each other

Continuing this line of reasoning, the following contingency framework for studies of R&D teams is proposed (Figure 12). It is suggested that, for an R&D team to perform successfully, simple R&D tasks (technical service tasks) should be matched with less developed transactive memory system. Complex R&D tasks (research project tasks) should be matched with more developed transactive memory system.

Contingency variable	*Fit*
Simple task	Less developed transactive memory system
Complex task	More developed transactive memory system

Figure 12. Proposed contingency framework for studies of R&D teams.

3.2.4. Specifics of distributed settings

The proposed framework does not differentiate between collocated and distributed organizational settings. However it could be that distributed work has its own effects on a transactive memory system.

To begin with, in distributed teams people rely more on electron media than face-to-face communication. It is agreed that communication technology has an "effect" (Biocca, Harms, & Burgoon 2003). However there is no agreement on the causes of these effects, their mechanisms and, basically, on what these effects are for different processes taking place in distributed teams.

There are, basically, three groups of theories that seek to explain media effects in organizations. The first group includes theories of media richness (Daft & Lengel 1984, 1986), media synchronicity (Dennis & Valacich 1999), and social presence (Biocca et al. 2003). These are theories of rational choice. According to them, media features are fixed, objective and uniformly salient; they affect human cognition and are a cause of change (Fulk, Schmitz, & Steinfield 1990; DeSanctis & Poole 1994). A less deterministic view is hold by the second group which takes into account social processes and treats media features as socially constructed. Adaptive Structuration Theory (Fulk et al. 1990) and Social Influence Model of Technology Use (DeSanctis & Poole 1994) belong to this group. According to these theories, inherent structural characteristics of technology influence, but do not fully determine, interaction patters; hence, an outcome of technology use cannot be predicted. The third group consists of theories developed from the institutionalist viewpoint (DeSanctis & Poole 1994; Scott 1987). For this group, the use of technology, rather than its properties, is more important.

Altogether, there is no one agreed-upon view on the role of technology. Specifically in groups, the body of empirical research on computer-mediated interaction is methodologically clustered which impedes comparison of findings (Hollingshead & McGrath 1995; Hollingshead, McGrath, & O'Connor 1993). The effects of electron media on development and functioning of a transactive memory system are not clear.

Furthermore, it has been discovered that the frequency of communication, independent on media used, decreases as the distance between people increases (Allen 1977). A recent study by Sosa, Eppinger, Pich, McKendrick, & Stout (2002) supports this early finding. Moreover, these researchers found that the decay rate of face-to-face communication frequency is much higher than that of telephone and email communications' frequency. Additionally, the probability of using face-to-face communication mode decays rapidly with distance. The probability of telephone use increases with distance, peaks, and then decays as well. On the contrary, the probability of email use increases with distance. Sosa et al. (2002) also found that communication frequency, independent on media, increases with importance and with the presence of strong organizational bonds. At the same time, neither importance nor presence of strong organizational bonds influences the media choice.

Apparently, there is a complex interplay of factors whose influence on development and functioning of a transactive memory system in a distributed setting is not clear. Several conceptual papers elaborate on this issue. Griffith and colleagues (Griffith & Neale 2001; Griffith et al. 2003) propose that the more team members are geographically or temporarily distributed, the more difficult it is for them to develop a transactive memory system. The lack of visual and interpersonal cues can make team members perceive each other more homogeneous than it actually is. Alavi & Tiwana (2002) hypothesize that in distributed settings the lack of antecedent collaborative history and diversity of members' expertise and backgrounds may constrain transactive memory development. Fulk et al. (2005a) share the same viewpoint and add that the lack of physical proximity inhibits team members' awareness of the task and its progress. In distributed teams, even when team members have an opportunity to observe each other, they lack situational awareness and shared interpretation. Differences in norms, languages, experiences, and culture, all may impede development of a transactive memory system.

A recent work of Jackson & Klobas (2008) on a transactive memory system in a distributed organization provides empirical data on the topic. It shows that distance between organizational members indeed affects structure and processes of a transactive memory system. Specifically, physical separation hinders update and maintenance of personal directories of "who knows what". Information allocation process is hampered: people in distant locations are less likely to send each other information because they do not know well others' specializations and knowledge needs. Remote staff is less likely to receive information even when its needs are known. Retrieval is also affected by physical separation. It is more difficult to use knowledge of those who are far. Specifics of electron communication means (e.g. low bandwidth) may call for different strategies for making information inquiries. In the studied organization, managers played the role of gatekeepers: they knew the best "who knows what" and channeled information accordingly. This scheme worked when managers were in the head office and easily accessible. However when managers were away, others could experience difficulties with information access. This data provides the evidence that distributed work indeed affects a transactive memory system.

3.2.5. Research questions

To sum up, transactive memory phenomenon in distributed settings is not well-understood. Moreover, regarding the proposed framework, the words “more” and “less” developed transactive memory systems are, definitely, matters of degree. The theory of transactive memory system does not say at the moment anything on to what degree, for example, should people know “who knows what” in the team, for the team’s transactive memory system to be called “developed” (chapter 2.3). Adding to these problems is the absence of a single agreed-upon measure of transactive memory system (chapter 2.5).

For investigation into phenomena that are not well understood and whose measurement is not well developed, qualitative approach is more appropriate (Yin 2003; Ghauri, Grønhaug, & Kristianslund 1995). Thus, a qualitative research design is used in this study. The research questions are as follows.

Given the not well understood hypothesized impact of distributed settings on transactive memory system development (chapter 3.2.4), the first research question is:

RQ1: How does a transactive memory system in a distributed R&D team look like?

Taking into account results of the previous studies of communication in R&D and the possible impact of communication on transactive memory system development (chapter 3.2.3), the second research question is:

RQ2: How is a transactive memory system in a distributed R&D team connected to its communication pattern (frequency of communication between team members)?

Regarding the proposed contingency framework, instead of testing it statistically, a falsification approach is chosen. It is assumed that, according to transactive memory theory, a developed transactive memory system is both a sufficient and necessary characteristic of a successfully performing team. In order to falsify this assumption, the third research question seeks to test if a developed transactive memory system is a necessary attribute of any successfully performing team. According to the proposed contingency framework, a developed transactive memory system is not a necessary attribute of a successfully performing team with a simple task. Thus, the third research question is:

RQ3: Is a developed transactive memory system a necessary attribute of a successfully performing R&D team with a simple task?

The next chapter describes empirical part of this work. Research design and measurement of a transactive memory system, communication pattern, task complexity, and team performance are discussed there as well.

4. EMPIRICAL RESEARCH

4.1. Research design

To answer the first question, two approaches were used. In the first one, individual answers were collected with a 15-items scale developed by Lewis (2003) and then aggregated to a group level. The scale (appendix 1) measures indirect manifestations of a transactive memory system along three dimensions: (1) specialization, (2) credibility, and (3) coordination. Specialization dimension shows how differentiated and specialized knowledge of the group members is. Credibility dimension pertains to how deeply people trust expertise of each other. Coordination dimension refers to how coordinated communication in a group is: this is a manifestation of how well group members know “who knows what” and how this knowledge fits together.

The second approach was team-specific: team members were asked to report on expertise of other team members (Rau 2005a, 2005b). This data provided detailed knowledge on “who knows what” which is an important part of a transactive memory system (Hollingshead 2000; Moreland 1999). Data collected with the two methods was compared in order to obtain a better picture of a transactive memory system in a distributed setting (Ghauri et al. 1995).

It should be noted that a transactive memory system is not a static phenomenon. Furthermore, teams could also go through different developmental stages (Levine & Moreland 1990). Thus the abovementioned approaches allow taking only a “snapshot” of a transactive memory system in a distributed setting. Those approaches were chosen, however, deliberately because the focus of this study is on how a transactive memory system in a distributed setting looks like when it is, presumably, developed. The process of the development was not supposed to be studied.

To answer the second question, team members were asked to report on how often they contacted each other (the options were 1=*never*, 2=*seldom*, 3=*from time to time*, 4=*often*, 5=*always*). Contrary to the approach used by Tushman and colleagues (Tushman 1978a, 1978b, 1979a, 1979b; Katz & Tushman 1979; Allen et al. 1980), who studied reports on *verbal work-related communication*, in this research contacts were not differentiated on a basis of either different communication means or their content. Communication was not differentiated on a basis of communication means because of distributed settings’ specifics: some teammates may never meet face-to-face and use only emails to contact each other. Barczak &

McDonough III (2003) also note that in distributed settings, email communication may be as effective as face-to-face one provided that team members had an extended (three days or more) initial meeting. Furthermore, communication was not restricted to only “work-related” one because transactive memory system could develop during both formal and informal interactions (Wegner 1987, 1995; Wegner et al. 1991).

To answer the third question, team performance and task complexity were measured. There is no uniform measure of team performance in general (Guzzo & Dickson 1996) and of R&D team performance in particular (Ojanen 2003). In this research and following Tushman and colleagues (Tushman 1978a, 1978b, 1979a, 1979b; Katz & Tushman 1979; Allen et al. 1980), the team manager was asked to judge team performance on a scale from 1 (very low) to 7 (very high). This approach is also consistent with how project performance has been measured in other studies (Faraj & Sproull 2000; Rouse et al. 1992).

Task complexity was assessed with two methods; then collected data was compared. First, definitions of the opposite ends of task complexity continuum, proposed by Tushman and colleagues (Tushman 1978a, 1978b, 1979a, 1979b; Katz & Tushman 1979; Allen et al. 1980), were used to evaluate R&D team’ task complexity on a basis of broad task descriptions provided by team managers. For example, product improvement would be a simple task; long-term research project would be a complex task. Second, a finer measure of task complexity, described below, was developed.

Building on the description of the transactive memory system’ retrieval process, it was assumed that the memory system is used when teammates lack information and seek it from others. In other words, it was supposed that transactive memory system works in a “pull”-mode: information is sought out and obtained from others when it is needed. Interestingly, Faraj & Sproull (2000) assumed, though without discussing it directly, that a transactive memory system functions in a “push”-mode. According to them, information need is anticipated and required information is provided by the team. The theory on transactive memory does not discuss explicitly in which mode a transactive memory system functions. Taking into account, that a “push”-mode can be fairly criticized for reification, a “pull’ perspective on transactive memory functioning was taken in this research. Following this line, the literature on information seeking was used to develop task complexity measure.

In information seeking studies, both people and different kinds of documents are considered as information sources. It has been discovered that as a perception of task complexity increases, people become more valuable sources of information and are contacted more often (Byström & Järvelin 1995; Byström 1999, 2002). It should be stressed that this finding holds for *perceived* task complexity. Perceived task complexity depends on both task characteristics and task performer's prior knowledge about the task. Tushman and colleagues did not discuss explicitly what type of task complexity was used in their studies. Taking into account a positivistic viewpoint of the structural contingency research, it is most likely that they kept in mind objective task complexity. At the same time, in the definitions of different tasks, they used such words as "well understood" which imply task doers' perceptions.

Apparently, the distinction between objective and perceived task complexity is very subtle. Campbell (1988) mentions that they are close but different. At the same time, as objective task complexity increases, more cognitive demands are put on the task doer; hence, perceived task complexity increases as well (Campbell 1988; Byström 2002). Keeping this in mind, it was assumed that perceived task complexity serves well the purposes of this study and the findings of information seeking studies could be used to develop task complexity measure.

To be more specific, a definition proposed by Byström (Byström & Järvelin 1995; Byström 1999, 2002) was used. She defined perceived task complexity as *a priori* determinability, from a worker's point of view, of information inputs, processing, and outputs. Simple tasks are those whose inputs, process, and outputs are a priori determined. Conversely, complex tasks are those when a task doer cannot say in advance anything certain about task input, process, and output. This definition was built upon to develop task complexity measure.

Task complexity measure consists of three statements pertaining to task input, process, and output. To keep uniformity with Lewis' scale, these statements are evaluated on 5-items Likert scale from 1=*strongly disagree*, 2=*disagree*, 3=*neutral*, 4=*agree*, 5=*strongly agree*. Individual answers are reversed and averaged to get a team task complexity score. The statements are:

(1) Usually, when I get tasks during the project progress, I can in advance describe in detail how I will perform a task. (*reversed)*

(2) Usually, when I get tasks during the project progress, I can in advance describe in detail what information I will need. (*reversed*)

(3) Usually, when I get tasks during the project progress, I can in advance describe in detail what an outcome will be. (*reversed*)

Regarding the choice of cases, those R&D teams were selected for this research that were at the development, rather than idea generation or testing, stage of the research and development process (Lettl, Herstatt, & Gemuenden 2006; Urban & Hauser 1993). Such teams satisfied the needs of this research because its focus was on knowledge utilization by means of a transactive memory system, rather than on knowledge creation. Furthermore, those teams were chosen in which individuals had already been working together for some time. It was done to assure that transactive memory systems of those teams had time to develop. Additionally, a transactive memory system is a team-level concept which requires a clear definition of team boundaries. Every team, especially in a big organization, does not exist in a vacuum (Levin & Moreland 1990). On an individual level, it could be that a team member is involved into several projects. On a group level, team's activity can be intertwined with other teams in the organization. These possible connections are not taken into account by the theory of transactive memory. Therefore, in this research team boundaries were defined according to the organizational chart. In this way, possible individuals' involvement into other projects was not taken into account. Similarly, interdependences with other projects were not considered either.

Two project teams were studied. Data collection in both cases started with team managers' interviews. Then a questionnaire was used to collect answers from team members. The questionnaire consisted of two parts. The first part was composed of Lewis' scale and questions on task complexity. The second part was customized for each team. In this part team members were asked about how often they communicated with their teammates and what they knew about teammates' expertise. When necessary, reminders and follow-up emails were sent where individuals were asked for clarifications. Responses were analyzed in MS Excel; to visualize communication networks UCINET software was used.

To obtain group level measures, individual answers were aggregated, namely means of individual answers were calculated. Statistical analysis of aggregation appropriateness was not conducted due to small size of the samples.

During all the time of data collection, project managers were contacted and interviewed when any questions about projects' work arose. Data collected with interviews and questionnaires was complemented by observations. The author of this research was a member of Case 1 Team and made participant observations on the ongoing basis. In Case 2 Team five project meetings were observed. The author did not participate in the discussions but was making notes on team members' communication and context in which somebody's expertise was mentioned.

4.2. Case teams' description

Data collection was conducted in two software development teams. The choice of the teams was based on their conformity to the abovementioned requirements. Main attributes of both teams are shown in Table 11.

Table 11. Main attributes of the studied teams.

	Case 1 Team	**Case 2 Team**
Team size	8	30 (originally 35, but 5 did not return the questionnaire)
Location of team members	Two cities in Finland. Six people were located in the same city but their offices were located in different buildings.	Three countries: Finland, Switzerland, and India. At all these sites people had offices in the same buildings.
Life span	The team had an explicit deadline; team members were not expected to work together as a team in the future	The team had an explicit deadline but was expected to continue the work on the following software releases
Cultural composition	Multicultural (Chinese, Russian, Finnish)	Multicultural (Indian, Finnish, Russian, German, New Zealand, Swedish, Swiss)
Communication means	Face-to-face communication, emails, phone calls, project website	Face-to-face communication, emails, phone calls, phone conferences with Genesys Meeting Center, net-chats, project database
Project meetings	Face-to-face project meetings organized on demand. No meeting was attended by all team members.	Project meetings for all members held with Genesys Meeting Center every two weeks

Case 1 Team had a task to develop original supply chain management software. The team was formed specifically for that purpose and had a clear deadline. It consisted of eight people who were representatives of an academic institution (University of Vaasa) and one of the Finnish offices of an international manufacturing company. The author of this research was a member of this team and could observe team processes from inside. For the sake of anonymity, in this work team members' names are labeled with tags "FI", which correspond to the country name (Finland), and numbers, that are assigned arbitrarily. "M" denotes managerial position.

Team members were located in different cities in Finland. At the moment of data collection, six people (FI 1 M, FI 2, FI 5, FI 6, FI 7, FI 8) lived in city A, two people (FI 3, FI 4) lived in city B. In city A, team members were located in two buildings in different parts of the city. Two persons (FI 7, FI 8) shared the same office space. Others, though located in the same university building, had separate work cubicles. In city B, team members had separate offices in the same building.

The study was undertaken during the final stage of the project that had been running by that moment for a year and a half. Six people had been working in the project from the beginning. Two individuals (FI 5, FI 6) had been working in the project for four months. Cultural composition of the team was as follows: Finns, Russian, and Chinese.

Project meetings were organized on demand and held face-to-face in English. Participation depended on the meetings' topics: only those responsible for areas related to a particular topic were present. One team member's (FI 5) English mastery was not good; he had never attended project meetings. The project manager discussed with FI 5 project matters in Finnish individually. Communication means used by project members were face-to-face communication, emails, and phone calls. The project also had a website where project reports, minutes of project meetings, and relevant papers were stored.

Case 2 Team belonged to an R&D department of a big international company and was a part of a larger project whose members had a task to develop a new family of hardware products. Team task was to develop software which could provide interface for the hardware products' end-users. That software should suit the specifications of already existing products as well as their future modifications. The team had developed previous versions of the software and was supposed to work on future releases. The project had a clear deadline.

Team members were situated in three countries: Finland, India, and Switzerland. It had three development subgroups in each country (Tool Components subgroups); two testing subgroups (in Finland and India); and a management subgroup. The management subgroup consisted of the project manager and managers responsible for different aspects of the software. The project manager was also responsible for the Finnish Tool Components subgroup. In all project sites team members had work places in same buildings. Names of group members are labeled in the following manner: location is tagged with a country name: "FI" (Finland), "CH" (Switzerland), or "IN" (India); "M" denotes managerial position; numbers within subgroups are assigned arbitrarily. "GM" denotes that a manager belongs to the management subgroup, "TC" denotes Tool Components subgroup, "T" denotes testing subgroup. Team structure is presented on Figure 13.

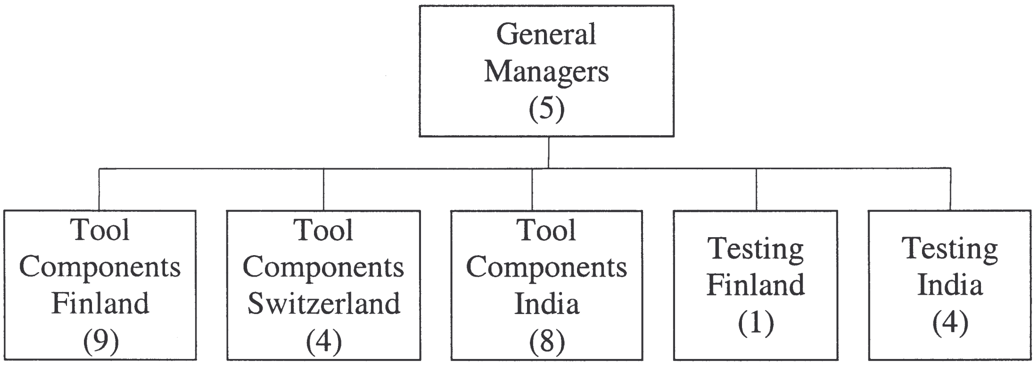


Figure 13. Structure of Case 2 Team[4].

The team consisted of 35 people. Five of them did not return the questionnaire. Among those, two belonged to the Finnish subgroup, two – to Indian subgroups, and one – to the Swiss subgroup. Therefore, it was concluded that the non-respondent group was not culturally or locationally biased and those people were excluded from the subsequent analysis.

The study was undertaken during the final stage of the project: a new software release had to come out in about three months. The team was culturally heterogeneous: among team members were representatives of India, Finland, Russia, Germany, New Zealand, Sweden, and Switzerland. The official language of the project was English.

Membership in Case 2 Team was, according to the managers, rather stable. Specific data collection about members' tenure turned out to be problematic. Project managers did not keep records on when every member joined the project. When project members were asked to provide data on when they joined the project and the company, some did not answer. Gathered data is presented in appendix 2. Though incomplete, this data confirmed that team membership was relatively stable. Indian development and testing subgroups joined the project about a year before the study. Many team members had been working in the company before joining the project.

In Case 2 Team project work was organized in a way that several country-specific subgroups could work rather independently. Within subgroups people worked on small tasks either relatively independently or in small groups. When a specific task was finished, team members could be (re)assigned to newly created small

[4] On Figure 13 the project manager is counted twice: in the General Managers subgroup and in the Finnish Tool Components subgroup.

groups to fulfill new tasks. In some cases those small groups might consist of people from different country-specific subgroups; so project-wise, according to the project managers, territorial "boundaries" were more hypothetical than real. The tasks were given mainly by (1) FI GM1/ FI TC1 M (overall coordination); (2) CH GM2 (customer viewpoint), (3) FI GM3 (coordination of technical issues), (4) FI GM 4 (coordination of the configuration management related issues), (5) FI GM 5 (coordination of some areas), (6) CH M1 (sub-project leader), (7) IN M 1 (sub-project leader), and (8) IN M 2 (line manager). Testing was organized on two levels. Functional testing was done by Indian team and coordinated by IN T1 M. System verification was done in Finland where the Case 2 Team product was tested as a part of the company's whole product family. This type of testing was led by FI T5 M. FI T5 M did not have any subordinates in Case 2 Team. However, to stress that he worked independently from the testers in India, he was tagged with "M" letter.

Every two weeks project meetings for all team members were organized that were held with the help of Genesys Meeting Center. This equipment provided verbal communication and desktop sharing of one of the participants' computers at a time. Other communication media used in the team were: face-to-face communications, email (Lotus Notes), chatting (Lotus Sametime, Windows Netmeeting), phone and phone conferencing on other occasions than during scheduled project meetings. Case 2 Team also had a project database (Lotus Notes). Its content was structured according to the phases of the project and in line with project management recommendations. It had the following directories: (1) project framework, (2) initial planning, (3) product planning, (4) project planning, (5) specification, (6) design and test, (7) validation, and (8) project evaluation. Each directory contained subdirectories with corresponding files.

Furthermore, since the project's outcome was deeply intertwined with the specifications of the hardware products' family, boundary-spanning activity was an indispensable part of the team members' daily work. Some of the managers and ordinary members were involved in so called Technical Reference Group (TRG). Permanent TRG members were FI GM3, FI TC2, CH TC1 M, IN TC1 M, IN TC2 M. Other team members could also participate in TRG meetings, if needed. TRG was an upper-level group that did not report to any authority. The sole purpose of its existence was coordination of Case 2 Team work with other project teams in the company. TRG made decisions on architecture and important design issues, for example, interfaces, workflow, and data management. TRG members belonged to different functional areas and met on request of any Case 2 Team member. For TRG meetings Genesys Meeting Center was used.

Both teams were studied during the final stage of their projects to assure the development of a transactive memory system. At the same time, in both teams individual tenure varied. In Case 1 Team two people joined the project four months before the study; others worked together from the beginning. In Case 2 Team some people also worked in the project since the beginning (year 2005), others joined later; among them, one person (FI TC9) had been working in the team for only several weeks (since January 2007). To decide if tenure differences matter, the theory of transactive memory was referred to. The theory says that time is, indeed, important for the memory system' development if expertise descriptions are not given explicitly: in newly created groups expertise recognition is based on stereotypes and often erroneous (Wegner 1987, 1995; Wegner et al. 1991; Hollingshead & Fraidin 2003). As time passes, people get to know each other better and transactive memory system of the group becomes more developed. However, how long it takes for the group to develop a transactive memory system is not discussed by the theory. In the laboratory experiments it took quite a short time (duration of the training session on how to assemble a radio kit) for test groups to develop a transactive memory system (Moreland 1999; Liang et al. 1995; Moreland et al. 1996, 1998). Therefore, tenure differences in both teams were assumed to be negligible.

Moreover, in both cases no conscious explicit actions were taken by project managers to either give team members information on "who knows what" in teams or encourage communication. Thus it was expected that empirical data would shed light on the result of "natural" development of a transactive memory system in distributed settings, i.e. when no special guidance on behalf of managers to develop a transactive memory system is given.

4.3. Data analysis

4.3.1. Research question 1

The first question asks how a transactive memory system in a distributed R&D team looks like. In order to find it out, answers to Lewis' questionnaire and reports on "who knows what" were collected. This data was complemented by observations of team meetings.

Results obtained with Lewis' scale

Individual scores collected with Lewis' scale are given appendix 3 for Case 1 Team and appendix 4 for Case 2 Team. Aggregated team scores are presented in

Table 12. Expertise specialization in both teams was, according to the scale, at the same level. Members of Case 2 Team felt a little bit less credible about each other's knowledge and coordination in Case 2 Team was worse than in Case 1 Team.

Table 12. Case 1 Team and Case 2 Team scores on three dimensions of a transactive memory system according to Lewis' scale.

	Case 1 Team	**Case 2 Team**
Specialization	3.9	3.9
Credibility	3.5	3.4
Coordination	3.4	3

These scores indicate the degree of transactive memory system development along three dimensions on a scale from 1 to 5. Because all scores were higher than 2.5, it was concluded that transactive memory systems of both teams were developed more than average. Knowledge on "who knows what" is an indispensable part of any transactive memory system; hence, it was supposed that teams' members would have little difficulty with reporting on their teammates' expertise. However, when reports on "who knows what" had been analyzed, this supposition was not supported.

Analysis of reports on "who knows what"

To be more specific, recognition of "who knows what" in both cases was very uneven. In Case 1 Team (Figure 14) only three out of eight team members could identify expertise of all the others (FI 1 M, FI 2, FI 4); three persons gave no answers (FI 3, FI 5, FI 7); two (FI 6, FI8) described only some of team members. In Case 2 Team (Figure 15) no one could describe expertise of all the others. Six ordinary team members (four from Tool Components Finland: FI TC2, FI TC4, FI TC5, FI TC9; two from Testing India: IN T3, IN T4) did not give any reports. Among those who answered, number of reports varied from two (IN TC4, IN TC6) to twenty six (FI GM5).

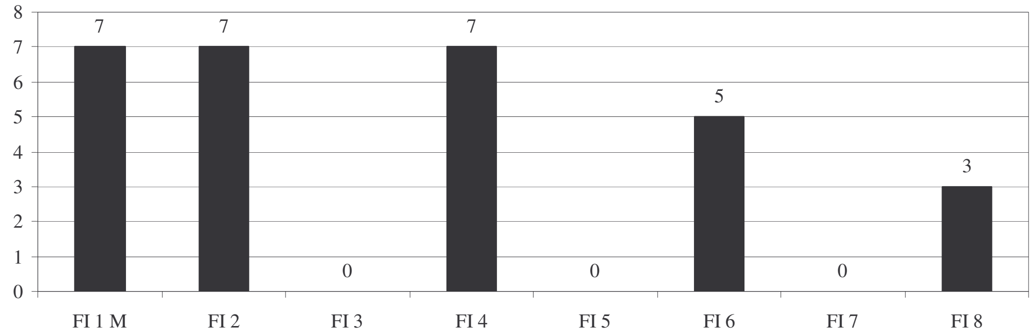


Figure 14. Number of reports on "who knows what" given by the members of Case 1 Team.

Inability to describe others' expertise could have been caused by (1) lack of knowledge on "who knows what"; (2) lack of time to answer the questionnaire; or (3) treating the questionnaire as non-important. In Case 1 Team those who didn't describe expertise of all the others were asked to give explanations. FI 3, FI 5, and FI 6 stated clearly that they were not aware of others' expertise:

> "I didn't specify their expertise because I did not know them very well and I have no idea what they were doing in a project so it was quite difficult to say anything about them" (FI 6).

FI 8 (a company representative) described expertise of FI 1 M (project manager), FI 5 (software developer), and FI 7 (another company representative) straight away. In response to explain the reason why he did not describe expertise of FI 2, FI 3, FI 4 and FI 6 (university representatives), he came up with the description: "background research and presentations" to all of them. This answer looks more as an attempt to save face rather than confirming that the knowledge of their expertise was lacking. FI 7 did not give any explanations.

Keeping in mind experience of Case 1 Team (i.e. that people may come up with socially desirable answers), in the instructions for Case 2 Team it was stated clearly that "*It is OK to leave the field empty, if you can't say anything about this person's area of expertise*". One person (FI TC9) took the initiative and mentioned himself that his rather short tenure (several weeks) was a reason why he could not report on anyone's expertise:

> "But my knowledge of the project details is in novice level because I have worked for this company and with this project only for few weeks." (FI TC 9)

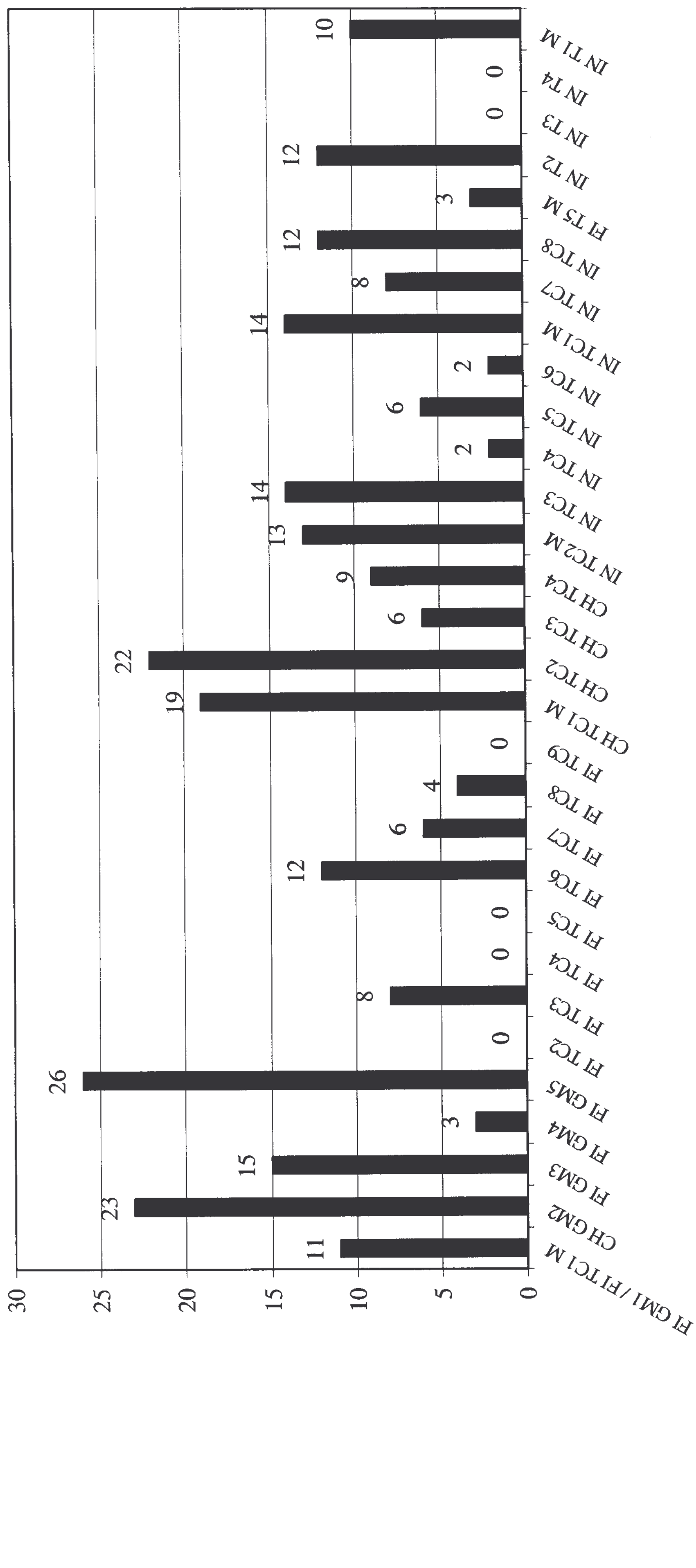


Figure 15. Number of reports on “who knows what” given by the members of Case 2 Team.

This comment is important because, contrary to the original proposition, it underscores importance of tenure for the development of a transactive memory system. It could be that in real work groups transactive memory system develops more slowly than in laboratory experiments.

Another member of Case 2 Team commented:

> “The answers I give could differ dramatically, depending on how you define "team". My immediate "team" consists of the developers here in Switzerland. But the "greater team" is much more extensive, covering several development centers in several countries.” (CH TC3)

This comment is also very important because it points out to the possible reason of why results of a transactive memory system measurement with Lewis’ scale and reports on others’ expertise did not converge.

In both teams, accuracy of the given reports was compared to how team members describe their own expertise and what was known about their roles in the team. In Case 2 Team, except for few wrong reports (5 out of 260 given), expertise recognition was accurate (examples are given in appendix 5). In Case 1 Team, insiders’ viewpoint provided finer understanding of expertise recognition’ pattern. Those who had clear responsibilities in the team (FI 3, FI 5, FI 6) were described accurately and in the same manner. For example, FI 5 was responsible for software coding and all descriptions of his expertise were “software engineering”. Similarly, FI 6 had a clear role to develop supply chain maturity models; and all except one descriptions of her expertise were “maturity models”. Two company representatives (FI 7, FI 8) had in the project similar functions; and their expertise was similarly described as “practical implementation”. On the other hand, two university representatives (FI 2, FI 4) did not have clear roles. Descriptions of their expertise varied depending on the part of the project they and their descriptors worked with. For example, FI 4 worked with FI 3 on inventory models; so FI 3 described FI 4’ expertise as “inventory models”, whereas FI 4 main responsibility was helping FI 1 M in project management. Similarly, FI 2 worked with FI 4 on supply chain optimization; so FI 4 described FI 2’ expertise as “supply chain optimization”. FI 2 also worked with FI 6 on supply chain integration; so FI 6 described FI 2’ expertise as “supply chain integration”. Taken together, this data shows that a formal role performed by a person in the project is important for the development of a transactive memory system in work settings.

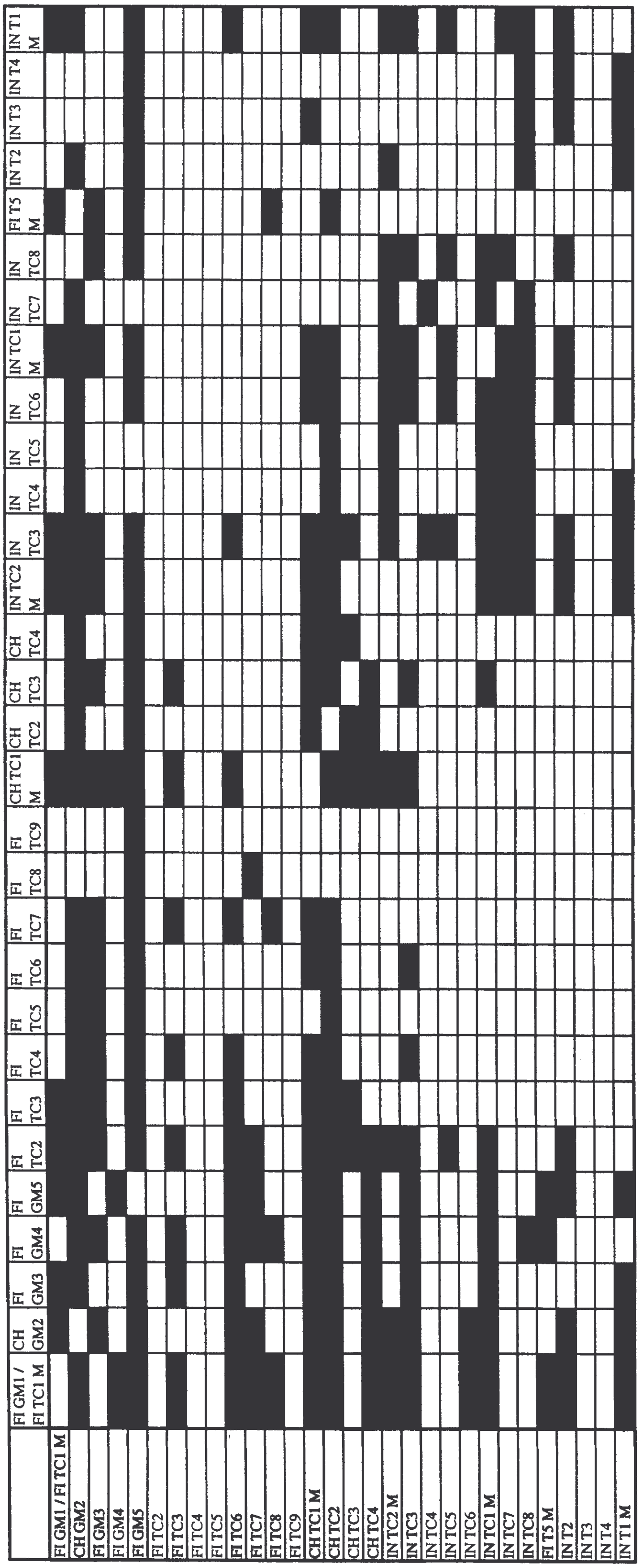
Furthermore, number of given reports was compared to the formal role performed by a person in the team. In Case 1 Team the project manager could describe expertise of all team members. Two ordinary team members (FI 2, FI 4) were also able to do that. In Case 2 Team, none of managers could describe expertise of all team members. However on average, managers recognized expertise better than ordinary team members (13 vs. 6 reports correspondingly). This finding points out once again that formal role performed by a person in the team could be important for the development of a transactive memory system.

Moreover in Case 2 Team, visual representation of the reports (Figure 16) indicated that both physical proximity and a formal role could be important for expertise recognition. On Figure 16, if a person in a horizontal row reported on expertise of a person in a vertical row, the cell is marked black; otherwise, cells are white.

To get a better understanding, a finer analysis of whose expertise team members knew better was done. Case 2 Team' members were regrouped: all the managers, irrespectively to their location, were included into one "managers" group; ordinary members remained in their respective subgroups which, thus, included only peers. After that, percentage of reports given about expertise of the peers and managers were calculated for each subgroup: number of reports given for each subgroup out of the total number of peers in the corresponding subgroups (Table 13). It should be noted that FI T5 M person, as it has been mentioned, was not either a peer for Indian testers, no a manager who gave tasks to others. Numbers presented in the Table 12 were calculated when FI T5 M was included in the "managers" group. Similar numbers were also calculated when FI T5 was excluded from the analysis. Recognition pattern did not change.

Comparison of the numbers revealed that, except for the Finnish subgroup, team members knew better those who belonged to the same subgroup from both geographical and formal role points of view. Ordinary members of the Finnish subgroup recognized managers better than peers located in Finland. This could be due to physical proximity of the most managers to the ordinary members of the Finnish subgroup. Otherwise, expertise recognition of the peers in other locations was the lowest in the Finnish subgroup. Furthermore, in order to obtain a clear pattern, percentage of expertise reports given by ordinary Case 2 Team members was calculated for subgroup types: for the same subgroup, for managers subgroup, for other subgroups (Table 14).

On average, ordinary members knew the best peers from the same subgroup (52%), they also knew managers quite well (33%), and the worst-known team members were peers from other subgroups (10%). This finding indicates that, in a distributed setting, a complex interplay between individual location and performed formal role could influence development and structure of a transactive memory system.



Black box indicates that a person in a horizontal row reported on expertise of a person in a vertical row

White box indicates that a person in a horizontal row did not report on expertise of a person in a vertical row

Figure 16. Visual representation of reports on "who knows what" in Case 2 Team.

Table 13. Percentage of expertise reports given by all Case 2 Team members calculated for subgroups.

	Managers (all managers)	**Tool Components Finland (only peers)**	**Tool Components Switzerland (only peers)**	**Tool Components India (only peers)**	**Testing India (only peers)**
Managers (all managers)	**68**	36	37	45	30
Tool Components Finland (only peers)	23	**18**	4	2	0
Tool Components Switzerland (only peers)	57	38	**100**	28	0
Tool Components India (only peers)	32	8	6	**57**	17
Testing India (only peers)	20	4	0	17	**33**

Table 14. Percentage of expertise reports given by ordinary Case 2 Team members calculated for subgroup types.

	The same subgroup	**Managers**	**Other subgroups**
Tool Components Finland (only peers)	18	23	2
Tool Components Switzerland (only peers)	100	57	22
Tool Components India (only peers)	57	32	10
Testing India (only peers)	33	20	7
On average	**52**	**33**	**10**

Observations

In order to see how a transactive memory system manifests itself in project work and to complement data obtained with Lewis' scale and reports on expertise, team meetings were observed. In Case 1 Team the project manager (FI 1 M) had a clear picture on the project outcome and gave tasks to team members. He was well aware on what others were doing in the project. Team members, in their turn, were not actively involved in decision making. They performed tasks given by the project manager and reported on the results during the meetings.

In Case 2 Team two types of meetings were observed: "all team members" meetings and TRG meetings; both were held with Genesys Meeting Center. "All team members" meetings were organized once in two weeks; TRG meetings were held on demand. "All team members" meetings were similar to Case 1 Team meetings: their main focus was on reporting on the project progress. TRG meetings were, on the other hand, more oriented on looking for solutions to existing problems. During observations, the main attention was paid on who participated in discussions and if someone's expertise was mentioned.

Active discussion of issues during "all team members" meetings was not observed. Managers at different locations talked the most. During TRG meeting participants were, generally, more active and, apparently, asked questions and joined discussions whenever they felt like that. FI GM3 led meetings by introducing questions and then summarizing discussion. Thus, communication during TRG meetings was not centralized by managers.

During the meetings of both types, there were occasions when experts in certain areas were clearly identified. This was done only by people holding managerial positions. For example, during "all team members" meeting the following discussion was observed:

> FI GM1 / FI TC1 M: *"Are there any urgent questions?"*
>
> CH TC1 M had a question
>
> FI GM3 put the question into the agenda of the following meeting
>
> FI GM1 / FI TC1 M commented: *"You need to check it with Timo"*.

It should be noted here that Timo was not Case 2 Team member; thus FI GM1 / FI TC1 M' comment referred to boundary spanning activity.

During TRG meetings both team members and people working on related projects were mentioned:

> *"verify it with Abhilash"* (FI GM3), Abhilash worked in another project team,
>
> *"contact Alexei for specifications needed"* (FI GM3), Alexei worked in Case 2 Team,
>
> *"synchronize tasks with Magnus"* (FI GM3), Magnus worked in Case 2 Team,
>
> *"check the issue with Kishan"* (FI GM3), Kishan worked in Case 2 Team,
>
> *"I can't answer it now. But let's ask Lars how it has been done before"* (FI GM1 / FI TC1 M), Lars worked in another project team;
>
> *"verify with Vinod and Kishan how it should work"* (FI GM1 / FI TC1 M), Vinod and Kishan worked in Case 2 Team,
>
> *"Markku is the main person to check this question"* (FI GM1 / FI TC1 M), Markku worked in another project team.

There were also cases when managers could not identify experts. For example, during one TRG meeting, FI GM3 showed a chart with units' interaction and asked others to finalize the chart by calling *"anybody who knows"* and the meeting participants started to correct the chart together. Another time, FI GM3 asked: *"Can we define persons who can work with it?"* Discussion continued, but the question remained unanswered. During the same meeting, FI GM1 / FI TC1 M asked: "*Who should provide this information?*" At that time, participants gave their clear opinions by identifying other projects connected to Case 2 Team; however, no names were mentioned.

Several times project database was mentioned as a source of information:

> *"Sami is not here at the moment. But everyone can go to the database"* (FI GM1 / FI TC1 M);
>
> *"Powerpoints are stored in a database. We should check if we need to make any specifications"* (FI GM1 / FI TC1 M);
>
> *"Results of the local discussions were forwarded to you as powerpoints"* (FI GM3).

During TRG meetings, arrangements of future face-to-face meetings were also made. After one of "all team members" meetings, one ordinary member left the room together with one of the managers discussing the issue face-to-face instead of going to "all team members" level.

Comparison of the empirical data and conclusion on the first research question

In the studied teams, results obtained with Lewis' scale indicated that transactive memory was developed more than average. However, after comparison with reports on expertise recognition, this result was not confirmed. In fact, knowledge on "who knows what" in the studied teams was geographically localized, i.e. team members knew better those who were located close to them. Bearing in mind that knowledge of "who knows what" is an indispensible part of a transactive memory system, it could be said that a transactive memory system in studied teams was geographically localized. Such localization is not discussed in the theory of transactive memory. Comparing with the original definition of a developed transactive memory system, geographically localized transactive memory system cannot be called well developed.

This conclusion is further supported if approach to measurement of individual knowledge of "who knows what" used by Yuan et al. (2007) is taken into account. They assessed individual expertise directories along two dimensions: accuracy and extensiveness. Accuracy reflects deviation of individual perceptions of "who knows what" from the group-level perception. Extensiveness refers to how many team members an individual could describe. Individual directories of "who knows what" are well developed if they are accurate and extensive. In this study accuracy was understood in a bit different way: perceptions of expertise were called accurate if they were similar to team members self-reports on their expertise. However, extensiveness, though it was not called like this, was taken into account (Figures 14, 15). The data analysis showed that individual expertise directories were accurate but not extensive. Therefore, individual directories could not be called well developed; hence, transactive memory systems which consist of these directories cannot be called well developed either.

Furthermore, ordinary members of the studied teams knew managers better than peers even when those managers were located in distant places. Managers also knew team members better independently of their location. This fact points out to a complex interplay between a formal role and location in a distributed setting.

4.3.2. Research question 2

The second question asks how a transactive memory system in a distributed R&D team is connected to its communication pattern (frequency of communication). To answer this question reports on how often team members communicate with each other were collected. Following Tushman (1979b), who used a communication frequency ("intensity" in Tushman's terms) threshold to discover communication patterns in R&D team, reports on communication were divided into frequent (answers "communicate always" and "communicate often") and infrequent (answers "communicate from time to time", "communicate seldom", "communicate never") ties. Then networks that correspond to frequent communication ties in both teams were drawn.

Communication network of Case 1 Team is presented on Figure 17. This network indicates that members of the Case 1 Team communicated mostly with the team manager. Observations of the Case 1 Team project meetings support this result.

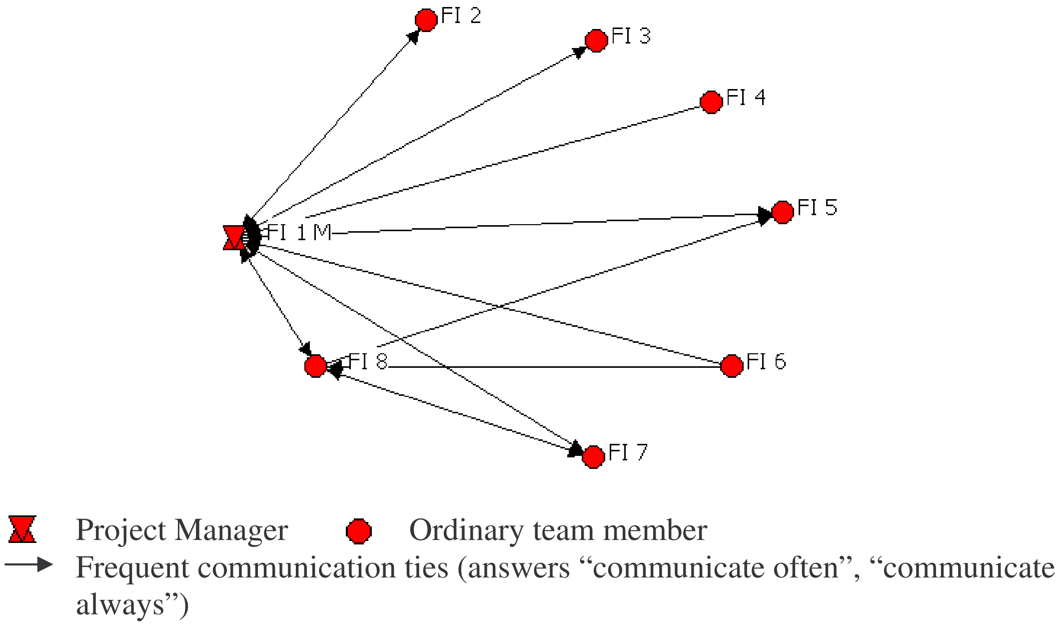


Figure 17. Communication pattern of Case 1 Team.

Communication network of Case 2 Team is presented on Figure 18. It indicates that Case 2 Team' members communicated mostly with the peers from the same subgroup and team managers. On Figure 18 the subgroups constitute easily observable clusters with a bunch of interconnected nodes in the centre representing the management subgroup. It should be noted that the word "clusters" is used here in qualitative sense. These formations are not clusters from a point of view of the network analysis.

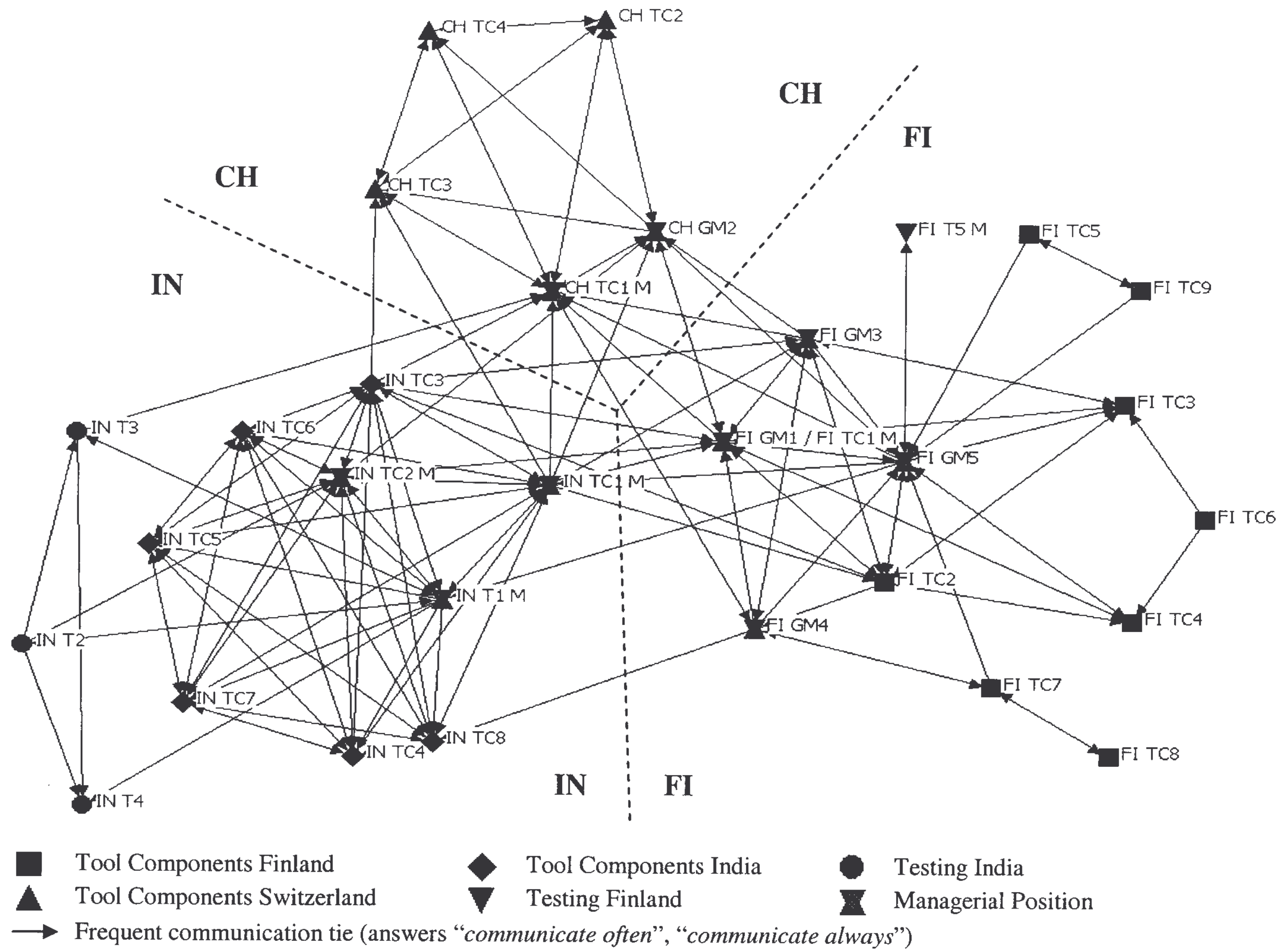


Figure 18. Communication pattern of Case 2 Team.

Geographical localization of the communication network in Case 2 Team was discussed with FI GM1 / FI TC1 M and FI GM3. They confirmed that indeed the work tended to be organized in such a way that ordinary members in distant locations contacted local managers whereas managers communicated with each other independently of their location.

Inside the subgroups of Case 2 Team communication patterns varied. Below corresponding networks are presented. Members of Finnish Tool Components subgroup communicated more with managers than peers (Figure 19), i.e. Finnish Tool Components' communication network was centralized. According to FI GM1 / FI TC1 M, this result was expected because members of the Finnish subgroup knew their field very well, i.e. they knew well the technical side of the company's hardware.

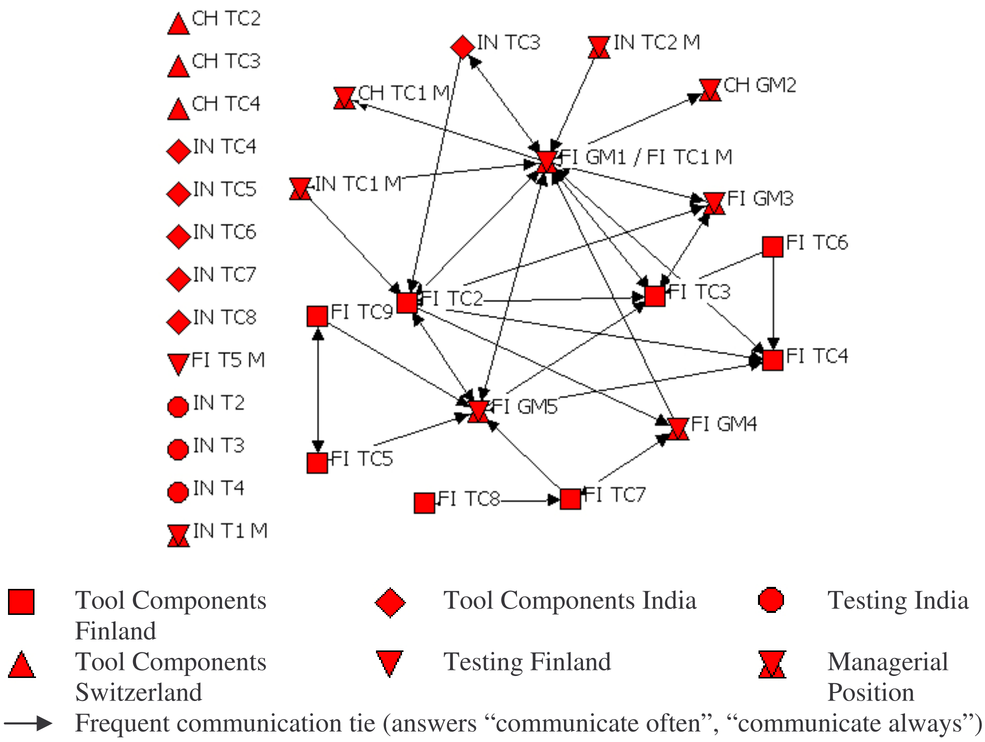


Figure 19. Communication pattern of Finnish Tool Components subgroup.

Tool Component Switzerland, Tool Component India, and Testing India had decentralized communication patterns (Figure 20, Figure 21, Figure 22 correspondingly). Commenting on this finding, FI GM1 / FI TC1 M said that highly connected communication network of Indian developers could have been caused by their rather low familiarity with the specific technical characteristics of the company's hardware. So they could seek advice from each other.

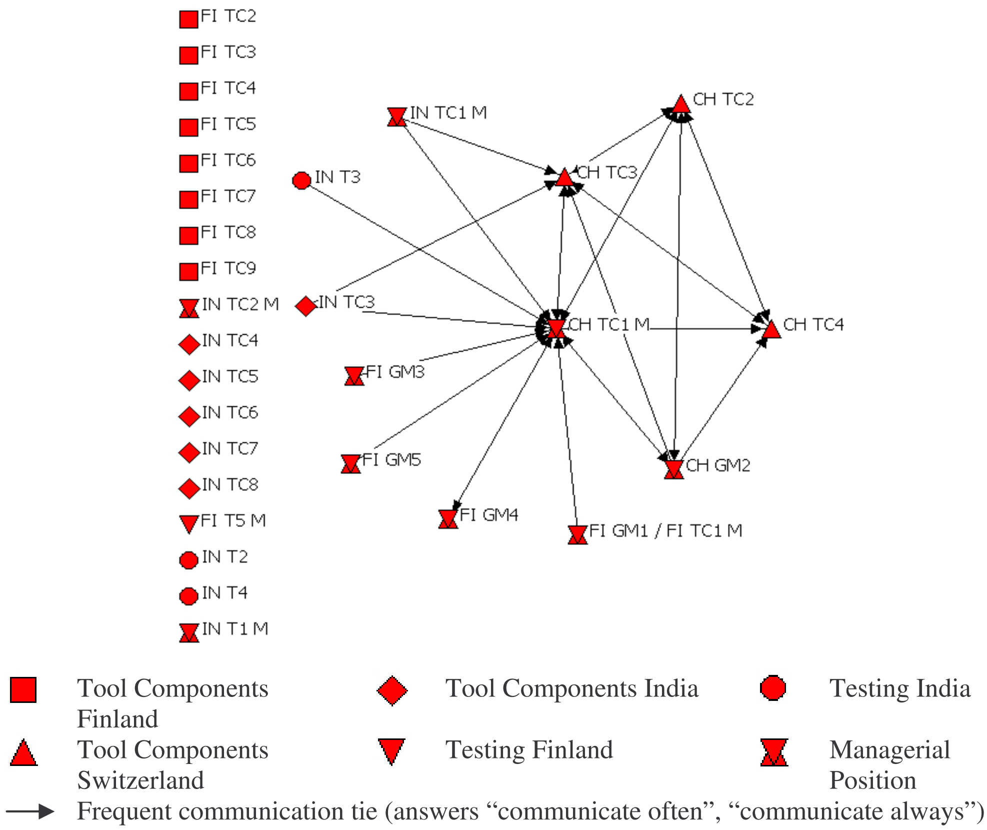


Figure 20. Communication pattern of Swiss Tool Components subgroup.

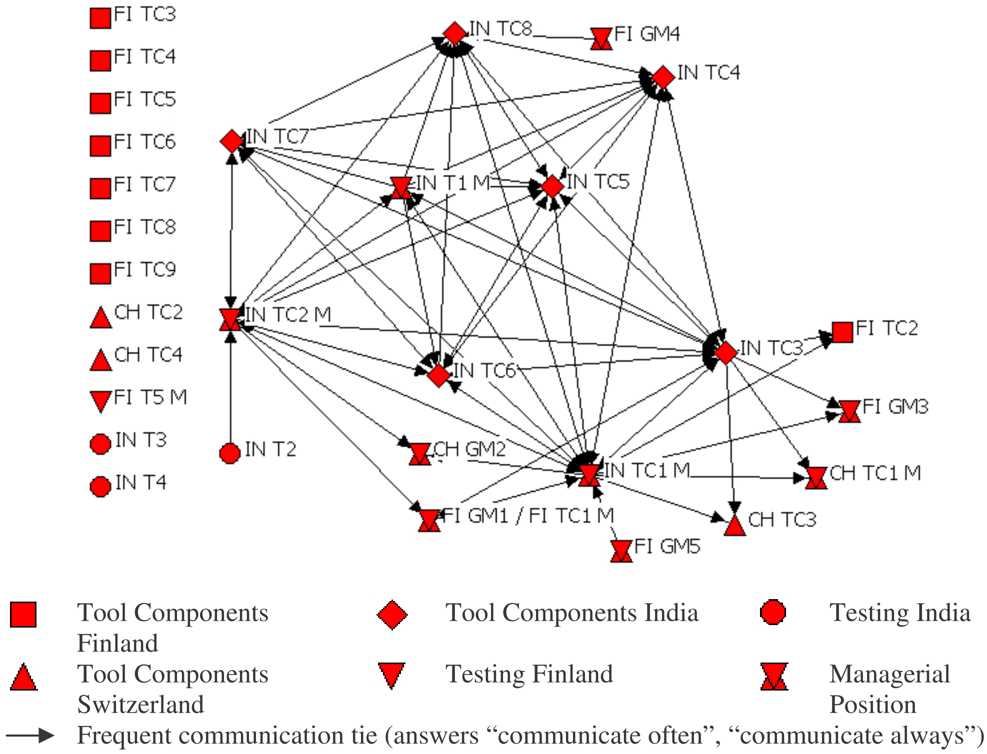


Figure 21. Communication pattern of Indian Tool Components subgroup.

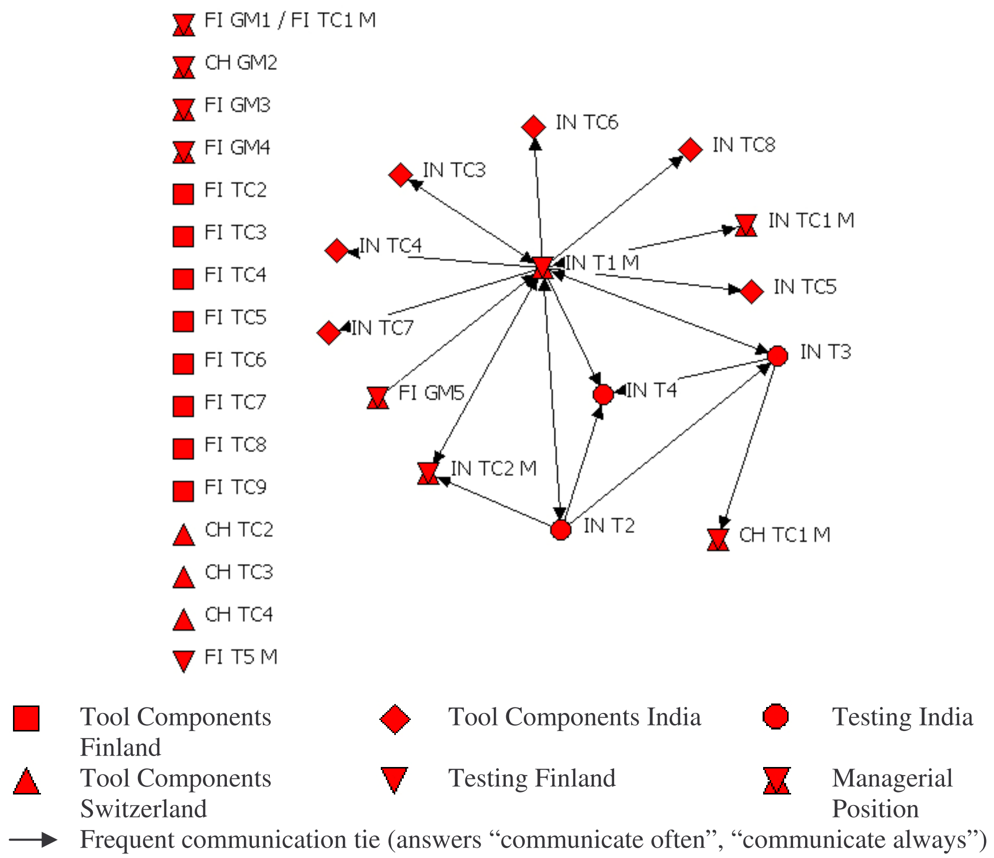


Figure 22. Communication pattern of Indian Testing subgroup.

To quantify centralization of communication networks, Tushman (1979b) used the following measure (0,05 is an arbitrary constraint preventing a zero from appearing in the denominator):

$$\frac{\textit{number of vertical ties/number of potential vertical ties}}{\textit{0,05+ (number of horizontal ties/number of potential horizontal ties)}}$$

According to this formula, the small horizontal ratio leads to higher degree of project centralization. The centralization degree could range from 0 (no vertical ties) to 20 (no horizontal, only vertical ties).

This formula has two weaknesses. The first one is that the zero-result can be obtained not only when there are no vertical ties and team members communicate freely with each other ("*number of vertical ties*" = 0; "*number of horizontal ties*" > 0) but also when there is no communication in the team at all ("*number of* *vertical ties*" = 0; "*number of horizontal ties*" = 0). So this formula should be applied with caution.

Moreover, this formula does not suit for teams with complex structures like Case 2 Team. There are several managers in that team who give tasks on different aspect of the work but it is not supposed that all team members would contact all of them. This complexity cannot be caught with the formula used by Tushman (1979b). Thus centralization coefficients were not calculated in this research.

Comparison of communication networks and expertise recognition in both teams suggested that both were geographically localized. To support this observation further, correlation coefficients were calculated (Table 15). Though built on small samples, these coefficients suggest that, indeed, frequent communication and expertise recognition are correlated.

Table 15. Correlation coefficients calculated for reports on others' expertise and frequency of communication

Type of communication	Case 1 Team	Case 2 Team
All reports on communication	0,51	0,57
Reports on frequent communication	0,35	0,43
Reports on infrequent communication	0,14	0,23
No communication	-0,3	-0,5

Comparison of the empirical data and conclusion on the second research question

Communication networks of the studied teams were geographically localized. This pattern was compared to the pattern of expertise recognition. Both communication networks and expertise recognition in the studied teams were geographically localized. Keeping in mind the hypothesized role of communication in the development of a transactive memory system, this result indicates that a transactive memory system develops on the basis of frequent communication.

Furthermore, in a distributed setting frequent communication depends on a distance between team members and performed formal role. That is peers tend to communication more with peers who are located close to them (this supports Allen's (1977) observation that as distance increases frequency of communication decreases). However, if needed, distance is easily crossed when it is necessary to contact managers. This fact again points out to the interplay between location and formal role in a distributed setting.

It should be noted also that in both teams there were individuals who did not communicate much but could describe others' expertise (e.g. person FI 4 in Case 1 Team). This data indicates that despite frequent communication is significant for the development of a transactive memory system expertise recognition could also develop in other ways.

4.3.3. Research question 3

The third question asks if a developed transactive memory system is a necessary attribute of a successfully performing R&D team with a simple task. This question requires team's task complexity and performance to be measured.

According to the managers' descriptions, Case 2 Team' task was to further develop the previous version of the software. The technology was well understood; thus Case 2 Team' task was relatively simple and close to "technical service task" in Tushman's terms.

Case 1 Team's task was to develop original supply chain management software. Though this software did not exist before, the team manager had a clear vision of what had to be included in the software and how to achieve it. The software code did not exist but the algorithms were well described elsewhere in the supply chain management literature. In this sense, Case 1 Team's task required mostly implementation in one software package of already existing algorithms and adding some specific functionalities requested by company representatives. Thus Case 1 Team's task was also close to the simple end of complexity continuum.

Managers' descriptions of tasks were complemented with team members' reports on task complexity (Table 16). Aggregated task complexity in both teams was the same (1.6 out of 5). In Case 2 Team Managers tended to rate their tasks as more complex than ordinary team members: score 2 for managers, score 1,3 for ordinary team members. In Case 1 Team the project manager rated task complexity as 1.3. This data confirms that in both cases teams' tasks were close to the simple end of task complexity continuum.

Table 16. Project performance and task complexity (means).

	Case 1 Team	**Case 2 Team**
Task complexity	1.6	1.6
Project performance	5	4

Performance of Case 1 Team was rated a little bit higher than that of Case 2 Team (score 5 vs. score 4 out of 7 possible) (Table 16). When Case 1 project was finished, its success was further confirmed by positive comments from the software end users. Case 2 Team was several months behind the deadline. The reasons were external rather than internal. The team was heavily interdependent with other projects within the same company. As a result, the project suffered from the difficulties in clarification of the final product requirements and interruptions caused by incompatibility with previous releases. The project manager of Case 2 Team was, at the same time, quite satisfied with the team's internal efficiency.

Comparison of the empirical data and conclusion on the third research question

Average performance of Case 2 Team does not allow to make any conclusions regarding the match between team' task complexity, team performance and team transactive memory system. Case 1 Team is more fruitful in this sense. This team performed successfully. In agreement with the findings of Tushman and colleagues (Tushman 1978a, 1978b; Allen et al. 1980), it demonstrated that a successfully performing team with a simple task has a centralized communication network. Moreover, Case 1 Team' transactive memory system was not well developed. Thus, this case demonstrates that a team with a simple task and not well developed transactive memory system could perform successfully.

Furthermore, importance of frequent communication for the development of a transactive memory system, discovered as the answer to the second question, indirectly supports the contingency proposition made earlier. That is, due to differences in communication networks, successfully performing teams with simple tasks would have less developed transactive memory systems than successfully performing teams with complex tasks.

5. DISCUSSION

5.1. Findings overview

The first research question asked: *How does a transactive memory system in a distributed R&D team look like?* This question was induced by the not well understood hypothesized impact of distributed settings on transactive memory system development. Empirical data revealed that in both studied cases transactive memory systems were geographically localized. Geographical localization was manifested in geographical localization of expertise recognition: team members knew better those from the same geographical location than those in distant offices.

The second research question asked: *How is a transactive memory system in a distributed R&D team connected to its communication pattern (frequency of communication)?* Empirical data revealed that in two studied teams both communication patterns and recognition of "who knows what" were geographically localized. Correlation coefficients, though calculated on small samples, indicated that communication patterns and recognition of "who knows what" were correlated.

The third question asked: *Is a developed transactive memory system a necessary attribute of a successfully performing R&D team with a simple task?* This question was chosen to falsify the statement that a developed transactive memory system is a necessary attribute of any successfully performing team. One of the studied teams had a simple task, performed well, and its transactive memory system was not well developed (it was geographically localized). Thus, the answer to the third question is positive: a developed transactive memory system is not a necessary attribute of a successfully performing R&D team with a simple task.

These findings as well as other qualitative data obtained in the empirical part of the research encourage further discussion. The topics are presented and examined below.

(1) *Comparison of answers to the first and the second research questions.* As it has been mentioned earlier (chapter 2.5), there is no uniform measure of a transactive memory system. Some researchers measure only "who knows what" in teams. From this point of view, the fact that in the studied teams expertise recognition was geographically localized points out directly to geographical localization of a transactive memory system (*RQ1*). Furthermore, Wegner (Wegner et al. 1985; Wegner & Wegner 1995) mentions that communication is also a very important part of a transactive memory system: it constitutes its process component.

Thus, the fact that communication patterns of the studied teams were also geographically localized (*RQ2*) further supports the conclusion about geographical localization of a transactive memory system in a distributed setting (*RQ1*).

(2) *Contradiction between results of transactive memory system measurement with Lewis' scale and reports on expertise recognition*. The contradiction between results of the measurement with Lewis' scale and reports on others' expertise could be explained by the use of the word "team" in the Lewis's scale. For example, one of the items in the scale says: *"Our team worked together in a well-coordinated fashion"*. Altogether, the word "team" is used 10 times in the Lewis' questionnaire. However, this word refers to a social aggregate which may have different meanings for different people (Starbuck & Mezias 1996). In a distributed setting it is very likely that people in different locations would have different perceptions of what their "team" is. As Mortensen & Hinds (2002) note, distributed teams tend to "drop" distant team members by not including them into team boundaries. In this way, differences in interpretation of the word "team" might cause different interpretation of the questions in Lewis' questionnaire which, as a result, led to a contradiction between the results of two measurement approaches.

This explanation is supported by empirical data. CH TC3 said that his answers would differ dramatically depending on what was meant by the word "team": Swiss colleagues or the whole team situated in several countries (quoted in full in chapter 4.3.1). He also continued about the question number 10 in Lewis' scale. This question (*"I did not have much faith in other members' expertise"*) referred to the team indirectly. CH TC3 said about it:

> "If I answered question 10 from the viewpoint of my "immediate team", the answer would be strongly agree. However if the scope was extended to the greater "team", then the "average" would be neutral, because I have some strong doubts about the expertise of other team members." (CH TC3)

Similarly, CH TC2 mentioned that:

> "Some of the questions are a bit too general. Some good examples would have helped to know what the intention of these questions is." (CH TC2)

Thus, the contradiction between transactive memory system measurement with Lewis' scale and reports on expertise recognition was most likely caused by the use of the social aggregate in the questionnaire. The social aggregate does not differentiate between different subgroups evolved on a basis of different geographical locations. Therefore, it follows that Lewis's scale may not be suitable for transactive memory system measurement in distributed teams.

Alternatively, it could be said that the scores obtained with Lewis' scale (Table 12), though high, were not the highest. So, rather uneven results of expertise recognition could have been, in a way, expected. This type of thinking leads to another important issue of how one could interpret scores obtained with Lewis' scale. Is, for example, coordination at 3.4 good for a team if its communication is centralized as it is in Case 1 Team? Should all the scores be high for the transactive memory to be developed? Or another combination is also possible? Obviously, if something is measured on three dimensions and these dimensions are not correlated, different combinations are possible. Which combination does, then, refer to a developed transactive memory? Apparently, this research cannot provide answers to these questions and calls for further studies.

(3) *Geographical localization of communication*. The fact that communication in the studied teams was geographically localized is in line with the previous finding of Allen (1977). He discovered that frequency of communication, independent on media used, decreases as the distance between people increases.

(4) *Relationship between communication and expertise recognition.* Similar patterns of communication and expertise recognition as well as correlation coefficients between them (Table 15) point out that frequency of communication and recognition of "who knows what" are connected. Correlation coefficients, however, do not allow saying anything about the direction of the causality. Is the observed pattern caused by communication, i.e. people know each other well because they communicate with each other? Or is it so that they communicate often because they know each other well (for example, they were initially introduced)?

Wegner (1987, 1995; Wegner et al. 1985) says that, initially, when people meet for the first time their knowledge of "who knows what" is often erroneous and based on stereotypes. For example, gender stereotypes play an important role in the initial expertise recognition (Hollingshead & Fraidin 2003). However, if people have a possibility to communicate they do so to discover what each other knows or to negotiate responsibilities (Hollingshead & Brandon 2003; Fulk et al. 2005b; Hollingshead 1998a; Rulke & Rau 2000). As people stay together, they constantly "update" their knowledge of others by comparing their perceptions with others' performance (Wegner 1995). It follows from this discussion that transactive memory system develops on the basis of communication. And, thus, geographically localized communication patterns in distributed settings lead to geographically localized knowledge of "who knows what".

Alternatively, it could be that team members get clear descriptions of others expertise from somewhere or somebody else. Experiments demonstrate that such teams perform as well as those which developed their transactive memory systems on the basis of communication (Moreland & Myaskovsky 2000; Hollingshead 2000). It is not clear, though, if the same would hold for actual, not laboratory, work teams. That is if people who got descriptions of team members' expertise would freely contact others without having any history of previous contacts. It could be that they would indeed happily seek advice and support. In this case, communication loses its importance in transactive memory system development and the causality becomes revised: people communicate with those whom they know. Or it could be that they would be very reluctant to contact those who are nearly strangers to them. In this case, knowledge of "who knows what" will not be used and a communication component of a transactive memory system will not function. In this situation, it hardly makes sense to talk about any positive impact of expertise recognition at all.

It could also be that the observed pattern is just an artifact of the development stage of the studied teams. As it is known, every team goes through different stages of development (Levine & Moreland 1990). Communication processes at different stages may be different. Both teams in this research were studied at the final stages of their projects. Case 1 Team existed for a year and a half. Case 2 Team existed for about two years at the moment of study. It could be that they were at about the same developmental stage. Thus, it is possible that the observed similarly between the patterns of communication and transactive memory system was caused by the similarity in the team development stage. It could be that the patterns would have been different if teams were studied at their initial developmental stages. Altogether, the role of communication in development and functioning of a transactive memory system requires more, preferably longitudinal case studies in actual work settings.

(5) *Interplay between formal role and location*. Qualitative data made for noticing that location was not the only factor that influenced transactive memory system and communication in the studied teams. Ordinary members knew managers better than peers in other locations even when those managers were located far from them. Managers also knew team members better independent of their location. Similarly, ordinary team members tended to communicate more with peers who were located close to them. At the same time, the distance was easily crossed when it was necessary to contact managers. This observation is in line with that of Sosa et al. (2002) who say that communication frequency, independent on media, increases with importance and with the presence of strong organizational bonds. The observed interplay between formal role and location could be very important for the development of a transactive memory system. The theory of transactive memory has not discussed this relationship so far. Collected data does not allow to make any suggestions on the nature of the relationship. Therefore, future re-

search is needed to discover how location and formal role influence development of a transactive memory system in a distributed setting.

(6) *Role of time*. The development of transactive memory system, i.e. the process of how it is being built over time, was not the focus of this research. It was assumed that, because in laboratory experiments transactive memory system developed quite quickly, tenure differences were not very important. However comments received from one team member pointed out that this might not be the case in work settings. FI TC9 said that his short tenure did not allow him to get to know team members better (quoted in full in chapter 4.3.1). This comment indicates that in actual work groups development of transactive memory system may take more time than in laboratory experiments. This difference should also be addressed in future studies.

(7) *Boundary spanning activity*. Boundary spanning activity of team members was deliberately not taken into account. However in Case 2 Team numerous references to experts from other projects pointed out to its importance (chapter 4.3.1.). To give few more examples, the following quotes, not mentioned earlier, demonstrate importance of boundary spanning for Case 2 Team. This dialogue was observed during one TRG meeting:

> FI GM1 / FI TC1 M: *"We can't collect problems only from our perspective"*
>
> Several participants of the meeting agreed: *"Yes, we need bigger picture"*.

CH TC2 member commented the questionnaire:

> "To be complete to see to whom I am communicating how and how often I strongly miss the people of the AAAs development, especially BBB, CCC, DDD and EEE. In reality we in Switzerland … have many contacts to the AAA developers (sometimes more than to the team members at FI or IN)!" (CH TC2; projects names were changed).

CH TC1 M also gave his comment on the questionnaire:

> "One comment: To get a complete picture it would have been necessary to include the AAA development teams in BBB, CCC and some people in FFF as well." (CH TC1 M; projects names were changed)

These comments indicate that members of Case 2 Team, in order to fulfill the team task, needed to communicate with people outside the team. This kind of boundary spanning activity is not discussed by the theory of transactive memory. As it has been mentioned in chapter 2.6.3, some attempts has been made to embrace the complexity of real work settings and extend the theory of transactive memory, which is essentially, a theory of *group* memory, to the organizational level. These attempts are largely theoretical. This study indicates that more research, preferably of qualitative character, is needed to develop the theory further.

(8) *Contingency framework.* According to the proposed contingency framework, developed on the basis of theory, an R&D team would perform successfully, if simple R&D tasks are matched with less developed transactive memory system and complex R&D tasks are matched with more developed transactive memory system (chapter 3.2.3). Because the nature of a transactive memory system in distributed settings was not well understood, a falsification approach was chosen to test this framework. Building on the theory of transactive memory, it was assumed that a developed transactive memory system is both a sufficient and necessary condition of a successfully performing R&D team. To falsify this proposition, it was checked if a developed transactive memory system is a necessary attribute of any successfully performing R&D team.

Case 1 Team demonstrated that a developed transactive memory system is not a necessary attribute of a successfully performing R&D team with a simple task. Thus one part of the framework was tentatively supported. Furthermore, assuming that communication is indeed important for the development of a transactive memory system (see topic 4 of the current discussion), the answer to the second research question suggests that transactive memory systems in teams with decentralized communication would, actually, be more developed than in teams with centralized communication. Therefore, taking into account that teams perform successfully if they match simple tasks with centralized communication and complex tasks with decentralized communication (Tushman 1978a, 1978b, 1979a, 1979b; Katz & Tushman 1979; Allen et al. 1980), better developed transactive memory systems should match complex tasks and less developed transactive memory systems should match simple tasks. In this way, proposed contingency framework is tentatively supported.

Alternative interpretation of these findings should also be mentioned. The falsification approach, used in this study, is based on the assumption that a developed transactive memory system is both a sufficient and necessary condition of a successfully performing team. Collected data falsified "necessary" part of the statement and it was assumed that it falsifies "sufficient" part as well. However it could be that a developed transactive memory system is sufficient but not necessary condition of a successfully performing team. For example, Yoo & Kanawattanachai (2001) point out that the influence of a transactive memory system on team performance is increasingly mediated over time by the team collective mind.

The theory of transactive memory does not elaborate further on this subject. However this alternative explanation of the findings should also be taken into account.

(9) *Role of the team members' geographical distribution.* The contingency framework developed for transactive memory in R&D teams does not differentiate between physically distributed and collocated (those whose members are located close to each other) teams. The fact that this framework was supported raises a question if the discovered geographical localization of transactive memory systems in the studied teams was indeed caused by physical distribution of team members or if observed geographically localized patterns simply coincide with centralized communication networks of both teams? For example, Akgün et al. (2005) did not find support for the hypothesis that team member proximity is positively related to the transactive memory system' development. Thus, putting the question another way, does geographical distribution between team members indeed matter?

Indeed, if the proposed contingency framework is valid, team members whose communication is centralized even in a collocated setting would not know each other well. This is particularly true for the Finnish subgroup of Case 2 Team. Its internal communication was centralized; its ordinary members did not know each other well (on average, 18% of the subgroup members). Similarly, in Case 1 Team FI 3 for some period of time worked close to FI 2 and FI 4 but could not say anything about them.

At the same time, ordinary members of the Finnish subgroup knew even worse those who worked in other locations: 4% of the Swiss subgroup, 2% of the Indian developers' subgroup, and none of Indian testers. Indian developers' communication was decentralized and they recognized, on average, 57% of the subgroup mates. However, comparing their recognition of the peers in other locations, they recognized 17% of Indian testers, 8% of the Finnish subgroup, and 6% of the Swiss subgroup. That is recognition of peers in distant locations was about twice worse. In case of Indian testers the pattern is even more striking: 17% of Indian developers, 4% of the Finnish subgroup, and none of the Swiss subgroup. At the same time, all subgroups knew managers much better than distant peers, regardless managers' location.

This data indicates that location indeed matters: in teams with centralized communication, i.e. when team members communicate mostly with managers, expertise recognition would be indeed not high (e.g. expertise recognition in the Finnish subgroup). However, when team members are separated by geographical distance, expertise recognition becomes much worse (e.g. Finnish developers' expertise recognition of their peers in India). Putting it another way, centralized communication pattern would be accentuated in geographically distributed teams, so that transactive memory system in a distributed setting becomes geographically localized.

(10) *Falsification of the general argument of the transactive memory theory.* The fact that the contingency framework is tentatively supported falsifies the general recommendation of the theory of transactive memory that a developed transactive memory system is beneficial for the performance of any team. Furthermore, taking into consideration geographically localized pattern of a transactive memory system that in the studied teams evolved naturally, achieving a high level of expertise recognition in a distributed setting would require conscious efforts and may turn out to be costly.

(11) *Generalization of the findings*. Research questions of this study were answered on a basis of two case studies. Literal replication approach (Yin 2003) was followed in the choice of cases. That is those cases were selected where, building on the presented theories, the same results should occur. Indeed, results obtained in both Case 1 Team and Case 2 Team were similar. This fact suggests that the findings should be generalized to the similar type of distributed R&D teams, i.e. quite successfully performing distributed software development teams at the late stages of team development.

This research has not investigated into teams where, building on the presented theories, contrasting results should be expected. That is neither teams with complex tasks nor poorly performing teams with both types of tasks have been studied. The fact that theoretical replication (Yin 2003) has not been conducted weakens the generalizability of research findings to other types of teams.

Furthermore, the following considerations should be taken into account when discussing generalizability of the findings. Both case teams had a software development task. Clearly, this task is just one of many other tasks that R&D teams may perform in companies. Moreover, as Hauptman (1986) notes, software development consists of many activities (e.g. design, programming, testing, documenting) which could have different information processing requirements. However, the emphasis in this research was made not on how a task is called (e.g. "software development") but on how it is perceived by those who fulfill it. Therefore, a part of the findings reflecting relationships between task complexity, a transactive memory system, and team performance does not pertain solely to software development and, hence, can be cautiously generalized to other tasks.

At the same time, studied teams are just two examples belonging to a big set of distributed teams existing nowadays in companies. For example, unlike in the studied cases, there are teams whose members do not see each other at all and communicate via electron communication means only. There are no available empirical data, to the best of our knowledge, indicating that the degree of physical distribution could have an effect on a development of a transactive memory system. However, the lack of evidence does not mean that such effect is indeed absent. Therefore, an extension of the findings pertaining to a transactive memory system in a distributed setting to all variety of distributed teams is recommended with caution.

5.2. Comparison to the previous studies

In order to evaluate the contribution of this work, it is good to compare its findings with the results of the previous studies. A list of the studies included in the review is given in Table 17. These works in one way or another investigated into one of the following topics: software development teams, a transactive memory system in a new product development, and a transactive memory system in a distributed setting. In those studies where physical distribution of team members was not explicitly specified, it is assumed that team members were collocated.

Table 17. A list of studies included in comparison of findings.

Authors	Type of teams	Physical distribution of team members	Research focus
Hauptman (1986)	Software development teams	Not specified	Relationship between communication and performance
Faraj & Sproull (2000)	Software development teams	Not specified	Effects of "who knows what" and coordination mechanisms in teams
Yoo & Kanawattanachai (2001)	Business simulation game	Distributed	Transactive memory system and collective mind
Lewis (2003)	Functional teams	Not specified	Test of a scale for transactive memory system measurement
Cramton & Webber (2005)	Software development teams	Distributed	Effects of geographic distribution on team processes and effectiveness

(continued on the next page)

(Table 17 continued)

Authors	Type of teams	Physical distribution of team members	Research focus
Akgün et al. (2005)	New product development teams	Not specified	Antecedents and consequences of transactive memory systems
Jackson & Klobas (2008)	Distributed organization	Distributed	Transactive memory system in a distributed organization
Espinosa, Slaughter, Kraut, & Herbsleb (2007)	Software	Distributed	Relationships between task and team familiarity, task complexity, team coordination complexity, and team performance
Oshri et al. (forthcoming)	Software	Distributed	Knowledge transfer in distributed teams through the lens of transactive memory theory

The early work of Hauptman (1986) investigated into relationships between communication patterns and performance in collocated software development teams. He noted that studies of Tushman and colleagues (Tushman 1978a, 1978b, 1979a, 1979b, Allen et al. 1980) were conducted in manufacturing R&D projects whereas software development represents "non-manufacturing" R&D. To find out where software development is situated on a "manufacturing R&D" continuum, Hauptman (1986) conducted a study in application software development division of a British company. The data suggested that software development projects resemble more technical service tasks than development ones. In other words, the data indicated that software development is closer to the simple end of task complexity continuum. This work supports that finding because in both studied teams perceived task complexity was low.

Interestingly, Cramton & Webber (2005) take an opposite view on software development tasks. Without testing task complexity empirically, they say that software development tasks are complex in a sense that they involve "high levels of interdependence and uncertainty". Suggestion presented by Hauptman (1986) can resolve this controversy. He notes that the very term "software development" could be a misnomer. Software development is not only programming; it includes also design, maintenance, testing, and documentation. These activities are quite different and Hauptman (1986) suggests that they could have different communication needs. The latter point was not taken into account in this research. Tasks of both teams were treated in a holistic manner. For example, Case 2 Team included both programmers and testers. However their tasks were not separated because both programmers and testers belonged to the same team. This approach was appropriate for this research because the unit of analysis was a whole team, rather than its components. Nevertheless, in order to gain deeper understanding of the subject, future research could take possible differences between software development sub-activities into account.

Faraj & Sproull (2000) studied effects of knowledge on "who knows what" and coordination mechanisms in collocated software development teams. Expertise coordination, based on recognition of others' expertise, was found to have strong positive impact on team effectiveness. Faraj & Sproull (2000) also tested for the moderating effect of task uncertainty but did not find any significant relationship. They attributed this result to task homogeneity of the studied teams: all of them were developing business application software. Unfortunately, measures of task uncertainty are not presented in their paper (probably, because it was not a major focus of the study). Therefore, it is difficult to compare findings of Faraj & Sproull (2000) to that of this research. Nevertheless, the fact that Faraj & Sproull (2000) propose that task uncertainty and complexity would moderate relationships between expertise coordination and team performance is in line with the contingency framework presented in this manuscript.

The work of Yoo & Kanawattanachai (2001) pioneered research on transactive memory systems in distributed settings. By studying virtual teams involved in a business simulation game, they investigated into relationships between communication volume, a transactive memory system, collective mind, and team performance. Communication volume was measured using a number of electron messages between team members. It was found that communication volume positively influences team performance only during early stage of team existence. Once a team develops a transactive memory system and collective mind, importance of communication volume for team performance diminishes. This finding could explain results of the studies by Allen et al. (1980) and Hauptman (1986). These researchers did not discover any significant relationship between amount of internal communication and team performance. It could be that those studies were conducted when transactive memory systems were already in place and communication volume did not have a significant effect on team performance.

In the current work, however, amount of communication between team members was not measured. Collected data on communication frequency did not reflect how many messages were sent by team members; rather, it pointed out how often team members contacted their teammates or, in other words, how communication was distributed among team members. Thus a comparison with the finding of Yoo & Kanawattanachai (2001) regarding communication volume is not possible.

Yoo & Kanawattanachai (2001) also found that the influence of a transactive memory system decreases as the influence of collective mind increases. Collective mind was not a topic of the current work. Furthermore, analogous study conducted in collocated teams is not reported in the literature, to the best of our knowledge. Thus it is not clear if relationships between communication volume, a transactive memory system, and a collective mind, reported by Yoo & Kanawattanachai (2001), pertain to virtual teams only or to all teams in general. Regarding task complexity, tasks performed by teams in their study were homogeneous (business games). Therefore, the possible effect of task complexity on discovered relationships is not known.

Lewis (2003), while testing a scale for transactive memory system measurement, discovered that functional teams were lower on specialization scores than cross-functional and project teams. Elaborating more on it, she suggested that functional teams' tasks may indeed require different expertise. However, fulfillment of these tasks depends more on expertise utilization than on expertise integration. Thus, there is little need in functional teams to develop a transactive memory system. This Lewis' (2003) suggestion is in line with the reasoning presented in this work: not all teams may need a transactive memory system. Moreover, words "expertise utilization" and "expertise integration" can be understood as different patterns of interdependence between team members (Thompson 1968): pooled in "expertise utilization" and sequential or reciprocal in "expertise integration". Thus, Lewis' (2003) comment points out to another reason why contingency thinking is appropriate for transactive memory systems research.

Cramton & Webber (2005) studied relationships between geographic distribution, team processes and effectiveness in software development teams. It was one of the first empirical studies that were designed to check for the effects of geographical distribution. Cramton & Webber (2005) used socio-technical perspective in order to investigate into these effects. According to this perspective, a work system, in order to perform well, requires both technology and social system that links individuals. Cramton & Webber' (2005) found that geographically distributed teams indeed have difficulties in developing and maintaining social systems. This finding is in line with one of the conclusions of the current research, i.e. that transactive memory systems of distributed teams are not well developed.

Akgün et al. (2005) tested for antecedents and consequences of transactive memory systems in new product development teams. They took into consideration that teams may have tasks of different complexity. For example, when a number of criteria (technical, manufacturing, or marketing) to be satisfied increases, task complexity also increases. Task complexity is also influenced by uncertainty about the match between team internal abilities and market characteristics, e.g. between product development process and environment. Akgün et al. (2005) differentiated between two components of task complexity: routines (repetitiveness of project task elements) and knowledge (established or new bodies of knowledge). They discovered that a transactive memory system has a higher impact on team learning, speed-to-market, and new product success when team tasks are more complex. Apparently, both task complexity and team performance were conceptualized differently compared to the current work. However, both studies point out to the important moderating effects of task complexity on the relationships between a transactive memory system and team performance.

Akgün et al. (2005) also checked for the effects of team member proximity and communication on the development of transactive memory systems in new product development teams. They hypothesized that team member proximity and communication are positively related to development of a transactive memory system. However, both hypotheses were not supported. These findings contradict those of the current work, i.e. that the development of a transactive memory system is likely connected to communication between team members and that physical distribution of team members impedes memory development. This contradiction could be partially explained by the research design of Akgün et al. (2005). For example, for the measurement of team members' proximity they used questions about proximity of "core engineers" and "core marketers" which, obviously, does not reflect all possible different cases of team members' collocation or physical distribution. Moreover, questions regarding informal communication, which referred to communication "at water cooler/coffee maker" and "at lunch or after work", imply that physical distance between team members was not a big issue in the studied teams.

Espinosa et al. (2007) studied how task and team familiarity in interaction with task complexity and team coordination complexity influence team performance. Task familiarity pertains to knowledge about the task; it is important for individual task performance. Prior work experience increases task familiarity. Team familiarity refers to knowledge about the team, including knowledge of "who knows what". This knowledge is important for team task performance. It is influenced by prior work experience with the same people or prior knowledge of them. In essence, task familiarity pertains to individual knowledge component of a transactive memory system; team familiarity pertains to the expertise recognition component. According to Espinosa et al. (2007), task complexity depends on (a) task size and (b) task coordination complexity. In case of software development, the former is a number of software code lines; the latter is a number of interdependent modules. Team coordination complexity depends on (a) geographic dispersion of team members and (b) team size.

Espinosa et al. (2007) found that team familiarity (knowledge of "who knows what") and task familiarity (individual expertise) are not complementary, as the theory of transactive memory suggests, but substitutive. This means that when one type of familiarity is lacking, the effect of the other becomes much stronger. Conversely, as either type of familiarity becomes more prominent, the effect of the other diminishes. This is an important contribution to transactive memory theory. As it has been mentioned earlier in this manuscript, current definition of a transactive memory system is rather vague. Moreover, empirical part of this work demonstrated that existing measures of a transactive memory system do not reflect all the complexity of the studied phenomenon. Substitutive relationships between team familiarity (knowledge of "who knows what") and task familiarity (individual expertise) could explain why teams with low level of team familiarity in both Case 1 Team and Case 2 Team could, nevertheless, perform well. However, more research is needed to incorporate this substitutive relationship into the definition of a developed transactive memory system.

Furthermore, Espinosa et al. (2007) found that team familiarity (knowledge of "who knows what") has stronger influence on team performance when teams are geographically distributed and when teams are larger. At the same time, influence of task familiarity (individual expertise) on team performance is unaffected by team size. Moreover, task familiarity (individual expertise) increases performance only for simple, well-defined tasks. Therefore, taking into account substitutive relationships between task and team familiarity, in order to increase productivity for irreducibly complex tasks it is necessary to increase team familiarity. Similarly to the current work, these findings point out to moderating effects of task complexity. At the same time, they indicate that relationships between transactive memory system, its dimensions, and performance could be more complex than it is suggested in the current work.

Jackson & Klobas (2008) studied a transactive memory system in a distributed organization. They found that physical distribution negatively influences transactive memory structure and processes. For example, Jackson & Klobas (2008) discovered that physical distance reduces opportunities to maintain and update knowledge on "who knows what". Presented study supports this finding and provides more detailed knowledge on the topic, i.e. that a transactive memory system in a distributed setting is geographically localized. Jackson & Klobas (2008) also found that physical distance hinders information allocation and retrieval from people in distant places. This is supported by geographically localized communication patterns in the studied teams. Furthermore, they discovered that allocation of knowledge responsibilities reflects to a great degree organizational structure and organizational roles. This finding is similar to that of the current work, i.e. that not only location but also a formal role performed by a person influences development of expertise recognition.

Oshri et al. (forthcoming) studied software development projects through the lens of transactive memory theory. They found that transactive memory system processes, i.e. encoding, storage, and retrieval, rely on either codified (e.g. databases) or personalized (e.g. project members' memories) directories of "who knows what" or both. In this research only personalized directories were taken into account for the measurement of teams' transactive memory systems. Incorporation of codified directories into longitudinal research on transactive memory systems would shed more light on the relationship between expertise recognition and communication of team members discovered in this work (see point 4 of chapter 5.1 for the relevant discussion). That is it could be that team members find first "who knows what" in team database and then contact corresponding experts. In this way, the causality of the relationship would be as follows: to get to know "who knows what" first and then begin communication. Thus, the current work and that of Oshri et al. (forthcoming) seem to be complementary.

Another complementarity can be observed between the findings of Oshri et al. (forthcoming), Jackson & Klobas (2008), and the present study. Both the present study and that of Jackson & Klobas (2008) discovered that physical separation hinders development of knowledge on "who knows what". In organizational settings studied in these works no special efforts on the part of managers were taken in order to develop expertise recognition of team members. At the same time, findings of Oshri et al. (forthcoming) indicate what should be done in order to develop both codified and personalized directories. Among the actions mentioned are standardization of project work, training, and rotation between different sites. However, it should be noted that Oshri et al.' (forthcoming) findings are based on observations; the authors did not use any formal measurement of a transactive memory system. Thus, despite the reported success of actions on the development of directories of "who knows what", it is not clear if transactive memory systems in the studied projects were geographically localized or not. A study which checks for geographical localization of a transactive memory system in response to managerial actions would shed more light on this issue.

5.3. Implications

Implications for practice

(1) The findings discussed above are based on teams whose managers did not pay particular attention to the development of expertise recognition and communication among team members. So geographical localization of the team memory system and communication is what one could expect to develop naturally in a distributed setting. Thus special actions should be taken if a well-developed transactive memory system is to be built in a distributed team.

If a transactive memory system develops indeed on the basis of frequent communication, as it has been discussed in the previous chapter, then special actions are needed to encourage frequent communication. Short face-to-face meetings could have positive impact on relationship building in distributed teams. However, in big teams and when distances between people are long organization of such face-to-face meetings could be very costly.

Alternatively, team members could be provided with systematized information about each other. For example, project database could list descriptions of each team member. Such information is called team "yellow pages". In this case everyone in the team, including newcomers, could access this information whenever they want. This approach is much cheaper. It was also chosen by managers of Case 2 Team after the discussion of the study findings. However, as it has been discussed earlier, there is a danger that team members may be reluctant to contact, when needed, teammates whom they have never talked to before.

Whatever approach to team memory development is chosen, it would incur costs. These costs would include monetary (e.g. money spent on trips to different locations) and human (e.g. work hours spent on socializing) and be particularly high in distributed settings. The higher the costs the more important it is to gain benefits from team memory building. This leads the discussion to the contingency framework or, in other words, when is it advisable to develop a transactive memory system and when it is not.

(2) Contingency framework proposed in this research and tentatively supported by data from the case studies recommends to pay attention to transactive memory system development only when team task is complex. In this case a well-developed transactive memory system would be indeed beneficial for team performance and costs spent on its building would pay off. If a transactive memory system would be built in a team with a simple task, in the best case it will not bring serious benefits for team performance. In the worst, time spent by team

members to support social ties might have detrimental effect on team performance. For teams with simple tasks, improved managerial coordination could be a better solution.

(3) It follows further that, because building a well-developed transactive memory in a distributed setting could be most likely difficult and costly it is recommended for managers to choose relatively simple tasks for distributed teams. It is much easier to coordinate implementation of such tasks "from the top" and team members would less likely need to seek information from each other.

(4) Managers should also be warned that Lewis' scale for transactive memory system measurement may produce erroneous results if team members are situated far from each other. Moreover, interpretation of the scores obtained with Lewis' scale needs further investigation. Altogether it is not recommended for managers to use the scores obtained with Lewis' scale as the only tool for team memory assessment.

(5) Alternatively, mangers could assess team memory by asking team members to describe their own expertise and expertise of the others. By comparing this data, accuracy of expertise recognition could be evaluated.

(6) Furthermore, reports on team members' own expertise could be used to create a team "knowledge map". In teams with simple tasks such map would help to understand in which areas the team is strong and in which areas knowledge is missing. This could lead to improved process of hiring new team members and better task allocation among those who already work in the project. When a task is complex, managers cannot decide in advance what knowledge is needed. In such situation knowledge map can be used to create team "yellow pages", so that team members can easily find knowledge within a team or engage into boundary spanning when required knowledge is missing.

(7) It is important to note that these recommendations are concerned with team internal processes. If a team is pestered with difficulties coming from interrelations with other projects within a company (e.g. difficulties in clarification of the final product requirements or interruptions caused by incompatibility with previous releases) or from the environment outside the company (e.g. changing customer requirements), following the abovementioned recommendations will not lead to significant improvements in team performance.

Implications for theory

Case study approach is very useful for theory development (Eisenhardt 1989) because it provides many details which cannot be foreseen by pure theoretical thinking and are often overlooked in quantitative research. In this way, current work draws attention to several topics which have not been discussed by the previous studies.

(1) Building on the analysis of laboratory experiments (Moreland 1999; Liang et al. 1995; Moreland et al. 1996, 1998), it was initially assumed that transactive memory system develops in teams quite quickly. So tenure differences of team members were neglected. However the qualitative data showed that this assumption may not hold for actual work settings. As one of Case 2 Team members commented, he did not know his teammates well because he had worked in the team only for few weeks (quoted in full in chapter 4.3.1.). It follows that theoretical descriptions of transactive memory development should take into account team members' tenure. In a similar vein, how long the team itself exists should also be considered.

(2) As it has been demonstrated before (chapter 3.2.4.), distance per se can be a strong factor leading to decrease in communication frequency and inability to access to contextual cues required for expertise recognition development. However empirical data shows that physical distance between team members is easily crossed between ordinary members and managers. The same is true for managers located in different countries. It does not hold for ordinary members located in different countries, though. This type of relationship between location and formal role and its influence on the memory development has not been discussed by the theory of transactive memory. Data collected in this research does not allow making any conclusions on the nature of this relationship. It indicates that more research on this topic is needed.

(3) Cognitive interdependence is said to be important for the development of a transactive memory system (Wegner et al. 1991; Brandon & Hollingshead 2004; Hollingshead 2001). Cognitive interdependence exists when individual outcomes depend on what others know in the group. Are members of teams that have shared goals always cognitively interdependent? Empirical data indicates that they are not.

For example, the outcome of Case 1 Team depended on everyone's inputs; at the same time, members of Case 1 Team did not depend much on each other. This type of interdependence is called pooled in the terminology of Thompson (1967).

Similarly, sequential interdependence, i.e. when output of one person is an input to another, may not necessarily require cognitive interdependence. Only reciprocal interdependence, i.e. one when output of each person is an input to others, would, most likely, result in cognitive interdependence.

The differences between pooled, sequential, and reciprocal interdependence between team members, caused by the nature of a certain task, and their relationships with cognitive interdependence have not been discussed by the transactive memory theory. It could be that teams with pooled interdependence between team members do not even need group memory. In this sense, Case 1 Team successfully demonstrated good performance without well-developed transactive memory. Apparently, more qualitative research is needed to understand links between interdependence caused by task requirements and cognitive interdependence of team members.

(4) Another interesting result is a contradiction between scores obtained with Lewis's scale and reports on others' expertise: the scores indicated that the team memory was developed more than average but reports on expertise recognition were very uneven. The contradiction is likely to be caused, as it has been discussed above (chapter 5.1), by the use in the scale of the word "team" which refers to a social aggregate whereas in distributed teams there could be several "subgroups" developed in every location. So Lewis's scale is not recommended for the use in distributed settings. There is a need of new transactive memory system measures which would take into account distributed character of contemporary teams.

(5) Furthermore, the use of Lewis scale raises some other questions. The first one is how to interpret the scores. For example, the coordination score for the Case 1 Team was 3.4. At the same time, reports on communication showed that the team communication network was centralized. So what does the score 3.4 mean in this case? Is it good or bad for the team performance? How the coordination score and communication network centralization are connected? From the data presented in this research it follows that the coordination score does not count for the centralized character of the team communication. However two case studies may not be enough to make reliable conclusions on this topic.

The second question is how big should be the scores on Lewis's scale to say that the transactive memory system is well-developed? Moreover, if something is measured on three dimensions and these dimensions are not correlated, different combinations are, likely, possible. Which combination does, then, refer to a developed transactive memory? Apparently, this work cannot provide any answer to this question and more research is, obviously, needed.

(6) Another very important issue is importance of boundary spanning for implementation of some tasks. As in Case 2 Team, managers and some of the team members had very strong connections with people from other projects in the same company. At the same time, the theory of transactive memory is essentially a theory of *group* memory. Boundary spanning activity has not been considered at a great length in either theoretical works or empirical studies on transactive memory systems. However, if the concept of transactive memory is to be applied to organizational teams, a further elaboration of the theory is needed which would include boundary spanning activity of team members and its influence on team performance.

(7) Case 2 Team experience raises one more topic for discussion. The team manager, when discussing the research findings, said that he was not surprised by the centralized communication pattern of the Finnish subgroup. He continued that the members of the subgroup knew the physical properties of the hardware quite well, so they did not need to seek for advice from each other. Members of the Finnish subgroup were also all experts in their relative areas of software programming. Could it then be so that at a certain point of knowledge differentiation it becomes not possible to find advice inside the team? So that the higher the differentiation between team members the less overlapping knowledge areas exist between them, the less it is possible that team members seek advice from each other? In this case the group memory could be of little use.

It could be that a curvilinear relationship exists between knowledge differentiation and communication. When knowledge held by team members is complementary and there are also some areas held in common, people communicate quite easily because they have common ground to understand each other. As knowledge differentiation increases, communication is also increases, but to a certain point. When knowledge held by team members is so different that they cannot help each other any more, communication starts decreasing. This research does not provide any support or counterargument to this idea; it rather suggests an important direction for further investigation.

5.4. Research limitations

The limitations of this work are as follows. It could be that despite the members of both teams were ensured that their responses would be kept confidential the given answers might still be socially desirable. For example, in response to the follow up letter, one member of Case 1 Team came up with a very broad description of expertise of those whom he could not describe at first. This attempt to “save face” was taken into account when doing research in Case 2 Team. It was explicitly said to its members that there was nothing wrong in not knowing some teammates. However this might not have completely excluded the possibility of coming up with answers that would be seen as desirable. Social desirability as well as informants’ cognitive limitations is often mentioned as possible sources of inaccurate answers (Huber & Power 1985).

Analysis of the data might be biased by personal preferences of the researcher. Extensive theoretical investigation preceded empirical data collection might have biased the data interpretation (Eisenhardt 1989; Yin 2003; Ghauri et al. 1995).

Measurement of task complexity might bias conclusions made on contingency approach. Task complexity of both teams was assessed by using two approaches: on the basis of team managers’ task descriptions and by aggregating team members’ answers on predictability of task input, output, and process. Though these approaches gave the same result, it should be noted that both of them pertain to *perceived* task complexity. At the same time, most of contingency research implies positivistic viewpoint that would require measuring *objective* task complexity. Campbell (1988) and Wood (1986) say that perceived and objective task complexity are related but not the same. However, it is highly questionable that objective task complexity could be assessed without any human involvement. Similarly, Tushman and colleagues used in their studies, in essence, perceived task complexity when asked members of R&D projects to evaluate their tasks on the basis of offered descriptions.

Both studied teams had a similar type of R&D task: product development. The fact that neither teams with complex tasks nor poorly performing teams have been studied weakens the generalizability of research findings to other types of teams.

Furthermore, this research did not take into account multicultural composition of the studied teams. In Case 1 Team three cultures were present; in Case 2 Team – seven. Cultural differences could influence communication between team members as well as team memory. Moreover, questions asked during data collection might have been perceived differently by different cultures. The focus of this research was not on possible cultural effects, though. However it is recommended that future studies take it into account.

Another weakness of this study is that it did not count for possible influence of politics on communication and transactive memory. It was implicitly assumed that team members did not compete with each other and were positive and friendly to each other. Moreover, this is a general implicit assumption of the transactive memory theory. Indeed, in Case 1 Team no open conflicts were observed. About Case 2 Team no data is available. However, as a case study presented by Guzman (2008) shows, people may be very reluctant to cooperate with others, even when such behavior cannot be rationally predicted by the managers. Incorporation of possible influence of politics in future transactive memory studies would improve transactive memory theory descriptive accuracy.

Similarly, possible effects of communication media on communication frequency, development of expertise recognition and, hence, transactive memory system were not taken into account (see chapter 3.2.4. for the discussion). Information systems (databases) could also play their role in transactive memory system development and functioning (see chapter 5.2. for the discussion). Future research should take this also into account.

One more weakness of this research is that it did not differentiate what transactive memory system was used for: problem solving or decision making. However usage and importance of transactive memory system could depend not only on task complexity per se, but also if it is a problem solving or decision making task. For example, Case 2 Team was rather big; its project was connected to other projects in the company. Given that, it is unlikely that all team members could be engaged into decision-making process and their better knowledge of "who knows what" could lead to better task allocation and improved project performance. Research on transactive memory system does not take the difference between problem solving and decision making into account. It is recommended that future research would pay more attention to this issue.

5.5. Directions for future studies

Taking into account the previous discussion, the following directions for future studies are suggested:

1. Qualitative research into how team members are connected to and look for knowledge from people in other teams and even companies would help to extend the theory of transactive memory outside team boundaries. This would greatly improve its descriptive accuracy;
2. Closely investigating the interplay between formal role, distance, and communication between team members would increase understanding of how transactive memory systems develop in distributed organizational teams;
3. In this work only some studies from information seeking research were used. Further integration of these research streams could be beneficial for understanding of transactive memory processes. Similarly, integration of transactive memory research with studies on intercultural communication and effects of

communication media would bring better understanding of transactive memory system development;

4. Role of time has been several times mentioned during the discussion. Thus a longitudinal study that follows one team from its inceptions through different stages of team life would be appropriate. Such study could focus on how communication differs at different stages of team existence and how transactive memory develops over time;
5. Some attention should also be paid to the role of databases, tenure, politics, and managerial actions in transactive memory system development;
6. Taking into account task structure in terms of pooled, sequential, and reciprocal interdependence between team members would increase knowledge on when team members seek for information from teammates on the basis of a transactive memory system;
7. Possible curvilinear relationship between knowledge differentiation and communication in teams requires further investigation. It could also improve descriptive accuracy of transactive memory theory;
8. Necessarily, a qualitative research into transactive memory in distributed teams with complex tasks as well as poorly performing teams is required. It would bring more certainty into contingency framework proposed in this study.

Altogether, empirical studies on transactive memory systems and distributed organizational teams are at their development stage. This work has shed light on some of important aspects of distributed work as well as outlined directions for future research.

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Appendixes

Appendix 1. Three-Dimensional Scale for Transactive Memory System Measurement (Lewis 2003).

Specialization

1. Each team member has specialized knowledge of some aspect of our project.
2. I have knowledge about an aspect of the project that no other team member has.
3. Different team members are responsible for expertise in different areas.
4. The specialized knowledge of several different team members was needed to complete the project deliverables.
5. I know which team members have expertise in specific areas.

Credibility

6. I was comfortable accepting procedural suggestions from other team members.
7. I trusted that other members' knowledge about the project was credible.
8. I was confident relying on the information that other team members brought to the discussion.
9. When other members gave information, I wanted to double-check it for myself. (reversed)
10. I did not have much faith in other members' "expertise." (reversed)

Coordination

11. Our team worked together in a well-coordinated fashion.
12. Our team had very few misunderstandings about what to do.
13. Our team needed to backtrack and start over a lot. (reversed)
14. We accomplished the task smoothly and efficiently.
15. There was much confusion about how we would accomplish the task. (reversed)

All items use 5-point disagree-agree format where 1=*strongly disagree*, 2=*disagree*, 3=*neutral*, 4=*agree*, 5=*strongly agree*.

Appendix 2. Tenure of Case 2 Team' members.

	Works in the project since …	**Works in the company since …**
FI GM1 / FI TC1 M	5/2005	1989
CH GM2	N/A	N/A
FI GM3	2003 – 8/2005. Rejoined in 10/2006	1994
FI GM4	2005	1997
FI GM5	N/A	N/A
FI TC2	2005	1994
FI TC3	N/A	N/A
FI TC4	N/A	N/A
FI TC5	N/A	N/A
FI TC6	10/2006	10/2006
FI TC7	02/2004	06/2000
FI TC8	08/2006	08/2006
FI TC9	01/2007	01/2007
CH TC1 M	6/2004	1995
CH TC2	12/2004	1989 (3 years break: 1995-98)
CH TC3	5/2005	1999
CH TC4	6/2005	2001
IN TC2 M	2005	1994
IN TC3	2005	2004
IN TC4	2005	2005
IN TC5	2006	2006
IN TC6	2005	2004
IN TC1 M	2005	2005
IN TC7	2006	2006
IN TC8	2006	2005
FI T5 M	N/A	N/A
IN T2	2005	2003
IN T3	2006	2005
IN T4	2006	2006
IN T1 M	2006	2006

The study was conducted in January-March, 2007.

Appendix 3. Individual scores on transactive memory system' development collected with Lewis's scale in Case 1 Team.

		Specialization							**Credibility**							**Coordination**					
FI 1 M		5	4	4	5	4	4,4		5	5	4	2	1	4,2		3	4	3	4	2	3,2
FI 2		4	3	4	5	3	3,8		3	3	4	3	3	2,8		3	2	2	3	4	2,4
FI 3		4	3	4	4	3	3,6		4	4	4	2	4	3,2		4	5	2	5	2	4
FI 4		4	2	4	5	5	4		4	4	4	2	2	3,6		4	4	1	4	2	3,8
FI 5		4	4	3	4	3	3,6		4	4	4	2	2	3,6		4	4	2	3	2	3,4
FI 6		4	2	4	4	1	3		5	4	4	2	2	3,8		2	3	3	4	3	2,6
FI 7		4	4	2	5	4	3,8		4	4	4	2	4	3,2		4	4	2	4	2	3,6
FI 8		4	4	5	5	5	4,6		4	4	4	3	2	3,4		4	4	2	4	1	3,8
		mean					**3,9**		**mean**					**3,5**		**mean**					**3,4**
		min					**3**		**min**					**2,8**		**min**					**2,4**
		max					**4,6**		**max**					**4,2**		**max**					**4**

Appendix 4. Individual scores on transactive memory system' development collected with Lewis's scale in Case 2 Team.

		Specialization							Credibility							Coordination					
FI GM1 / FI TC1 M		4	4	4	5	5	4,4		4	4	4	3	1	3,6		4	3	3	3	2	3
CH GM2		3	3	4	4	4	3,6		4	4	4	2	2	3,6		4	2	2	3	3	2,8
FI GM3		5	3	4	5	4	4,2		4	4	4	3	2	3,4		4	2	3	3	3	2,6
FI GM4		4	5	3	3	4	3,8		4	3	3	3	1	3,2		2	2	3	2	3	2
FI GM5		5	4	4	5	4	4,4		4	5	3	4	2	3,2		4	3	2	3	3	3
FI TC2		4	3	4	4	4	3,8		4	3	4	3	2	3,2		2	2	3	3	3	2,2
FI TC3		4	5	5	4	5	4,6		4	5	5	2	1	4,2		3	4	2	3	3	3
FI TC4		4	4	4	3	5	4		4	4	4	3	2	3,4		3	3	2	3	3	2,8
FI TC5		4	4	4	5	4	4,2		4	4	4	3	2	3,4		4	4	2	3	3	3,2
FI TC6		5	5	4	5	2	4,2		5	3	4	2	2	3,6		4	4	2	3	2	3,4
FI TC7		4	5	4	5	2	4		4	4	4	2	1	3,8		4	4	2	4	2	3,6
FI TC8		4	4	4	4	3	3,8		4	4	4	2	2	3,6		4	4	3	3	2	3,2
FI TC9		4	1	4	4	2	3		3	4	4	2	1	3,6		3	3	3	3	3	2,6
CH TC1 M		4	4	4	4	4	4		4	4	3	2	2	3,4		3	2	3	2	4	2
CH TC2		4	2	4	4	4	3,6		4	4	4	2	2	3,6		3	3	2	2	2	2,8
CH TC3		4	5	3	2	2	3,2		3	2	3	4	3	2,2		2	2	4	1	4	1,4
CH TC4		3	3	3	3	3	3		4	4	4	2	2	3,6		3	3	3	3	3	2,6
IN TC2 M		4	5	3	3	5	4		5	5	5	2	1	4,4		5	4	2	5	2	4
IN TC3		4	3	4	4	4	3,8		4	4	4	3	2	3,4		5	3	3	4	3	3,2
IN TC4		4	3	4	3	4	3,6		4	4	3	3	3	3		4	4	2	3	3	3,2
IN TC5		4	5	4	3	4	4		4	3	4	3	2	3,2		4	2	2	4	2	3,2
IN TC6		4	3	4	4	3	3,6		5	4	3	3	2	3,4		3	3	3	4	3	2,8
IN TC1 M		5	2	4	5	5	4,2		4	4	4	2	1	3,8		5	2	2	4	4	3
IN TC7		5	5	4	4	5	4,6		5	4	3	4	2	3,2		5	5	2	5	2	4,2
IN TC8		4	3	4	2	3	3,2		3	3	4	4	2	2,8		4	5	2	4	2	3,8

(continued on the next page)

(Appendix 4 continued)

		Specialization							Credibility							Coordination					
FI T5 M		5	4	3	4	4	4		4	4	3	2	1	3,6		4	3	2	3	3	3
IN T2		4	3	4	5	4	4		4	4	4	2	2	3,6		4	2	2	3	2	3
IN T3		3	4	4	4	4	3,8		4	5	3	4	2	3,2		4	3	3	3	2	3
IN T4		4	3	4	5	4	4		4	4	4	4	2	3,2		5	3	3	4	2	3,4
IN T1 M		4	2	1	4	4	3		4	4	3	4	4	2,6		4	2	3	3	2	2,8
		mean					**3,9**		**mean**					**3,4**		**mean**					**3**
		min					**3**		**min**					**2,2**		**min**					**1,4**
		max					**4,6**		**max**					**4,4**		**max**					**4,2**

Appendix 5. Examples of the reports on expertise recognition given by Case 2 Team members.

1. FI GM1 / FI TC1 M

Total number of received reports: 17
The reports were:

Project manager
Project management
Project Management
Overall picture of the project
Project management
Project leader
Leadership
Project Organization & schedule
Project management, knowledge about related projects
Project Management
Project Management
Project Management
Project Manager
Road Map/Project Management of all connected projects
Project management (scope, time schedule, etc.)
Project Management
Project Planning

2. FI TC 4

Total number of received reports: 8
The reports were:

Developer of parameter settings
Parameter setting
Parameter settings
Parameter setting
Parameter setting
Parameter setting
Parameter setting, parameter data server
Parameter setting component

3. CH TC2

Total number of received reports: 5
The reports were:

Developer of graphical display editor and event list
Graphical display editor
Graphical display editor, event viewer component
Architecture, graphical display editor, event viewer
Event viewer/ graphical display editor

4. IN TC3

Total number of received reports: 16
The reports were:

Technical key person
Developer of Application Configuration Tool (TRG member)
Application Configuration Tool
Application Configuration Tool
Application Configuration Tool
Application Configuration Tool
Application Configuration Tool
Application Configuration Tool
Fast grasping of technology, expert in software and product
Download and upload configuration, execution order
Very good project knowledge
Overall Technical Responsibility of Application Configuration Tool
Application Configuration Tool Architecture, Automatic Execution Order
Coding using C#.Net
Software development
Development

5. IN T3

Total number of received reports: 5
These reports were:

Tester
Automated tests
Automation Testing
Test Automation
Test Automation